of protozoans and monogeneans, while the injection of drug is to treat the systemic bacteria vibrio infection. This freshwater treatment and injection of drugs have been successfully used in many farms in Malaysia and have been incorporated into routine activities in some fish farms with very satisfactory reduction of mortality.

These treatments as described in the previous paragraph are effective against most diseases except for scale drop disease in seabass and ulcerative disease in mangrove snapper. They do not assist in treating viral infections. Seabass juveniles are very susceptible to tail-rot disease in Southeast Asia. The symptom of this disease is the rotting of the tail and the breaking down of the muscle at the base of the tail. All seabass in that net cage should be immediately treated with freshwater.

Should fish be vaccinated against disease? Unfortunately, we know very little about the types of disease in cultured marine fish in Southeast Asia. Most of the cultured fish are affected by vibriosis, particularly grouper. Vaccine for vibriosis is commercially available in Europe and USA. The results of vaccination against vibriosis in greasy grouper are fairly encouraging and vaccinated grouper were less susceptible to vibriosis during the grow-out cycle period. For the vaccination to be effective the grouper should be at least 10cm in length and after vaccination, fish should be given prophylactic treatment as described in the previous section. It takes between 10-14 days post vaccination for the fish to develop some immunity to vibrio bacterial infection. During this period the fish may be affected by other pathogens, as most diseases are caused by multi-species pathogens infection, reducing the effectiveness of the vaccination. It is important that the vaccination programme be carried out in the farm with participation of the fish farmers. Other fish farmers will adapt the vaccination programme once they find out that less fish are dying from disease. The vibrio vaccine has not been used to determine its effectiveness against vibriosis in other fish species. With the availability of vibrio vaccine, an active field research vaccination programme should be undertaken to determine its effectiveness against vibriosis in various fish species.

Aquaculture Fundamentals

Simon Wilkinson, NACA

A general approach to disease treatment and control

In the context of aquaculture, disease may be broadly defined as any condition that leads to sub-optimal production[1]. The aetiology of disease involves an often complex interaction between three main factors: The status of the host organism, the environment and pathogens[2]. When one or more of these factors is unfavourable the host must adapt its physiology and/or behaviour to compensate. These adaptive responses, stress, impair normal physiological functioning and reduce the hosts chance of survival[3]. In particular, chronic stress lowers the resistance of fishes to infectious agents. This is caused by depression of the immune response and progressive leukopenia resulting from the release of corticosteroid hormones[2,3]. The relationship between disease and stress highlights the link between disease and poor management practices in aquaculture[4].

The essential principles of disease treatment and control[1] are to:

- Establish an accurate diagnosis;
- select an appropriate and environmentally responsible treatment;
- evaluate management practices within the farm and determine if future outbreaks could be prevented by changes in procedure or design.

1. Establish an accurate diagnosis

An accurate diagnosis is an essential first step in disease control since it is fundamental to the selection of an appropriate treatment[1,2]. Investigations should commence as soon as a disease problem is detected[5]. This can reduce losses by facilitating early treatment and allowing infected populations to be isolated. It can also assist diagnosis through by allowing the selection of fresh specimens.

Diagnosis requires a systematic approach considering all possible factors to determine the cause or causes of the disease. Ideally, investigations should include the following the following studies[2]:

- Investigation of environmental factors, water quality and stress related factors;
- investigation for pathogens; and
- histopathology (investigation of the host).

Unfortunately, few farms have the facilities or expertise to carry out detailed investigation of pathogens or histopathology[4]. If the farm has the resources (and if one is available) then an appropriate fish health specialist should be consulted to provide a professional diagnosis in addition to on-farm investigations.

Laboratory investigations

A range of clinically affected individuals at various stages of disease should be collected along with some apparently healthy specimens for comparison[5,6]. Sampled fishes should be sent to the laboratory live if at all possible since autolytic changes occur rapidly in fish and freezing destroys or inactivates some pathogens[7]. Anaesthetics should not be used on specimen fish since they kill ecto-parasites and make them more difficult to observe[6]. A comprehensive account of the clinical signs and losses, recent records of environmental parameters, stocking densities, feed and management practices should accompany the sample, along with a sample of the water supply[2].

Strategies for on-farm investigations

On-farm investigations and treatment of disease should focus on identifying and reducing sources of stress[2]. Two approaches to on-farm disease investigations are[1]:

1. Examine the major components of the culture system (fish, water, containment facilities and diet) with reference to the

requirements of the cultured species, looking for ways to improve the management;
2. assess the entire production system for faults that could cause unusual disease and mortality rates from beginning to end, starting with the water intake and finishing with the end product.

A combination of these approaches provides a thorough framework for the investigation of disease, particularly when considered in the context of environmental, pathogen and host related factors.

Environment

The major environmental components of culture systems are the water and containment facilities. One or more environmental parameters may be unsuitable, particularly if the species is exotic and being cultured outside its natural range. Water temperature may be of particular concern in marginal climates or under unusual extremes.

