Health and diseases in aquaculture

Diseases of aquaculture species caused by parasites and infectious pathogens have attracted the attention of veterinarians and fish biologists from the early days of aquaculture investigations. A number of prophylactic and curative measures have also been suggested, althoughmany of the chemicals have not been cleared for use in some countries. With increasing investments in aquaculture and closer examination of factors that contribute to the risks faced by an aquaculturist, the concept of integrated health protection measures has developed in recent years. Similarly, experience of fish farming in the tropics has brought into focus the public health aspects of fish farm development and the possible role of aquatic farming in the spread of communicable human diseases. The extensive introduction and transplantation of aquaculture species occurring at present have clearly shown the need for regional and international cooperation in controlling the spread of communicable diseases and implementation of mutually acceptable measures for the purpose.Thus fish health and disease control are now viewed from different angles, that include environmental protection and pollution control, human health and epidemiology, site selection and culture technologies, monitoring and sanitation of aquaculture facilities, diagnosis and treatment of diseases of cultured species, avoidance of nutritional diseases, prevention of epidemics of mortality in culture facilities, formulation and implementation of regulatory measures to control national and international spread of communicable diseases, development of disease-resistant strains through genetic selection and hybridization and individual and mass immunization of cultured species.

Undoubtedly the research, development and regulatory measures needed for an integrated health management programme in aquaculture involve considerable expertise, organization and expense. Both the State and the aquaculture sector will have to share the responsibility for the successful implementation of such a programme.

Being probably the most important risk factor in an aquaculture enterprise, such a programme will have direct relevance to the development of a risk insurance system to protect the farmer from unavoidable losses. While the need for these measures is readily recognized, the low magnitude of the industry at present and uncertainties about the extent to which it can develop and contribute to the overall national economies have prevented its realization in most countries. There is now, however, a greater recognition of its importance among aquaculturists. For example, in

Asia disease problems were considered to be of only secondary importance when extensive farming was the most common practice. With the adoption of semi-intensive and intensive systems, the occurrence of several forms of diseases and consequent mortalities have significantly increased. Similarly, improved expertise and facilities in disease diagnosis have led to the identification of several previously unknown pathogens and disease conditions. Consequently, greater efforts are now being made to diagnose and control disease conditions in the region.

Factors affecting fish health

Fish health or the health of aquaculture organisms has to be conceived as a state of physical well-being. The importance of proper nutrition for rapid growth and the prevention of nutritional deficiencies have been discussed in Chapter 7. Adequate nutrition is also vital for the overall health and vigor needed to cope with a variety of disease agents. Nutritional deficiency symptoms associated with vitamin imbalances are well documented (see Table 7.7). However, imbalances in vitamin content of fish diets are not the only causes of nutritional diseases. Thyroid tumours, liver degeneration, visceral granuloma, anaemia and pigmentation impairment can be caused by other forms of nutritional imbalances. High levels of starch may give rise to symptoms of diabetes in trout and enlarged liver in channel catfish. Freedom from disease is an essential element of physical well-being, but physical and environmental stress have also significant roles in the maintenance of healthy conditions. Many of the potential pathogens of aquaculture species are normally found in the aquatic environment, but in spite of their presence disease may not occur. Obviously, disease is essentially the result of interaction between the species, the disease agent and the environment. So the three major factors of significance are the susceptibility of the species to the pathogens present, the virulence of the pathogenic agent and the environmental

conditions that may trigger epizootics.
Despite the individual importance of each one of these factors in the maintenance of good health or avoidance of disease, it should be emphasized that it is the balance between these factors that determines the state of health. Even in the presence of all three factors, the interaction may be such that no disease occurs. But a disturbance in any of the factors, leading to disruption of the relationship, can give rise to disease.

Susceptibility of the host

The susceptibility or the resistance of the culture species to the action of the disease agent is governed by its physical barriers, its exposure experience and its age. Among the physical barriers are the skin, scales, exoskeleton or shells and mucous membranes which limit the entry of toxic, infectious and parasitic agents. The physiological defences that keep the body from being overrun include the white blood cells that engulf pathogens, avoidance mechanisms, detoxification of chemicals from water or diet by the liver, storage of certain metals by the bones and local tissue reactions. The overall nutritional well-being is the source of the host's physiological ability to defend itself.The immune system and its specific activity against biological agents such as viruses, bacteria and parasites forms an important means of disease resistance. Populations with previous exposure to specific disease agents will generally not be as readily susceptible as those on a first encounter.For this reason and also because of the fragility of their defence system, young ones are more susceptible to diseases than older ones, except that the spawners may experience additional stress because of their reproductive functions. The species specificity of certain disease agents is also a factor of importance in understanding health hazards.
Once the pathogen has established itself within or on the host under favourable condition, the infection may take one of three routes:
(1) the pathogen proliferates, eventually

causing mortality of the host;
(2) the defences of the host surmount the infection and eliminate the pathogen from its system; or
(3) a carrier state develops, whereby a balance between the host and the pathogen may persist generally, with no evident disease symptoms.

