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HISTORY AND PRESENT STATUS OF FISH DISEASES[1]

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INTRODUCTION

Inasmuch as a complete chronological review of research and development of control methods for diseases of fishes would require far more space than has been allotted to me, I have merely selected the highlights and stressed the major problems and achievements.

Although most developments in fish medicine are relatively recent, McGregor[56] compiled a bibliography on fish parasites and diseases that began with the year 330 B.C. Mawdesley-Thomas[54] reached back even further—to 1450 B.C. —and reproduced an Egyptian painting of tilapia with a grossly enlarged abdomen. The history of fish pathology was recently reviewed by Snieszko.[75,76]

The intensive culture of domestic animals became possible only after man had learned how to control communicable diseases of animals held in crowded conditions. Similarly, intensive fish culture, in which recycled water and commercial feeds are used, depends on the development of effective methods of disease control.

In the following successive sections. I discuss fish diseases caused by parasites, bacteria, viruses, and inadequate nutrition. In a final section, I comment on methods of disease control.

DISEASES CAUSED BY PARASITES

Parasitology of fishes is the oldest part of fish pathology. Thousands of parasites are already known, and more are being described. Literature on this subject is enormous. Fish parasitology can be divided into these principal parts: (1) taxonomy; (2) diseases caused by parasites; and (3) control of parasitic diseases.

Taxonomy belongs to zoology, therefore, it is not part of this presentation.

The mere presence of parasites is not an indication that they are causing an overt disease. If a fish is invaded by sufficient numbers of parasites that its functions are impaired, the parasites may be considered fish pathogens.

Under natural conditions 80 to 90% of freshwater and saltwater fishes harbor at least one species of parasite. Parasitism is much more common and diversified in the wild than in fish farms and hatcheries. Under the crowded conditions common in artificial culture, parasites can be more destructive than in nature if they are permitted to spread unchecked. Parasitology of fishes has been reviewed in a number of books on fish diseases. The first was Hofer's "Handbook on Fish Diseases."[41] His book was a review of the field in the 19th century. A companion volume to Hofer's book was published in 1924 by Plehn.[60] This was followed by several editions of "Fischkrankheiten"[69] by Schäperclaus, the most detailed textbook of fish diseases published to that date.

In the Soviet Union, ecological aspects of parasitology of fishes attracted much attention. The Symposium on Parasitology of Fishes[19] contains this quotation from Dogiel: "When we have at our disposal not only dry lists and descriptions of new species, but when we get to know the entire life of the parasite found in any locality, we shall have a powerful weapon with which to fight outbreaks of

[1] Presented at the 1974 Annual Wildlife Diseases Conference, Pacific Grove, California.

parasitic diseases." He defined "ecologic" parasitology as "the influence of changes in the external environment and in the physiological condition of the host on its parasitic fauna."

Research on fish diseases and their control is vigorously pursued in the Soviet Union. This vigor is reflected in the large number of research papers, books, and published proceedings of annual conferences and symposia. Some of these have been translated and published in English.[4,10,52,59,61]

The study of parasitology and diseases of fishes in Central Europe has a long tradition. In addition to the previously mentioned books by Hofer, Plehn, and Schäperclaus, more recent textbooks on fish diseases were published in Poland[48] and in Czechoslovakia.[36,21]

The most recent German books on diseases of fishes available in English editions are those by Amlacher,[1] by Reichenbach-Klinke and Landolt,[68] and include the color atlas of fish diseases by Elkan and Reichenbach-Klinke.[23] In Italy, Ghittino[32] published a textbook on diseases of fishes. It is hoped that this modern book will also be published in English.

Parasitic diseases of fishes are important in North America. Diseases and their control are of great economic significance because of the presence of many fish hatcheries operated by conservation agencies and private industry; the extensive fisheries in the Great Lakes, large and numerous rivers, impoundments and along the Atlantic and Pacific coasts; the development of mariculture; and the existence of millions of home aquaria.

Students of fish parasitology in the United States and Canada have published many excellent scientific reports, textbooks, and symposia which follow the progress of the study of fish diseases and their control and include bibliographies that have adequate and up-to-date coverage. Only a few of these contributions can be mentioned within the limits of this article.

Emmeline Moore was one of the early leaders in fish pathology (active in this field from 1926 to 1944) and the only woman president of the American Fisheries Society (1927-28). H. S. Davis, who established the research and teaching of fish diseases at Leetown, West Virginia, was the author of a monograph on protozoan parasites[17] as well as author of the classic textbook "Culture and Diseases of Game Fishes"[18] which for years was the only text in the English language.

