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Challenges to Health Management in Asian Aquaculture

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Abstract

Diseases are a major constraint to the sustainable development of Asian aquaculture. Many diseases affecting present-day aquaculture result from intensification of culture prac-tices without a basic perception of the intricate balance between host, pathogen and envi-ronment. Often, disease outbreaks are closely linked to environmental deterioration and stress associated with intensification of culture practices. Stress factors such as inadequate physico-chemical and microbiological quality of culture water, inferior nutritional status and high stocking densities can cause infection by opportunistic pathogens, leading to mortality. Unprecedented movement of aquaculture seed and broodstock between regions and locali-ties has created fish and shrimp populations with inherent pathogens, making these popu-lations more prone to serious diseases when they are under stress. Indiscriminate use of chemicals, including antibiotics, may cause serious environmental problems. Outbreaks of diseases, caused by virulent primary pathogens, can be minimized through careful quaran-tine, prophylaxis, and therapy. However, the much emphasized practice of "good on-farm management" will become costly and ineffective if basic culture requirements such as ap-propriate site selection, farm design, quality of incoming water, nutritional status of feed, and quality of seed are not guaranteed. The present paper attempts to discuss the chal-lenges that we have to face in formulating strategic aquatic health management programs for the sustainable development of Asian aquaculture.

Introduction

World aquaculture production increased from 10.5 million mt in 1984 to 27.8 million mt by 1995, for an average compounded growth rate of 9.6% per year. During this period, freshwater finfish and mollusc production has increased steadily while relatively high value crustacean production showed a comparatively rapid growth. The total contribution of aquaculture production to global fisheries increased significantly during this period, as did the value of aquaculture production (global aquaculture production in 1995 was valued at US$42.3 billion) (FAO 1997). Considering the present rate of population expansion and keeping in mind the present average per capita fish consumption of 13 kg/year, it is estimated that the global demand for fish and shellfish may be in the order of 87 million mt by the year 2010 (FAO/Japan 1995). In order to meet this predicted demand, global aquaculture production would have to double over the next 15 years.

Asia is in the forefront of aquaculture production, both in terms of volume and value, with China, India and Japan accounting for over 65% of world production. Asian aquaculture production comes from a number of different aquaculture systems ranging from intensive and semi-intensive to extensive systems and culture-based fisheries. Aquaculture in Asia holds considerable potential for further growth, through intensification, diversification and further expansion. However, for this potential to be realized, Asian aquaculture must grow in a sound and sustainable manner. In particular, one of the most significant constraints that will re-emerge as Asian aquaculture expands and develops is the threat of disease.

Asian aquaculture will undoubtedly intensify during this process of development and expansion, mainly due to the competition for the use of common resources such as land and water. Although diseases and health are usually not significant problems in extensive aquaculture practices in Asia, experience has shown that as systems are intensified, diseases and pathogens often become unavoidable and, sometimes, become severe obstacles to aquaculture development.

The conventional methods and approaches that have been utilized so far have had limited success in the prevention of aquatic animal diseases in Asian aquaculture (Phillips 1996). Considerable challenges still remain in dealing with existing problems, such as economically important diseases in shrimp culture. Large-scale outbreaks of aquatic animal disease, particularly in shrimp culture, demonstrate the importance of addressing such outbreaks within a wider environmental context, *i.e.* where and when problems are easily spread beyond the control of individual farms, affecting many farms in a given area (Phillips 1995; see also Pullin 1995). Such problems require broader management approaches to control farm-level environmental deterioration and allow preventive measures to be taken against pathogens. Therefore, in order to confront the threat of disease in the context of sustainable development, it is imperative to adopt holistic approaches to health management, possibly within a wider framework of integrated resource-use planning and management, which should not only reduce the emergence of disease outbreaks, but also help minimize potentially adverse impacts on the environment (Phillips 1996). The main purpose of this paper is to encourage cooperation among scientists, government officials and aquafarmers on the issues and challenges described, for the benefit of sustained supply of aquaculture products to and the socio-economic development of people in Asia.