From an aquaculture point of view, the greatest concern is the rapid multiplication of the pathogen within the host and the danger of transfer to other individuals of the host population, which may result in an uncontrollable epizootic. During the incubation period (which is the interval between the penetration or establishment of the pathogen in the host and the appearance of the first symptoms of the disease), the host will often be shedding the pathogen. If the host recovers after this initial stage, or after any of the later stages of the infection, without entirely eliminating the pathogen, a carrier condition exists. A carrier surrounding environment or can harbour it in a latent state without shedding. So, even after the clinical stage of infection, some individuals recovering from the disease continue to disseminate pathogens in a manner similar to those that are chronically ill.

As the transfer of infection can occur without the manifestation of disease symptoms, the infections may often be difficult to identify and can be passed unnoticed from individual to individual or even generation to generation. Until the population experiences particularly stressful conditions, which exacerbate disease symptoms, no infection may be suspected. The problem of carrier states in aquaculture species remains one of the most crucial ones for the aquaculturist.

When a disease outbreak is encountered, the pattern of losses, the size of hosts affected and the duration of the epizootic provide valuable information. Sudden, explosive mortalities often implicate acute environmental problems, such as oxygen deficiency, the presence of lethal concentrations of toxicants or lethal levels of temperature.The appearance of a few sick individuals, unusual behaviour or loss of appetite can indicate the beginnings of infectious disease.A disease is generally due to the inability of the host to adjust adequately to environmental stress and consequent dominance of the pathogen, and so the aquaculturist should act quickly when losses occur in typical patterns.A balance between the host and the pathogen should be restored by resolving environmental problems and by effective therapeutic treatment. Timely action is the essence of success in controlling epidemics of mortality in aquaculture, but it needs considerable skill to correct adverse environmental conditions in time to prevent major losses.

The type of aquacultural practice adopted has a decisive role on the susceptibility of the culture species. As indicated earlier, a high density of stocks and the use of restricted spaces like cages, tanks and raceways lead to closer contact between individuals as well as environmental stress. Higher stock densities also mean the use of larger quantities of concentrated feeds and/or fertilizers. This leads to denser growth of plankton and benthos which may include intermediate hosts of disease agents. The environmental and disease risks related to overloading of ponds and enclosures with organic manures are very considerable. The use of heated water effluents from industries and sewage effluents also has built-inrisks; so an aquaculturist has to be prepared for quick and effective action, when an adverse situation develops.

While some of the aquaculture practices are conducive to diseases, there are others that are effective in controlling them. For example, the practice of regular drying of fish ponds and application of lime on the pond bottom helps to kill parasites and many other infectious disease agents.

Pathogen

Biological agents are probably the most

common cause of disease initiation and are the primary focus of attention in infectious diseases. As mentioned earlier, potential pathogens are always present in the aquatic environment. They may include viruses, bacteria, fungi, protozoans, parasitic crustaceans, helminths and other worms. The virulence or pathogenicity of the agent is the relevant factor in the determination of health hazards. It depends upon the physical or biochemical attributes of the agent. Bacteria with flagella or with capsules are generally better equipped to invade the host and resist adverse conditions. Some bacteria are able to elaborate toxins, which cause haemorrhage or affect the nervous system of the host. Enzymes such as chitinase enable bacteria to erode chitinous membranes. Parasites, on the other hand, attach themselves to the host through special organs of attachment, such as suckers.

Penetration into the host is the first step for a microbial agent to multiply and invade the vital organs of its host. This normally happens through ingestion, rupture of the skin, transgression of gill lamellae or penetration of the egg membrane. The specific point of entry may have a decisive role on the virulence of the microbe. Wounds in the skin are common entrance points for some of the bacterial and viral infections, which in turn invite fungal secondary invaders such as Saprolegnia sp. Other routes of entry are usually (i) the gills, where the pathogens can either enter the body through the delicate and thin epithelium, or establish themselves on them as in the case of protozoan infection with Schizamoeba salmonis or Ichtyobodo necator (Costia necatrix), and (ii) the digestive tract, where protozoans like Ceratomyxa shasta may become numerous enough to weaken the fish. Some bacteria may penetrate the intestinal lining under certain conditions. Eventually the pathogen may return to the aquatic medium when shed by the host.