A very important contribution to fish parasitology was the research on life cycles and intermediate hosts of helminths. It is probably unfair to mention only a few names associated with this achievement. R. V. Bangham, J. H. Fischthal, G. W. Hunter, VanCleave and Mueller carried out pioneering research on the biology and life cycles of fish parasites between 1925 and 1957. The numerous publications by these authors have been listed and reviewed in texts by Davis,[18] Hoffman,[42] and Hoffman and Meyer.[43] The texts by Hoffman, and Hoffman and Meyer are the most detailed contemporary American works on identification, biology, and control of parasites of freshwater fishes.

Parasitology of marine and estuarine fishes has a long history and large bibliography. Sindermann[74] compiled and reviewed this information and included descriptive information on diseases and parasites of marine shellfish. He initiated his research on diseases of fishes in the early 1950s[73] and has continued to carry out and support investigations on diseases and parasites of marine fishes and shellfishes. This activity is becoming increasingly important with the growth of mariculture. It is clearly evident that intensive mariculture is not possible without development of effective methods for control of diseases.

A very important group of freshwater and marine fish parasites are the crustaceans which cause great losses in hatcheries, fish farms, and open seas. Kabata, the leading authority on parasitic crustaceans, compiled the most recent textbook[45] on these parasites.

A survey of fish parasitology would be incomplete without mentioning some current disease problems.

Early in this century whirling disease of rainbow trout, caused by *Myxosoma cerebralis*, was considered most destructive in Europe. The presence of this disease in America was discovered in 1956, and declared a "resource disaster" by Stewart L. Udall, Secretary of the Department of the Interior in 1969.[2] The outbreak and spread of *M. cerebralis* in the United States resulted in laws and regulations (Title 50)[3] requiring certification that all live or frozen salmonids imported to the United States are free from this disease, and also from viral hemorrhagic septicemia which is still absent in America. The Canadian government introduced similar controls. These steps not only stopped further spread of whirling disease but resulted in its eradication in some areas.

Pacific salmonids are susceptible to whirling disease.[44] Since the spawning channels for Pacific salmon present conditions which are suitable for the transmission of whirling disease, vigilance is recommended to keep *M. cerebralis* out of Northwest America.

A similar disease caused by another myxosporidian, *Ceratomyxa shasta*, is endemic in Shasta County, California[83] and in certain tributaries of the Deschutes and Columbia Rivers in Oregon.[66] This disease is transmissible only by exposing fishes to water from contaminated areas.

Still another sporozoan, *Plistophora ovariae*, is an important pathogen of female golden shiners (*Notemigonus crysoleucas*) in the south central states.[79] Similarly to *M. cerebralis* and *C. shasta*, *P. ovariae* is also transmitted when juvenile fishes are exposed to infection under normal conditions. The observation that transmission of sporozoan parasites of fishes seems to take place only under natural conditions, or simulated natural conditions, makes research on these parasites extremely challenging and interesting.

Protozoan blood parasites represent another group which recently attracted much attention. These parasites, similar to human malaria and trypanosomiasis, are widely distributed among freshwater and saltwater fishes and occasionally cause heavy mortalities. This subject was recently reviewed.[5,62]

Control of diseases caused by parasites can be accomplished by various means. Isolation of fishes from the source of parasites is best, but often not practical. When parasites require intermediate hosts —elimination of these is recommended.

When parasites are on the surface, or in the intestines of fishes, the addition of certain chemicals to the water or food produces excellent results. Some intradermal parasites such as *Ichthyophthirius* can be controlled only during their free-living stage. Crustaceans in fish farms can be controlled by certain insecticides, but the control is a delicate process because the margin of safety of these pesticides is usually very narrow. A textbook of parasite control has recently been published.[48]

BACTERIAL DISEASES OF FISHES

Study of bacterial diseases is the second-oldest division of fish pathology. Since there are recent textbooks and reviews on this subject, only the most important diseases are discussed here.

Fish furunculosis was one of the first recognized bacterial diseases. The history of research on furunculosis was reviewed in detail by McGraw[55] and Herman.[40] At this time the disease exists in all parts of the world except Australia and New Zealand.

A very important contribution to research on furunculosis was made in the

[2] Federal Register, Doc. 69-1174.

[3] Federal Register, Doc. 65-8126.