Aquatic Animal Diseases

Aquatic animal diseases can be caused by: a) primary pathogens without involvement of environmental stress; b) primary pathogens as a result of environmental stress; c) opportunistic pathogens as a result of environmental stress; and d) poor environmental conditions without involvement of pathogens. Categories a) and d) are relatively rare but b) and c) appear to be the most common causes for diseases prevailing in Asian aquaculture. The degree to which an animal is susceptible to pathogens and the occurrence of clinical disease largely depends on the environment in which animals are cultured. Therefore, understanding the relationship between host, pathogen and environment is important in recognizing the cause, prevention and treatment of many aquatic animal diseases.

Conventional Methods of Controlling Aquatic Animal Diseases

Six major approaches are generally considered in controlling aquatic animal diseases: i) on-farm environmental manipulation to minimize stress in cultured animals; ii) avoidance of pathogens; iii) disease prevention by prophylaxis; iv) immunomodulation; v) vaccination; and vi) chemotherapy.

On-farm environmental manipulation

This approach is based on the concept that "a given water volume will support a given weight of fish/shrimp at a specific range of temperature, oxygen concentration, fertility, and food availability under natural conditions" (Plumb 1992). As systems are intensified and these weights are increased, significant demands are placed on the environment that, if not corrected through manipulation, may cause great stress on the animals under culture, leading to large losses. Addition of feed, accumulation of fecal waste and the subsequent process of decomposition result in increased levels of CO_2, ammonia, nitrite and other harmful metabolites. Manipulation of on-farm environment through interventions such as the use of realistic stocking densities, provision of water exchange and aeration at appropriate times and avoidance of temperature shocks will reduce disease-predisposing conditions, thus reducing the risk of disease outbreaks.

Avoidance of pathogens

The avoidance of pathogens in an aquaculture system is probably the best way to prevent outbreaks of diseases in cultured animals (Subasinghe and Shariff 1995). However, this is a difficult task. Pre-treatment of water supplies to eradicate harmful microbes may be feasible in commercial hatcheries but are not realistic in semi-intensive grow-out systems. Proper siting and synchronized water intake (in cluster operations) will undoubtedly reduce entry of pathogens into culture units. The establishment and maintenance of an effective regulatory framework to control movements of aquatic species, the enforcement of effective health certification and quarantine practices, and the implementation of macro-environmental approaches for management of water supplies and aquaculture effluent discharge are the key factors to consider in the avoidance of pathogens. Development of Specific Pathogen-Free (SPF) broodstock and seed could be a way to reduce entry of pathogens into aquaculture systems. However, at present, availability of cost effective SPF animals is beyond the reach of most Asian aquaculturists.

Prophylaxis

Disease prevention by prophylactic use of chemicals emphasizes procedures that prevent infections even if pathogens are present in the environment

(Subasinghe and Shariff 1994). These procedures are generally employed when organisms are most vulnerable to injury, trauma and physiological stress. This approach is quite useful but provides protection only during certain events of the culture cycle.

Immunomodulation

Great hope is currently attached to harnessing the host's specific and non-specific defense mechanisms in controlling aquatic animal diseases. Besides vaccination, immunostimulants and non-specific immune-enhancers are being incorporated into diets to provide added protection to the cultured animals. Non-specific defense mechanisms in fish are very important for protection against invasive microorganisms (Chen and Anisworth 1992). If these mechanisms can be stimulated, the occurrence of cyclical or seasonal epizootics which may be predicted could be minimized. Using these compounds in anticipation of disease outbreaks may enable aquaculturists to achieve economic benefits through reduced mortality of fish and growth impairment of pathogens. However, much remains to be done with respect to dose levels and delivery schedules to maximize the effectiveness of immunostimulants. Also, fish culturists and pathologists need assistance in selecting immunostimulants which will have minimal side effects, will not endanger the health of consumers, and are environmentally safe. Nevertheless, immunostimulants should be used as marginal aids to health rather than as substitutes for good husbandry. The efficiency of the immune system can only be enhanced by immunostimulants if it is not already under stress from poor environmental conditions (Anderson *et al.* 1995).

