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Meeting the Future Demand for Aquatic Food through Aquaculture: the Role of Aquatic Animal Health

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The increasing importance of aquaculture, at present, is undoubtedly recognized. The sector is expected to effectively contribute to food security, nutritional well-being, poverty reduction and economic development. However, biosecurity lapses and transboundary aquatic animal diseases pose significant constraints to aquaculture sustainability. This paper discusses how aquaculture development brings new challenges to aquatic animal health. These challenges include compliance to international treaties, practical implementation of regional guidelines and national strategies, increasing biosecurity and biosecurity awareness at all levels, empowering farmers to manage disease and other risks through better management practices, and conducting targeted research that will support biosecurity assessments. A short brief on emerging and re-emerging issues such as chemical usage, climate change and disease ecology, fish welfare and fish health, fish-vet cooperation and certification scheme for aquatic animal health service providers is included.

KEYWORDS aquatic animal health; aquaculture; biosecurity; transboundary aquatic animal diseases; risk analysis

1. Introduction

Aquaculture is now known as the emerging agriculture, the catalyst of the 'blue revolution', the answer to world's future fish supply, the fastest food producing sector, the future of fisheries.

The increasing importance of aquaculture is, at present, undoubtedly recognized. Aquaculture production has substantially grown accounting for nearly 50 percent of

the world's aquatic food supply. It is anticipated that aquaculture will further contribute 85 million tonnes of aquatic food by 2030, an increase of 37.5 million tonnes over the 2004 level (FAO 2007a), with minimum impact to the environment and maximum benefit to society. Thus, the sector is expected to effectively contribute to food security, nutritional well-being, poverty reduction and economic development.

Aquaculture's contribution to the food fish supply continues to increase. Given that production from capture fisheries will likely stagnate, it can be foreseen that a greater share of future food fish supply will come from aquaculture. Figure 1 illustrates the past and projected contribution from capture fisheries and aquaculture. The green line shows that in 2005, aquaculture supplied nearly half (45.5%) of all food fish for human consumption; the yellow line shows that by 2015, aquaculture will be required to supply half of the food fish supply; the white line shows that aquaculture will be required to supply 85 million tonnes by 2030. In both scenarios, the assumption is that capture fisheries production and the proportion of the catch destined for fish meal and fish oil (non-food uses) remain equal to the average 2000–2005 figures (FAO 2007a).

The 2006 State of the World Aquaculture (FAO 2007a) identified five major trends, namely: (i) intensification of aquaculture production driven by the availability of sites and ability to exploit non-agricultural land; (ii) diversification of species use, e.g., high value marine species; (iii) increasing attention on better management of the sector; (iv) increasing influence of markets, trades and consumers—greater attention to food quality and safety, moving towards adding and processing of products for export; and (v) enhancing regulation and improving governance, with emphasis on self-regulation by farmer association.

The levels of projection shown in Fig. 1 and the major trends identified will pose a big challenge to the aquaculture sector.

2. International Trade

Alongside with the expansion, intensification and diversification of aquaculture is the enhancement of trade in aquaculture species, products and services. The global trade in live aquatic animals (fish, crustaceans, molluscs, other invertebrates, aquatic plants, amphibians, etc.) and their products is carried out for a variety of reasons such as: ornamental/aquarium trade, aquaculture development,

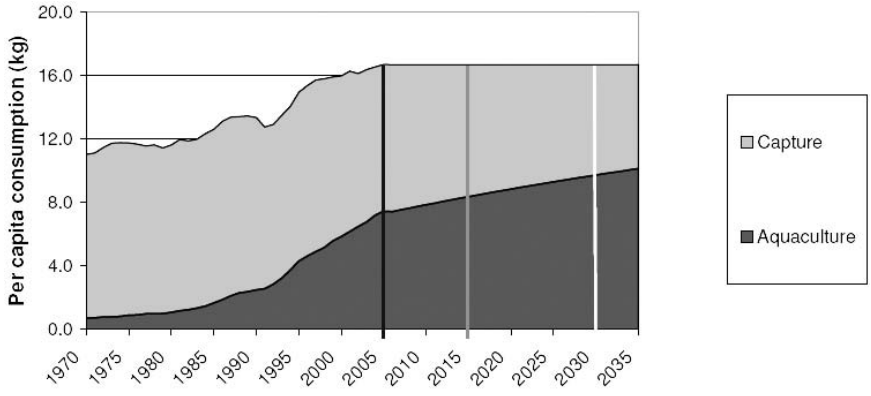

Fig. 1. Past and projected contribution of aquaculture to per capita food fish supply.