United Kingdom. In 1929 the British government appointed a Furunculosis Committee consisting of leading microbiologists, medical epidemiologists, and fishery biologists to survey the problem and make recommendations. Reports of the Committee[51] may serve as an example for the study of any communicable disease of fishes and should be considered mandatory reading for any student of fish pathology.

This Committee concluded that furunculosis is a disease of fishes which occurs primarily in freshwater. All salmonids and most other species of freshwater fishes are susceptible; however, eels are highly resistant. Adult salmon become infected when they enter freshwater. If few bacteria are present, bacteriological examination is not a reliable method for detection of carriers. Ova are not infected internally. Young salmonids in freshwater are more resistant than adults entering freshwater. The optimum temperature for this disease is 12-19 C; at 5 C or below outbreaks are not likely to occur. Furunculosis is also historically important as the first fish disease against which oral immunization was tried.[20]

There is another representative of this genus known as *Aeromonas liquefaciens* (*A. punctata* and *A. hydrophila* are synonyms) which cause a wide variety of diseases in freshwater fishes all over the world. On occasion, it is also a pathogen of amphibia, reptiles, and even humans. Bacterial hemorrhagic septicemia is the preferred name for the disease caused by this bacterium.[9] This disease was known to Hofer[41] and Plehn,[60] but Schäperclaus[68] named it infectious dropsy (Bauchwässersucht) and identified an aquatic bacterium, *Bacillus punctatus*, as its cause. The basic concepts regarding infectious dropsy are now changing rapidly.

In most countries bacterial hemorrhagic septicemia is recognized as a disease of freshwater and warmwater fishes caused by a polar flagellated organism belonging to the genus *Aeromonas*. In Central Europe and the Soviet Union, the etiology and name of the disease are still controversial. It gradually becomes more clear that infectious dropsy of cultured carp (*Cyprinus carpio*) is a disease of complex etiology and rather vaguely defined pathology. In other parts of the world, bacterial hemorrhagic septicemia of fishes is recognized as a disease caused only by *Aeromonas liquefaciens*.[9]

There are two excellent reviews on this subject.[3,58] Some of the Soviet investigators do not minimize the role of *Aeromonas*, which they call *Achromobacter punctatum*. Soviet investigators call it rubella and consider it to be a viral disease. Also, some investigators in Germany, including Schäperclaus,[70] do not minimize the possible role of a virus in the disease complex.

A great help in elucidation of the nature of this carp disease in Europe was the publication of a series of papers by Yugoslavian investigators as reviewed by Fijan.[25] He and his associates described a viral disease which they named spring viremia of carp and isolated *Rhabdovirus carpio* as its cause. Fijan also indicated that carp erythrodermatitis, another component of the complex of carp disease called carp dropsy, may be the equivalent of the Soviet rubella.

The myxobacterioses are another group of bacterial fish diseases with an interesting history. These diseases are known better under the names columnaris, peduncle disease, coldwater disease, and bacterial gill disease.[9]

Most bacteriologists were not familiar with myxobacteria until about the early 1960s. Therefore, when Davis[15] saw columnaris disease for the first time in about 1922 in Mississippi River fish near Fairport, Iowa, he named the associated organism *Bacillus columnaris*. Garnjobst[30] isolated and cultivated this bacterium 23 years later and recognized its similarity to the fish pathogenic myxobacteria described by Ordal and Rucker.[57]

The first review paper on myxobacterial diseases of fishes was Borg's doctoral thesis.[7] This was followed by numerous papers by Ordal's students and others.

Myxobacterial diseases of fishes are now known all over the world. The most recent reviews are by Bullock *et al.*,[9] Anderson and Conroy,[2] and Bullock.[8]

Bacterial gill disease is one of the most common diseases of hatchery-reared juvenile salmonids. Myxobacteria, so far not sufficiently described, are strongly implicated in this disease. They were seen for the first time by Davis.[16] In spite of the frequency of this disease, heavy losses in hatcheries, and satisfactory methods of control, the nature of bacterial gill diseases is not adequately explained.