Vaccination

Vaccination may be used to control infectious diseases in aquatic organisms. However, at present, only three vaccines are used in Asian aquaculture: a multivalent, nonspecific vibrio (*Vibrio* spp.) vaccine for shrimp (*Penaeus* sp.), a *Vibrio anguillarum* preparation for rainbow trout (*Oncorhynchus mykiss*), Atlantic salmon (*Salmo salar*), ayu (*Plecoglossus altivelis*) and occasionally for other brackishwater or marine cultured fishes, and a vaccine for *Yersinia ruckeri* (enteric redmouth) in trout. No commercial vaccine is yet available for cultured tropical finfish species in Asia (Plumb 1995). The efficacy of these vaccines, especially the shrimp vaccine, are uncertain, although scientific literature claims that they can maintain an acceptable level of protection in cultured animals (Horn *et al.* 1995).

Although vaccines are not currently as widely used as chemotherapeutics, they have made a positive impact on aquaculture in some developed countries (Roberts 1995). In the next decade, researchers may be able to develop effective, technologically advanced and economical vaccines which could be used in Asian aquaculture. However, it is imperative that a significant shift in attitudes from the use of chemotherapeutics to vaccines be created first among aquaculturists. As vaccines are developed and incorporated into management schemes, the need for chemotherapeutics will be reduced, if not eliminated.

Although not infallible, vaccines, if used wisely, can be an asset to the aquaculture industry.

Chemotherapy

The general approach of many Asian aquaculturists towards disease problems in aquaculture has revolved around chemotherapy. Chemotherapy is an essential component of health management in many aquaculture practices (Plumb 1995; Meyer and Schnick 1989; Schnick 1991). While it is imperative that good environmental conditions be provided to produce healthy aquatic animals, it should be borne in mind that the biological demands and technical characteristics of the culture system itself does not allow for indiscriminate chemotherapy. Although the need for chemotherapeutics in aquaculture is obvious in a range of circumstances, efforts must be made to reduce dependence on their use and minimize release of potentially hazardous compounds. It should be emphasized that chemotherapeutics are not a substitute for good culture management and will not correct the detrimental effects of mismanagement and incorrect husbandry.

There are also major disadvantages in using chemotherapeutics (Leong 1993; Bell and Lightner 1992). Chemotherapy has a short-term effect and, once stopped, may not prevent a disease from recurring, especially if an environmental stressor that may have precipitated the disease still persists. Moreover, the cost of chemotherapy can be variable and not be predetermined. It has been shown that continuous or inappropriate use of antibacterials can promote development of bacterial strains resistant to antimicrobials (Aoki 1992; OIE 1992; Alderman *et al.* 1994). Some chemotherapeutics used in aquaculture can be environmentally hazardous (Primavera *et al.* 1993; Choo 1994), and may have potentially detrimental side effects not only on the treated animals (Baticados and Paclibare 1992; Karunasagar *et al.* 1994), but also on those who consume them (Yndestad 1992; Park *et al.* 1994; Saitanu *et al.* 1994; Srisomboon and Poomchatra 1995; FAO/WHO 1994). The considerable increase in consumer concern matched by the increasing resistance of pathogens to the current, relatively inexpensive antibiotics and treatment chemicals will reduce their present high levels of usage considerably. Newer products which are currently being tested and licensed may well have advantages for the future, but they will probably be expensive, reducing their usefulness unless they prove to be highly cost-effective.

The Environment and Aquatic Animal Disease

When defense systems are severely compromised by any of the wide range of stressors imposed by a culture system, aquatic animals become prone to invasion by opportunistic pathogens. As diseases, either infectious or non-infectious, often depend on the stress imposed by the quality of the environment in which the animals live to thrive, the first important step in controlling disease is by maintaining the best quality environment possible in a culture unit. It is well known, however, that "optimal" environmental conditions are often not present in many aquaculture farms.

The majority of losses from diseases in Asian aquaculture are husbandry-related (FAO 1995). Too often have the environmental limits of the systems been exceeded, resulting in intolerable stress to cultured stock. As a consequence, existing farms with inadequate soil and water quality, in many cases, have experienced severe difficulties in sustaining their production. This has been the experience in some areas of Asia where aquaculture production has collapsed (Lin 1989) and many aquafarms have been abandoned (Liao 1990). The lesson learned from this experience is that if there is excessive pressure on the "environmental" capacity of such farming systems, aquafarms will inevitably fail and close down.