From a production system perspective, critical production points that warrant investigation include any physical, biological and chemical filtration systems, pumps, aerators and water circulation infrastructure[1]. This can be achieved through:

- Examination of current and historical farm-records of physio-chemical water properties to see if they have deviated from preferred levels and may have contributed to the disease outbreak[8]. Records should also be examined for any rapid changes in environmental factors since this can also result in stress[2] even if the changes occur within ranges normally tolerated by the species[9,10];
- supplementary investigations to assess parameters that are not routinely monitored such as the possibility of chemical contamination of the water supply[2]; and
- physical examination of water management and containment infrastructure for proper function and its safety/suitability as a habitat for the cultured species[1].

Pathogens

Affected fish should be examined for pathogens as far as the facilities and expertise of the farm permit, even if this just involves external examination of the fish. The water supply, introduction of new stock, live feeds, contact with wild animals, quarantine and hygiene procedures are critical points in the production process where a pathogen could enter[2,11]. Farm records should be examined to determine if the disease could be traced to these factors.

Many of the organisms that cause disease in aquatic animals are facultative pathogens in that they are a normal part of the host's microflora and will cause disease only when the host is under stress[2,8,12,13]. Epidemiological studies must therefore take into account post-infection events[3] and consider interactions with environmental and host-related factors[2].

Host

Key host related considerations include nutritional factors and behavioural interactions between the host species.

Nutritional deficiencies can arise from the use of new or inappropriate feeds[2]. However, most deficiencies are caused by inappropriate storage or feeding regimes rather than by inadequate formulation[1]. Some vitamins and macronutrients, particularly fats, are not stable and may quickly degrade with lengthy or inappropriate storage and handling[14,15]. Nutritional deficiencies can be diagnosed through histology[2], further highlighting the need to submit specimens to fish health laboratories for professional diagnosis.

Feed delivery, in terms of ration size, frequency, timing and distribution is also a critical point in the production system[14]. Records of feed regimes and feed type should be evaluated to see if they are appropriate for the species under culture and if there have been any recent alterations that might have contributed to the disease outbreak. Ideally, feed should periodically be analysed to test for contaminants and to verify composition[1].

High stocking densities are recognised to contribute to the risk of disease outbreaks by having a detrimental effect on water reducing environmental quality and facilitating the transmission of pathogens[11,16]. High stocking densities or inadequate provision of shelter can also encourage fighting and aggression between fish[1] leading to wounds and subsequent infection. Stocking densities should be reviewed in light of the suitability of the prevailing environmental conditions. If conditions are poor, consider reducing stocking density.

2. Select an appropriate and environmentally responsible treatment

A holistic approach should be adopted to treatment that considers the interaction between the host, the environment and pathogens[4]. Clearly the most appropriate treatment for the disease will depend on the diagnosis determined by a fish health specialist and also on the specific management practices and resources of the farm. However, even where a reliable diagnosis is not available the farm should adopt a precautionary approach to try and minimise losses. Precautionary measures should be aimed at reducing stress, particularly as part of the initial on-farm investigation of disease[2].

Five general principles must be considered in the selection of a treatment[16]:

- What is the likely outcome if the treatment is or is not given ?
- Is the treatment economically viable relative to the value of the fish ?
- Will the fish withstand the treatment ?
- Does the loss rate and the particular disease justify the treatment ?
- Is the treatment acceptable in terms of risk to human health or the environment, or market acceptance of product ?

Under some circumstances the most appropriate response may be to simply harvest the fish before additional losses occur, or to destroy them.

Environment

Poor water quality can be alleviated through water exchange assuming that the water intake of farm is of a higher quality than that in the culture system. This will reduce organic loads that boost populations of fungi, bacteria, and protozoans[1] and assist to flush out the larval stages of ectoparasites[2]. In closed systems, filtration of water down to 1um to remove organic solids is an alternative means of reducing organic loads[1]. Supplementary aeration should also be provided to reduce stress[2].

Pathogens

Strategies for the control of pathogens include:
- reducing stress (considered elsewhere);
- use of chemotherapeutants;
- eradication; and
- a combination of the above.

Usage of chemotherapeutants may be warranted to treat a presumptive microbial infection (subject to diagnosis), or in some cases as a prophylaxis against infection. However, it should be stressed that antibiotics will not remedy poor management and the underlying causes of disease also need to be addressed.

Factors that need to be considered prior to use of a chemotherapeutant include[16]:
- the properties of the chemical and its impact on non-target species, toxicities, effective doses, and spectrum of activity;
- the tolerance of the culture species to the chemotherapeutant;
- the tolerances of the disease agent;
- the volume and properties of the water in the culture facilities - this may affect dose rates and tolerance of the chemotherapeutant;
- human health, market and environmental considerations.

Inappropriate use of antibiotics can lead to the development of resistant strains that may be difficult to treat[11,17]. Many countries, such as the USA, set maximum residue limits and withdrawal periods for antibiotics used in food for human consumption[18]. Consideration should be given to the constraints that will be imposed on harvesting by the withdrawal periods and residue standards of the intended market.