Mycobacterial diseases of fishes, also called fish tuberculosis, are less important from the economic point of view because food fishes are rarely affected. A small percentage of wild marine fishes are infected with mycobacteria. The most frequent outbreaks occur in freshwater and marine ornamental fishes. The incidence and significance of mycobacterial diseases have recently been reviewed.[9,13,63,64]

From the historical and epidemiological points of view a temporary but widespread occurrence of mycobacteriosis in several species of Pacific salmon in Northwestern America is of great interest. These outbreaks were first reported in 1952 in adult chinook salmon (*Oncorhynchus tshawytscha*) returning from the ocean to Bonneville Hatchery, located on a tributary of the Columbia River in Oregon.[92]

This discovery was followed by methodical surveying of fall and spring chinook salmon for the presence of mycobacterial infection between 1952 and 1957. Adult salmon returning to freshwater to spawn were confined in holding facilities until ripe. During that time the weak and diseased fish died. The greatest losses were at the beginning of confinement. About 25% of these fish had mycobacteriosis. In fish which survived, until killed for artificial spawning, the prevalence of mycobacteriosis was about 5%. The infected salmon were smaller and more vividly colored. The secondary sexual characteristics were absent and gonads were underdeveloped so that sex was not readily apparent. The prevalence of infection was higher in males. The study of returning marked spring chinook salmon in 1955 and 1956 showed that 5 of 19 salmon, which spent 5 months in the hatchery as fingerlings, had mycobacteriosis. The number of infected salmon increased significantly among fish that had spent their first 8 months in the hatchery. This observation was the first indication "that the incidence of tuberculosis was influenced by the length of hatchery rearing."[92]

Surveys made in 1959[65] also showed that 5% of the adult salmon returning to the Columbia River for spawning were infected. All species of Pacific salmonids are susceptible to infection, since mycobacteriosis was found in sockeye salmon (*O. nerka*), coho salmon (*O. kisutch*), chum salmon (*O. keta*), and sea run rainbow trout (*Salmo gairdneri*). The prevalence of disease was very low among salmon which spawned and hatched in spawning channels before going to the sea. Chum, pink (*O. gorbuscha*), and sockeye salmon spawn and hatch in spawning channels and consequently are not kept and fed in hatcheries.

Prior to the discovery of the epidemic of mycobacteriosis in salmon, feed of hatchery-raised salmon included raw viscera from adult salmon. Salmon raised in hatcheries where raw viscera were not included in the diet showed no mycobacteriosis. On the basis of this information, the use of raw salmon viscera in the diet was stopped. As a result, mycobacteriosis in adult salmon almost completely disappeared. This is an excellent example of how contaminated feed can result in greatly increased prevalence of infectious diseases of fishes.

The last bacterial disease discussed here is vibriosis, which is sometimes called saltwater furunculosis. It was first reported by Canestrini[11] in Italy in 1893 and received scientific recognition in 1909 after Bergman,[6] described the disease and the characteristics of its etiologic agent, *Vibrio anguillarum*. Vibriosis is a world-wide disease of marine fishes, particularly when kept crowded in saltwater enclosures at high water temperatures. In mariculture, vibriosis is a very serious factor limiting production.[2,9] It is a very important disease in Japan, where eel culture is very intensive.

Research on control of vibriosis is centered on chemotherapy; chemoprophylaxis with sulfonamides, antibiotics, and nitrofurans; and immunization. Among the effective drugs is the new Japanese nitrofuran, Furanace, which may be added to water or given orally.[14] Fish vibriosis is also a subject of intensive studies of oral administration of a vaccine in the United States,[29] Japan,[89] and Scotland.[27] Under well controlled laboratory and small-scale pilot tests, the results are most encouraging. Unfortunately, oral vaccination in large-scale fish production is still disappointing—possibly because the stress of crowding and high water temperature overcomes the protection conferred by drugs and vaccine.

Another species of vibrio must be mentioned here—*Vibrio parahaemolyticus*—which is common during the summer in coastal waters, where it invades fish and shellfish. It seldom causes disease but is highly pathogenic to humans, particularly in Japan.[12] It may cause disease, or even death, in people who become infected by eating insufficiently heated seafood.

Correct diagnosis of bacterial diseases of fishes requires positive identification of the pathogen. This is usually time consuming because it requires isolation and determination of characteristics of the microorganism. Recently a positive and rapid diagnosis of kidney disease by Chen *et al.*[11a] and furunculosis by McCarthy[54a] was made possible by serologic identification of bacterial antigen directly in the tissues of diseased fishes.

DISEASES CAUSED BY VIRUSES

In early research there were two criteria for establishing the etiology of a viral disease. One was to transmit the disease by bacteria-free filtrates, the other was to show the presence of inclusion bodies in the cells of the affected organs. The second approach was used by Weissenberg,[83] who suggested that lymphocystis disease of fish was of viral etiology because the greatly enlarged cells contained typical inclusion bodies. By means of an electron microscope, Grützner[34] found virus particles in the enlarged cells. Final proof of the viral nature of lymphocystis was isolation of the virus and demonstration of its multiplication in centrachid fish cell lines by Wolf *et al.*[89] There was a span of 52 years between the demonstration of the inclusion bodies and the isolation of the virus. Study is needed at the molecular level to determine how the virus alters the cellular metabolism to produce cellular hypertrophy.