food (live food market), baitfish, capture fisheries development/enhancement, biological control, angling/sport development, others (e.g. animal feed, medicine and health products, etc.) (Arthur 2004). Trade of aquaculture commodities, whether live animals or products, is an important income-generating activity for primary producers which contributes significantly to their economic well-being. It is thus expected that trade will continue, legally or otherwise, and new market opportunities will be seen. Since all movements of live aquatic animals involve an element of pathogen risk, it can be expected that unregulated and irresponsible trading will facilitate new mechanism by which pathogens and diseases may be spread to new areas together with host movement. Aquatic animal health will therefore continue to be a challenging issue to aquaculture development and sustainability.

3. Biosecurity Lapses and TAADs—Significant Constraints to Aquaculture Production

Transboundary aquatic animal diseases or TAADs, similar to transboundary animal diseases (TADs) in the livestock sector, are diseases that are highly contagious, have the potential for very rapid spread irrespective of national borders and cause serious socio-economic consequences (Baldock 2002; Bondad-Reantaso 2004). The introduction and spread of many of these pathogens across many aquaculture regions of the world is one of impacts of trade globalization. Other factors responsible for the current disease problems faced by the aquaculture sector include intensification of aquaculture through translocation of broodstock, post-larvae, fry and fingerlings; development and expansion of the ornamental fish trade; enhancement of marine and coastal areas through stocking with aquatic animals raised in hatcheries; the misunderstanding and misuse of specific pathogen free (SPF) stocks; unanticipated interactions between cultured and wild fish populations; slow awareness on emerging diseases; climate change. In additional to the above, inadequate or poorly implemented biosecurity measures ranks high in the factors which have led to significant losses due to aquatic animal diseases on a global scale (Bondad-Reantaso *et al*. 2005).

Infectious diseases are constraining the development and sustainability of the aquaculture sector through direct production losses and increased operating costs and indirectly, through restrictions on trade and impacts on biodiversity. Even though systematic assessments of the impacts of transboundary aquatic animal diseases are lacking, some data are available in the grey literature. Bondad-Reantaso *et al*. (2005) reviewed these impacts which have been expressed in terms of monetary estimates, percentage decrease in production, export losses, unemployment, closure of aquaculture operations, lost of consumer confidence, etc. Economic impacts have also been estimated in terms of cost of investment in disease research and other health management programmes as well as economic investments (e.g. development of national strategies, setting up of research institutes, operating costs for a reference laboratory, funding research and disease control programmes and investments in development programme). Available data reveal high figures for both economic impacts and investments. It could range from national level estimates as low as US$ 17.5M (white spot disease (WSD) of shrimp in India in 1994) to as high as US$ 650M (for yellowhead virus and WSD in Thailand in 1994) to a global estimate of US$ 3019 (Israngkura and Sae-Hae 2002).

4. Strategies for Reducing the Risks of Aquatic Animal Diseases

There are a number of strategies and approaches all aimed at minimizing the risks

of aquatic animal disease incursion. They are briefly described below.

4.1. Compliance with international codes, regional guidelines through national strategies and other implementation mechanisms

Table 1 lists a number of instruments (international treaties/codes, regional guidelines, national strategies) concerned with aquatic animal health. The general objective of these guidelines is to assist countries in reducing the risk of introduction and spread of serious TAADs via the international and domestic movement of live aquatic animals. These instruments are in a state of constant change requiring revisions and modifications which are necessitated by factors such as rapid development in the aquaculture sector, increasing knowledge on diseases and better understanding of the dynamics and epidemiology of aquatic diseases, improved diagnostic and detection methods, emergence of unknown diseases, changing trade patterns which reflect the changing political, social, industrial and economic environments of trading countries, etc. Practical field application of such guidelines will be required.

Improved compliance to these international, regional and national instruments will encourage adoption of appropriate practices, assist in minimizing the risk of disease transfer and other adverse effects on wild and cultured stocks, promote responsible movement of live aquatic animals and healthy aquatic production.