The USFDA has developed a code of practice for the use of antibiotics that includes additional guidelines for farmers[1]:
- antibiotics should be used only as last resort;
- a definitive diagnosis (including antibiotic sensitivity) is required to effectively target a pathogen;
- less expensive and environmentally friendly chemotherapeutants, eg. salt, are preferred.

In some circumstances, such as the occurrence of a serious or persistent pathogen it may be necessary to attempt eradication. Eradication involves the removal of all susceptible or potentially susceptible species, drying out and liming of ponds and disinfection of contaminated equipment[19].

Host

The nutritional state of fish influences the production, maintenance and repair of tissues[3]. It may be desirable to obtain a fresh supply of feed from a different manufacturer if possible and mild vitamin and mineral supplementation may be considered until a definitive diagnosis can be made. These measures will reduce the risk of further damage to the fish in the event that the feed is contaminated or spoiled, or that it does not meet nutritional requirements. In particular, supplementary levels of vitamin C have been shown to confer additional protection against disease in fish apparently by boosting both specific and non-specific immunological defence mechanisms[19].

Reducing the population density of the host is an effective means of reducing stress and may be sufficient to lead to recovery in some circumstances[3].

3. Prevention - Controlling disease through effective management

Disease in fishes is often secondary to environmental insult[16] and an expression of poor nutrition and/or environmental quality[19]. The most important approach to disease control is managing the culture unit to reduce disease predisposing conditions[16]. This is best achieved by through the use of realistic stocking densities, preventing the introduction of pathogens, maintenance of good water quality, avoiding stress and through the provision of adequate nutrition[16,20]. Elements of a preventative approach are:
- Continuous evaluation and improvement of management techniques.
- Awareness of disease and of the requirements of the cultured species;
- A systematic approach to health monitoring and record keeping;
- Hygiene and quarantine; and
- Contingency planning;
- Continuous evaluation of management practices

An essential component of treating a disease outbreak is to evaluate management procedures to determine if they contributed to the condition and if they can be improved. Farm records and management processes should be reviewed and adjusted accordingly. Similarly, any experiences or lessons learned in the response to the disease should be incorporated into the farm's contingency plans to facilitate future responses to disease. The systematic approach to the on-farm investigation of health problems suggested above could also be usefully applied in a pro-active manner to the production system to identify potential hazards prior to the occurrence of disease.

Awareness

An understanding of the environmental, nutritional and behavioural requirements of the cultured species is fundamental to the provision of an adequate diet, environment and habitat. Farm staff need to be adequately trained in the recognition, life cycle and aetiology of disease in order to detect predisposing factors and early signs[11].

Monitoring

A systematic approach to monitoring of the behaviour and condition of fish and of the culture facility are essential for effective management of the system and for the early detection of disease[2,4,11,19,22]. Fish tissues should be regularly examined[4,11]. However, it should be recognised that the value of screening to exclude disease is limited for those of low prevalence[23]. Similarly, equipment and should be regularly inspected and serviced and staff should be able to identify malfunctions in critical equipment such as pumps and filters.

Accurate and comprehensive records of environmental parameters, observations and all activities should be maintained[2,11]. Historical records provide a base-line that allow perturbations in the system to be detected and acted upon before they result in disease. Records can also help to retrospectively identify factors contributing to the outbreak of disease and to subsequently improve management practices. Records should preferably be kept on computer to facilitate analysis and a variety of pond and tank management software is now available.

Hygiene and quarantine

Good health in hatcheries and farms is best achieved through efficient hygiene. This includes regular disinfection or drying of equipment and culture facilities and hygiene of staff, prevention of aerosols and cross contamination between facilities, the use of anaesthetics during handling procedures to reduce stress and wounds, and the use of prophylactic treatments where appropriate[11,19].

Newly arrived stock and live feeds such as forage fish should be quarantined for a period and examined for signs of disease[11]. Prophylactic treatments may be judiciously applied in quarantine[24] or when host resistance is low[11]. If possible, stock should be purchased from specific pathogen free sources[2]. This is particularly important for broodstock.

Similarly, the water supply in ponds and hatcheries should be screened to prevent the entry of larval pathogens or of animals that may carry disease[11,19]. In problem areas, water should be obtained from well or bore sources, or stored in a fish-free reservoir for an appropriate time prior to use[19].

Contingency planning

Contingency plans for disease investigation and control should be established as part of the farms general preparation for a disease emergency. Plans should outline mechanisms for identifying diseases and treating outbreaks of disease, as well as procedures for isolating affected culture facilities, collecting and dispatching specimens and contacts for fish health specialists and relevant government authorities.

Conclusion

A holistic approach should be adopted to the diagnosis, treatment and prevention of disease. This should consider the interaction of the environment, pathogens and host-related factors. An accurate diagnosis is fundamental to the selection of an appropriate treatment and consultation with a fish health specialist should be an integral part of any investigation where circumstances allow. The economics, possible side-effects and environmental impacts of treatments should be considered prior to application. Preventative management is the most important step in disease control since a systematic and thorough approach to health management can reduce the incidence of disease and associated production losses.

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