From Micro-Environments to Macro-Environments of Aquafarms

Experience has shown that fish and shrimp culture systems, when present in great numbers of farming units in a given area and depending on their level of intensification, carry the potential to cause "self-pollution", mainly through nutrient and organic enrichment of waters receiving their effluents, particularly if the water exchange rate of the recipient water bodies is low. Although basic husbandry techniques may help clean the systems effectively, pond effluents (or wastes released from cage farms) can cause significant loads of wastes to be discharged into common water supplies, thus leading to the deterioration of the overall aquatic environment. This has been clearly indicated in the recent outbreaks of shrimp disease in several Asian countries.

In addition, industrial effluents, urban sewage, run-off of agricultural pesticides and fertilizers, excessive water abstraction, and silt loadings deriving from poor land use practices and erosion in watersheds have created serious problems which can jeopardize aquaculture development efforts in inland and coastal aquatic environments (see Alabaster 1986; Chua *et al.* 1989; Gomez *et al.* 1990; Dubey and Afroz 1995; IPFC 1994; Petr 1995; UNEP 1990; Yap 1992; Barg *et al.* 1997).

In brief, there are a number of environmental interactions relating to aquaculture systems (FAO/NACA 1995; Kutty 1995; Bagarinao and Flores 1995). In addition to the deterioration of environmental conditions within the farming unit, e.g. quality of water and soils (Yoo and Boyd 1994; Boyd 1995a; Boyd 1995b), these include impacts of aquaculture on aquaculture (e.g. through "self-pollution" of water supplies through discharge of pond effluent), environmental impacts on aquaculture (in particular, those caused by industrial, domestic and agricultural pollution of water supplies for aquaculture), and environmental impacts of aquaculture (e.g. through discharge of pond effluent and habitat changes caused by pond construction, etc.). Documentation on aquaculture-environment interactions has increased during the last decade (Beveridge 1984; Bailey 1988; Pullin 1989; Primavera 1991; Iwama 1991; GESAMP 1991; Phillips *et al.* 1991; Pillay 1992; Lee and Wickins 1992; Macintosh and Phillips 1992; Pullin *et al.* 1992; Barg 1992; Phillips *et al.* 1993; Csavas 1993; Beveridge and Phillips 1993; Pullin 1993; Pullin *et al.* 1993; Beveridge *et al.* 1994; Phillips 1995; Flaherty and Karnjanakesorn 1995; Rajagopal 1995).

Disease Control and Environmental Resource Management

From the above discussion, it is evident that aquaculture farms and their management cannot be considered in isolation from the surrounding environment. The challenge, however, is not only to consider environmental concerns related to aquaculture but also to design and carry out effective health management measures which will help minimize adverse environmental effects on, and of, aquaculture.

A broader health management approach which should be based on an understanding of the ways in which the different components of an aquaculture system interact and how these are influenced by changing environmental conditions, both within and outside the farming unit, is therefore required. Such a broadened health management perspective would integrate changes in resource use (particularly water, soil, feed and seed), as well as on- and off-farm changes of relevant environmental parameters, into measures for assessment and management of fish health conditions.

This approach focuses on environmental management of resources utilized by a single aquaculture farm or by clusters of farms, and by other (non-aquaculture) users of resources. The major components of this approach which need to be considered and addressed by aquafarmers, scientists and government officials, can be grouped as follows:

- Physico-chemical components (type of soil, water quality and quantity, climate, location of culture unit, etc.);
- Biological components (cultured species, stress levels, nutrition and feeding practices, genetic factors, the presence or absence of pathogens, microbial quality of water, etc.);
- Regulatory aspects (policies and legislature governing resources allocation in aquaculture, chemical usage, quarantine, health certification, movement and trade of aquatic animals and animal products, environmental impact assessment and monitoring, etc.).

In order to reduce the occurrence of environmental and disease problems related to aquaculture, the following issues and options for their management should be considered.