Since about 1950, more evidence has been gathered showing that fish diseases caused by viruses are common. To review the achievements in this field and to chart future research, Snieszko *et al.*[78] organized an international conference on viral diseases of poikilothermic vertebrates held at the New York Academy of Sciences. It was a very important step in the development of fish virology and showed the remarkably fast growth of this branch of fish pathology. Reports were presented on lymphocystis; infectious pancreatic necrosis (IPN); viral hemorrhagic septicemia (VHS) of rainbow trout; viral diseases of Pacific salmon; infectious dropsy of carp; carp rubella; orphan viruses of fish; and neoplastic diseases of eels, flatfishes,[84] and amphibians of presumed viral nature.

At the Eastern Fish Disease Laboratory, K. Wolf became the first full-time fish virologist. He, and his associates, made many significant contributions to fish virology. They established methodology and developed the first fish cell lines and standard methods for diagnosis of viral diseases of fishes.[86,87]

In Denmark, where VHS is an important disease of rainbow trout, significant contributions to fish virology were made by Christensen, Rasmussen, Jensen and Jφrgensen, as reviewed by Schäperclaus[71] and Vestergard-Jφrgensen.[80]

Research on viral diseases of fishes, particularly carp rubella, has been carried out in the Soviet Union since 1950.[3,38]

Contributions to the knowledge about viral diseases of carp were made in Yugoslavia.[24,25] These results have shown that carp diseases, known under the vague name of "dropsy," consists of at least three disease units: spring viremia of carp, caused by *Rhabdovirus carpio;* carp erythrodermatitis; and bacterial septicemia. This disease of carp, in my opinion, seems to be similar to acute human pneumococcal pneumonia which usually, but not always, follows a viral respiratory disease which even alone may be fatal. This is supported by Schäperclaus,[69,70] and Bullock *et al.*,[9] who discuss the role of bacteria in this complex disease.

Viral diseases are causing considerable losses among juvenile Pacific salmonids raised in the hatcheries. Infectious pancreatic necrosis (IPN) and infectious hematopoietic necrosis (IHN) are the most important. Numerous research reports have been published on IHN by Amend and associates at the Western Fish Disease Laboratory as reviewed by Wolf[87,90] and by Wingfield *et al.*[85]

In the southern United States, viral diseases of catfish are also important. Fijan (who was an exchange professor at Auburn University in Alabama) and his associates described a viral disease of channel catfish caused by a herpesvirus which was named channel catfish virus.[26] Important contributions to fish virology are also being carried out at the fish disease laboratory at Thiverval-Grignon near Paris, France.[46,47,49]

NUTRITIONAL DISEASES

Nutrition is an environmental factor that influences fish health. Borderline nutritional deficiencies may result in somewhat slower growth or poor quality eggs. Severe deficiencies may cause visible pathological changes, or increase the host susceptibility to pathogens. Several examples of nutritional diseases that are important in the history of fish diseases are given here.

One of the earliest fish tumors studied in great detail was goiter, or thyroid hyperplasia, caused by deficiency of iodine in early diets of trout. The most complete of several reports on this subject is the monograph by Gaylord and Marsh.[31] More recent studies by MacIntyre[50] and Scarpelli[67] suggested that, although most of the goiters in trout are simple hyperplasias caused by iodine deficiency, a true malignant thyroid tumor in fishes also occurs that is not necessarily caused by lack of iodine.

Another significant fish tumor of nutritional origin is the hepatoma, which for a time over-shadowed the importance of all other tumors in fish. Approximately 20 years ago reports appeared on epizootic outbreaks of hepatoma in rainbow trout raised in hatcheries. The earliest reports were those of Scolari[72] in Europe, and Wood and Larson[91] in America.