The host/pathogen relationship generally undergoes several stages of development. The incubation period is when the pathogen multiplies but the host does not yet show clinical signs of disease. The incubation period may range from a day or two for virulent pathogens to prolonged periods of several months. After this asymptomatic period, specific and nonspecific signs of disease become evident.Whether the host dies or survives will depend on its ability to resist the infection. During an epidemic, some of the infected animals may not exhibit clinical signs at all and become carriers, capable of transmitting the disease agent or initiating a future epizootic. Animals that recover from a disease may be completely free of the disease agent or continue to be asymptomatic carriers. In many instances, a disease condition may involve more than one pathogen or the infection by one primary agent may create conditions suitable for a secondary agent to gain access. Bacterial infections often follow the establishment of a parasite or of a virus. It is not uncommon to find a wide array of disease and parasitic problems occurring simultaneously.

Environment

The environment plays a crucial role in disrupting the balance between the host and the pathogen. In many situations, the culture animals live a healthy normal life in the presence of pathogens; but when environmental stresses occur and the balance tips in favour of the disease, the pathogen gets the upper hand and disease conditions ensue.

As the primary environmental parameters required would have been adequately considered in selection of the site and species, the relevant stress factor would normally be environmental disturbances that extend the adaptive responses of the animal beyond the normal range or affect the normal functioning to such an extent that chances of survival are significantly reduced. Morphological, biochemical and physiological disturbances occur in different stages and are characterized by a variety of metabolic conditions, such as anoxia, fright, forced exertion, anaesthesia, temperature changes and injury. Though the effect of stress is the alteration of host biochemistry in order to increase the probability of survival of the host, some of the resulting metabolic changes contribute also to increased susceptibility to infection.

Of the physical factors, temperature is one that has an effect on a number of other variables in the environment. Temperatures above or below the tolerance limits of the host animal create stress. Increased metabolic rate caused by high temperature results in higher oxygen demand. However, dissolved gases, including oxygen, generally decrease in solubility with increasing temperature. Also the solubility of toxic compounds increases with increasing temperature, creating unfavourable conditions.

As well as the environmental effect on the host, the effect of temperature on the pathogen is also an important factor to be considered. For example, a rise in temperature generally accelerates to a certain limit all the biological processes of the causative agent, lowering its viability and sometimes causing its death. Similarly, lowering of temperature decreases the biological processes to a certain minimum below which the organism may not survive. Pathogenic organisms of the same genus in the same host may react differently to a change in temperature.

The minimum water quality conditions necessary to maintain fish health are:

dissolved oxygen 5ppm

pH range 6.7–8.6 (extremes 6.0–9.0)

free total CO_2 3 ppm or less

ammonia 0.02 ppm or less

alkalinity at least 20ppm (as $CaCO_3$)

Obviously there are differences in the tolerance limits of different species, but these values provide a general guideline. Levels of tolerance of other elements are chlorine: 0.003ppm; hydrogen sulphide: 0.001ppm; nitrite (NO_2): 100 ppb in soft water, 200 ppb in hard water; and total suspended and settleable solids: 80ppm or less.

Pesticide pollution is one of the common causes of environmental stress in aquaculture situations. The maximum pesticide concentrations that may be tolerated by fish, without noticeable effects, and recognized by the Environmental Protection Agency of the USA, are listed in Table 9.1.

Even though it is not a hazard to the aquaculture species itself, the development of offflavour is a phenomenon that seriously affects the economics of culture.

The earthy or musty taste of fish grown in affected ponds would make them unmarketable. The cause of offflavour is reported to be a compound called geosmin produced by actinomycetes and a number of blue-green algae of the genus Oscillatoria (such as O. princeps, O. agardhi, O. tenuis, O. prolifica, O. limosa, and O. muscorum).

All these organisms grow on mud that is high in organic matter. The organic matter decomposes, causing the reduction of the mud. These organisms grow well on the interface between the reduced mud and the oxidized water layer above it. The off-flavour generally disappears when the fish are held in clean water (preferably running water) for one to two weeks.

Another source of off-flavour in fish is industrial wastes.The odour and taste of these wastes are usually concentrated in the fat deposits of the fish's body. The most important chemicals that impart off-flavours are phenols, tars and mineral oils. Chlorinated phenols, such as ochlorophenol and p-chlorophenol, impart a distinct flavour to carp even in low concentrations of 0.015 and 0.06 mg/l respectively. Eels and oysters are even more sensitive and develop off-flavour when the water contains as little as 0.001 mg/l o-chlorophenol. A concentration of 5–14 mg/l mineral oil, or less if in suspension, also imparts a distinct flavor.