Environmental standards and guidelines

Intensification of aquaculture will inevitably lead to water and soil quality deterioration, unless sound on-farm management practices are employed. In addition to appropriate management of production and intensification processes, farm effluents must be managed efficiently to avoid the contamination of water supplies of nearby farms. In the case of open-water systems, the risk of environmental contamination of water, soil and fish products may be high, depending on water exchange rates and exposure of water supplies to contaminated sources. The use of closed-water-systems or recirculation systems may be considered as an alternative, but such systems are certainly not feasible in all aspects, particularly for financial reasons. Therefore, regardless of whether open- or closed-water systems are used, on-farm management of wastes and effluents will be a key factor in reducing degradation of the physico-chemical and biological quality of the environment. The development of guidelines and standards for the treatment and discharge of effluents, together with effective implementation of strict but realistic legal measures, may help reduce such environmental risks. However, there is a considerable lack of scientific data on both national and regional levels for the setting up of such standards and guidelines as well as little or no effective mechanisms in place which would facilitate effective transfer of information to and from aquafarmers regarding their farm management needs and the environmental conditions of water resources used in their farms (Cho 1995; Hambrey, in press).

Quarantine and health regulations

With the intensification of aquaculture, aquaculture systems will have to rely heavily on external inputs such as seed and feed (Tacon 1995; Tacon *et al.* 1995). This will increase threats of introduction of pathogens into aquaculture systems. An understanding of how to deal with such situations will become significant for the sustainability of aquaculture. Establishing effective quarantine guidelines and health certification procedures could help minimize the risk of introduction of harmful pathogens.

Quarantine programs form part of the first line of defense against possible adverse effects resulting from the trans-boundary movement of aquatic species. As such, they must be developed within the context of larger national and international plans addressing this problem. "Codes of Practice" for the international movement of aquatic species which have been developed by international organizations provide a starting point for designing national and regional fish health legislation as well as international agreements aimed at preventing the spread of disease. To succeed, such efforts must be accompanied by the development of regionally agreed-upon lists of notifiable pathogens, the standardization of diagnostic techniques and the production of health certificates of unambiguous meaning. A strong commitment by aquafarmers and governments and the cooperation of importers and exporters as well as seed producers and traders are considered key elements in the success of these programs. Successful disease prevention will also be directly related to (i) the ability of countries to reduce their dependence on imported broodstock and fry for the aquaculture industry; and (ii) the regulation of shipments for the ornamental fish trade, particularly those involving fishes caught in the wild (Arthur 1995).

Use of land and water resources

Competition for the use of resources such as water and land (used by agriculturists, industrialists and households, etc.) will increase with population growth and the expansion of aquaculture. This competition will lead to an increased risk of environmental degradation, particularly aquatic pollution, which may well have severe consequences for existing aquaculture enterprises or for future aquaculture development initiatives (FAO/FIRI 1995a; FAO/FIRI 1995b;

Muir 1995; Coates 1995). This could, for example, be particularly important to coastal aquaculture (GESAMP 1987; Chua *et al.* 1989; GESAMP 1990; Barg 1992; GESAMP 1994) and also for freshwater aquaculture, including culture-based fisheries, in sections of rivers, lakes and reservoirs which are exposed to increasing aquatic pollution threats (Dudgeon 1992; Barg *et al.* 1997). Since many of these environments and habitats are being placed under severe development pressure, and since adequate regulatory measures are sometimes lacking or not enforced, this may lead to deterioration or loss of required water and land resources, with serious impacts on aquaculture development in certain areas of Asia (Natarajan 1989; Petr and Morris 1995). Unfortunately, in many cases, aquaculture is not recognized as a legitimate user of these resources, resulting in little or no protection of aquaculturists' interest in and need for adequate quantities of quality water and land resources (FAO/NACA 1995; Van Houtte 1994; Van Houtte *et al.* 1989). Moreover, there is often little or no consideration given toward the long-term consequences of uncoordinated resource utilization in a given area, adversely affecting other areas in river basins and/or coastal zones (Chua and Pauly 1989; FAO 1991; UNESCO 1990; IPFC 1994; Scudder 1994; Boelaert-Suominen and Cullinan 1994; Hayton 1990).