There were some earlier epizootics of hepatoma in California from 1936 to 1942 which followed a change of diet; however, these were not publicized until hepatoma became an important issue.[61]

The great epizootic of hepatoma in rainbow trout between 1950 and 1965 followed the general replacement of wet diets, containing second grade fresh meat products, with diets consisting of dry meals. Dry pelleted fish feeds were introduced at about the same time. Soon afterwards, outbreaks of hepatoma in 1 year old or older rainbow trout became frequent. These findings coincided with the discovery, in England, that peanut meal was responsible for the high incidence of hepatoma in young poultry. G. N. Wogan isolated the carcinogenic component which was produced in meals by *Aspergillus flavus* as reviewed by Friedman and Shibko.[28] This agent was called aflatoxin and was found to be responsible for the high incidence of hepatoma in rainbow trout, a species which is very susceptible to this carcinogen. Trout hepatoma is now prevented by using feed components free from alfatoxin and by storing pellets in a dry, cool location not suitable for the growth of *A. flavus*. Mawdesley-Thomas[54] said about the highly successful research on trout hepatoma; "this is an example of a problem being supported by government agencies with a degree of urgency, adequate funds, and skilled workers."

Other neoplastic diseases are not discussed here because excellent and recent reviews on this subject have been published by Scarpelli,[67] Mawdesley-Thomas,[53,54] and Harshbarger.[37,38]

Determination of vitamin requirements of fishes is one of the most interesting chapters in the study of nutritional diseases, but space does not permit a historical review of the subject. There are several centers in the United States where most of the research was done on fish nutrition and nutritional diseases. Since 1932 the Tunison Laboratory of Fish Nutrition at Cortland, New York, under the leadership of A. Tunison and A. M. Phillips, Jr., carried out research, the results of which are published in annual reports of the laboratory. Some of the pioneering work on nutritional gill disease and anemia was carried out by the late L. Wolf, Rome, New York, in collaboration with the Cortland Laboratory. Research on nutrition of Pacific salmon and trout hepatoma was carried out at the Western Fish Nutrition Laboratory under the leadership of J. E. Halver. H. K. DuPree and his associates studied nutrition and nutritional diseases of channel catfish at the Fish Culture Laboratory, Marion, Alabama. Nutritional research and nutritional diseases have been reviewed in detail in a textbook "Fish Nutrition" edited by Halver.[35] The perusal of chapters by S. F. Snieszko and L. M. Ashley in this book show that nutritional diseases, caused by vitamin deficiencies, are very similar to those in mammals. The main difference is in the nutritional fish diseases characterized by pathology of the gills. These diseases are very important in intensive fish culture.

CONTROL OF DISEASES OF FISHES

A disease breaks out when a susceptible species of fish is exposed to a virulent pathogen under proper environmental circumstances. In the control of a disease, at least three factors must be kept in mind: the fish, the disease agent, and the aquatic environment.

1. The fish

We know that different species of fishes are adapted to specific range of temperatures, pH of water, dissolved oxygen, and salinity. Therefore, there is no sense in culturing fishes which are outside the acceptable amplitude of these environmental conditions. This is just good management. There are differences among strains of the same fish species in their susceptibility to certain diseases. Therefore, if a certain disease reoccurs frequently, at some locality, it is desirable to look for, or develop, a strain resistant to such disease. This is possible, practicable, and has been done.[90,22]

2. The disease agent

If at all possible it should be kept out. For the past 10 years, methods have been developed to provide fishes that are free from certain pathogens. Directors of well-managed fish cultural establishments are following this practice with determination. Further, the United States has Title 50 and Canada has similar regulations to prevent the spread, or introduction, of whirling disease and viral hemorrhagic septicemia. Regional fish disease control measures are being introduced and fish health legislation is pending in Congress. *Laws and regulations alone will not control fish diseases, but if their enforcement is in the hands of well-trained, open-minded, practical people, these can be of considerable help.*

3. The aquatic environment

We know very well that the condition of water influences outbreaks and severity of fish diseases. The effect of almost all parasitic, bacterial, and viral diseases can be aggravated by stress of bad environment, and alleviated by favorable environment.

Immunization of fishes against certain diseases is beginning to show promising results. At first it was restricted by the slow immunologic response of fishes at low water temperatures and the need for handling of fishes. Introduction of oral vaccines has given encouraging results in protecting fishes from vibriosis, columnaris disease, redmouth disease and furunculosis. Progress in this field was recently reviewed by Anderson.[2a]

Last, but not least, we have chemotherapy, as well as external treatments with various chemicals. Treatment can be compared to firefighting. It is most effective if started when the fire breaks out. Treatments usually have short-lived effect and a recurrence of the disease may take place if unfavorable conditions continue to exist. In disease, as in fire, prevention is much more important and practical than treatment. Nevertheless, treatment is essential when disease breaks out.

I will not give a list of treatments, these are well described in recent publications such as a comprehensive list published by the National Academy of Sciences.[77]

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