Sanitation

The maintenance of sanitary conditions in an aquaculture facility is of the utmost importance in preventing the outbreak of disease. This is obviously very much tied in with sound culture

practices and sometimes it becomes difficult to separate the two. Monitoring of the water supply is an effective and essential means of controlling diseases. Actual disinfection of supplies is often quite expensive and is generally possible only in hatcheries. Three acceptable methods of disinfection are recommended: tion.
When a facility is affected by infectious diseases and the necessary treatment has been applied or the stock destroyed as the disease is incurable, disinfecting the facility and maintaining sanitary conditions on a continued basis are especially important.
The main goal of a sanitation programme is to prevent the spread of pathogens of cultured species. Egg disinfection strives to prevent the transmission of pathogen from the parent stock to the progeny and transfer from the hatchery to the rearing areas. Sanitary measures can help in confining pathogens of an infected stock to one part of the farm and prevent them from spreading infection to other parts.
The roles of health inspection and infection monitoring to prevent the spread of disease have already been referred to.When introduction or transplantation of aquaculture species is essential and proper certification of eggs, fry or adults to be transplanted, based on regular health inspection, is not available, it will be necessary to consider quarantine measures. This involves retention of newly imported stocks in quarantine facilities for prescribed periods to ascertain whether they are carriers of disease agents. Quarantining is most relevant when the main purpose is to prevent the introduction of communicable diseases that have never been recorded in a country or region. It has been used more widely in research situations, rather than in commercial farming, because of the need for sophisticated holding facilities with capabilities for total disinfection of effluents.
Quarantine facilities must be separated by physical barriers or located away from the farm. All effluents from the quarantine must be fully disinfected. Chlorination of effluents at

200 mg/l total chlorine for two hours is recommended. Lower concentrations may be effective in certain facilities, particularly if a longer exposure is used. These levels may apply only to small water volumes, as use on large volumes of water could represent serious environmental hazards. It is obvious that effective quarantine measures are relatively very expensive, and regulatory agencies often have difficulty in justifying such expenses against the economic benefits to be derived from the introduction or transplantations that can be regulated through these measures.

Farm disinfection

As pointed out above, when a disease occurs the aquaculturist often has no choice but to destroy the stock and disinfect the rearing facilities before starting operations with new uninfected stock. The disposal of the infected stock and disinfection are of special importance if further rearing in the facility is to succeed. Experience seems to indicate that the control of certain diseases can be achieved only through disinfection and eradication of contaminated stocks.The two situations where disinfection becomes impractical are (i) when the probability of reinfection from nearby open waters or farms is unavoidably high and (ii) when the economic loss due to the disease is less than the cost of disinfection. When economic loss is assessed, not only the loss sustained by the particular facility but also potential losses to other facilities in the vicinity should be considered, if not by the individual farmer then at least by the regulatory agencies. Obviously it is easier to destroy the stock and disinfect small, well-controlled facilities like hatcheries, tank farms and raceways. Earthen pond farms are considerably more difficult to disinfect (fig. 9.1).The priority consideration for a commercial operator is the maximum utilization of the stocks in the farm in such a way as not to aggravate the disease problem or contribute to its spread to non-enzootic areas.
Though diseased animals should not be sold to

another farmer for rearing, marketable animals can in most cases be sold for human consumption if it is confirmed that the product (after processing or cooking) does not cause any health hazards to the consumers. If direct utilization is not an acceptable option, the stocks should be destroyed through burial or incineration.

For hatchery and raceway disinfection, chlorine is favoured by several agencies.A concentration of 200 ppm of available chlorine is recommended. If the chlorinated water will enter water bodies containing fish upon leaving the farm, it will be necessary to inactivate the chlorine by neutralization with commercial sodium thiosulphate (at the rate of 1.5 g for every litre of 200 ppm chlorine solution). For disinfecting hatcheries, an exposure of about one hour is recommended at the concentration of 200 ppm of available chlorine. For fish ponds, it may be necessary to super-chlorinate, to establish a chlorine residual of 5–10ppm, and have an exposure period of 12–24 hours. It will take one to two days for the residual to drop to 0, and only after that should any new stock be introduced into the ponds.

As chlorine dissipates rapidly and is inactivated by organic matter, it may be advisable to maintain in hatcheries a concentration of 100 ppm or more for several hours, after the initial treatment at 200ppm for one hour. In large hatcheries and raceways, treatment may have to be done in sections, but it should be done in such a way that no fresh contaminated water flows through parts of the system after they have been disinfected and that dilution of the chlorine solution does not occur.

When dealing with whirling disease, drained earthen ponds should be disinfected by applying slaked lime at the rate of about 2 tons per hectare of wet pond bottom. Several treatments may be required to disinfect earthen ponds thoroughly, because most chemicals are less effective in mud.