An adequate development framework dealing with the issues pertaining to shared use of resources and environmental protection, and promoting awareness and cooperation among aquafarmers and other resource users, government officials and scientists, is essential for the sustainable expansion of aquaculture (for related documentation, see De Silva 1985; Baluyut 1986; Sreenivasan 1986; FAO 1986; Costa-Pierce and Soemarwoto 1987; Chang 1989; Dunn 1989; Chua 1992; Chua and Fallon-Scura 1992; Clark 1992; Mitchell and De Silva 1992; Chua 1993; Martinez-Espinosa and Barg 1993; FAO 1993a; FAO 1993b; Barg and Wijkstrom 1994; Burbridge 1994; Ch'ng 1994; Kurien 1994; Edwards and Little 1995; De Silva 1995; McManus 1995; Pullin 1995; Pullin 1997).

While individual aquaculturists can and will have to take responsibility for on-farm environmental management, governments should regulate the use of resources, whether shared or privately owned, and provide legal and institutional arrangements in support of sustainable aquaculture development that will help minimize resource-use conflicts and environmental impacts of and on aquaculture (FAO 1995; Csavas 1995). Acceptable levels of production should be related to assured availability and quality of resources required, and to the technological and biological capacity of the aquaculture system to produce over the long-term without collapsing, or causing detrimental effects to, the environment. Such sustainable aquaculture will not necessarily yield dramatic, short-term profits but help increase general public acceptance that aquaculture is a long-standing, food commodity-producing sector.

Research and Development

Considering the broad-based approach outlined above, it is appropriate to discuss the role of fish health scientists in developing strategic health management programs for Asian aquaculture. Since the adoption of holistic approaches to health management, possibly within a wider framework of integrated resource-use planning and management, is critical for aquatic animal health management, fish health scientists should design and implement well-focused research programs addressing the needs of this broader approach.

While research focused on the obtaining of data on chronic sublethal effects of aquatic pollutants on growth, reproduction, etc. are vital, research on actual economic losses and their relation to mortality, production loss and feed conversion are also important. The situation with regards to disease of broodstock has to be properly studied as the practice of collecting broodstock from the wild on a continuous basis is unsustainable.

There is but a marginal understanding of the natural and acquired immunological defense mechanisms of many cultured aquatic species in Asia. Such understanding, however, is essential for the development of vaccines, immunostimulants and immune-enhancers. Nutrition is an important contributor to the susceptibility of fish to disease and the relationship between disease susceptibility and nutrition is particularly important but still poorly understood (Tacon 1992).

There are considerable opportunities for science to further the understanding of defense mechanisms by applying different methods of disease control and health management, together with the use of new diagnostic tools such as Enzyme Linked Immuno Sorbant Assay (ELISA), DNA Probes, and Polymerase Chain Reaction (PCR) technology. These methods and tools, combined with genetic engineering breakthroughs such as the development of disease-resistant strains, should contribute strongly to a new, more productive aquaculture. Fish health scientists should work closely with environmental scientists and designers, and implement research which are focused on the needs of aquaculturists, if expectations of aquaculture in Asia are to be fulfilled.

Training and Extension

It is pivotal to the sustainable development of aquaculture that novel research data and information are effectively communicated to those who can utilize them. The biggest challenge to aquaculture, therefore, in the 21st century will be the training and the dissemination of information on sustainable aquaculture methods. Hence, the mechanisms for information transfer must be in place. Communication of information on appropriate farming practices may be enhanced through "farmer train farmer" schemes.

Fish health trainers must change their attitudes towards providing training on mere conventional disease control measures and should incorporate environmental resource management into their training curricula. Aquaculturists must be exposed continuously not only to new developments in disease control, but also to husbandry and environmental resource management. Both governments and non-governmental organizations have major roles to play in aquaculture and concerned international agencies should provide support on a priority basis.

Conclusion

Conventional methods of disease control and health management will undoubtedly continue to play a major role in aquaculture development. Nevertheless, further emphasis will need to be given to the appropriate and more responsible application of these methods. There is much to be gained from increasing the effectiveness of such methods and for integrating environmental resource management approaches into disease control and health management. Related efforts should be undertaken in the specific areas of research and development as well as training and extension, with the main concern being that the needs of aquafarmers are met. By addressing these challenges, Asian fish health scientists and aquaculture practitioners should be able to contribute to fulfilling the expectations that the world has of Asia, the cradle of aquaculture and the largest fish farm on the planet.

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