4.2. Increasing biosecurity and bio-security awareness at all levels

General biosecurity issues had recently gained an increased profile on a global basis. A range of factors are behind it. International trade in animals, plants and their products have diversified and increased in volume. As previously mentioned, this is now accepted as a key contributor to the spread of pathogens from one region to another. Many examples of this scenario exist in aquaculture. Changing agricultural practices result in new hazards to health that are able to easily cross border. Changes in human ecology and behaviour have also contributed to the increased incidence and spread of hazards of public, animal and plant health importance. Alongside with trade liberalization, the global community is increasingly demanding improved biosecurity in order to ensure public health, protect the environment and conserve biodiversity. In the long term, effective biosecurity can be expected to improve human health, support agricultural development, improve food safety, maintain biodiversity, protect the environment, increase trade, improve genetics, and enable greater access to market.

In aquaculture, increasing effective biosecurity at all levels can be done, for example, through the following:

1) *Meaningful health certification and integrating quarantine as part of national biosecurity framework*

Previous efforts in implementing quarantine have not been successful in preventing the spread the entry and spread of exotic TAADs into national territory. Quarantine was seen as a separate activity and as a procedure that should be applied to all imports of live aquatic animals. Quarantine measures should now be fully integrated into national strategies on aquatic animal health within the overall biosecurity programmes as part of the risk analysis process. Health certification is a prerequisite for international movement of live aquatic animals and an important and integral part of the quarantine process. Standardization of science-based identification of all risk pathways and high-risk organisms, and implementation of pre-border, border and post-border measures to prevent pests and diseases from entering a country will be necessary (Subasinghe and Bondad-Reantaso 2006).

Table 1. Examples of different instruments at different levels concerned with aquatic animal health issues.

	Reference
International codes/treaties/guidelines	
OIE's Aquatic Animal Health Code	OIE 2007
Code of Practice on the Introductions and Transfers of Marine Organisms of the International Council for the Exploration of the Seas (ICES)	ICES 1995
Code of Conduct for Responsible Fisheries (CCRF) of the Food and Agriculture Organization of the United Nations (FAO)	FAO 1995
Sanitary and Phyto-sanitary (SPS) Agreement of the World Trade Organization	WTO 1994; Chilaud 1996
FAO Technical Guidelines for Responsible Fisheries. No. 5, Suppl. 2. Health management for responsible movement of live aquatic animals.	FAO 2007b
Regional guidelines	
Codes of Practice and Manual of Procedures for Consideration of Introductions and Transfers of Marine and Freshwater Organisms of the European Inland Fisheries Advisory Commission (EIFAC)	Turner 1988
FAO/NACA Asia regional technical guidelines for the responsible movement of live aquatic animals	FAO/NACA 2000
National strategies	
AQUAPLAN: Australia's National Strategic Plan for Aquatic Animal Health	http://www.daff.gov.au/animal-plant-health/aquatic/aquaplan
NAAHP: Canada's National Aquatic Animal Health Programme	Olivier 2004
USA's National Aquatic Animal Health Plan	Amos 2004
Thailand's Strategic Plan for Aquatic Animal Health	Kanchanakhan and Chinabut 2004

2) Surveillance programme and diagnostic services to detect and identify the emergence and spread of diseases and rapid response

Two decades ago, the term 'surveillance' is totally unheard of in the field of aquatic animal health. Surveillance programmes are now becoming important tools to detect the emergence of diseases. The focus should be on early detection followed by a rapid response to disease epizootics to prevent its spread and establishment and if possible to quickly eliminate the disease. With experience gained in establishing surveillance programmes and realizing the benefits of such program, we now see a recent trend where countries are now quick to implement targetted surveillance for emerging diseases.

3) Risk analysis: timely assessment of the threat from new or expanding species

Owing to the current global climate of free trade, there is now a growing demand

for public health and environmental protection. Risk analysis has become an important tool to achieve the goals of protecting human, animal and plant health and biodiversity. Governments and the private sector must often make decisions based on incomplete knowledge and a high degree of uncertainty. Such decisions may have far-reaching social, environmental and economic consequences. Risk analysis is a structured process that provides a flexible framework within which the risks of adverse consequences resulting from a course of action can be evaluated in a systematic, science-based manner. The risk analysis approach permits a defendable decision to be reached on whether the risk posed by a particular action or hazard is acceptable or not, and provides the means to evaluate possible ways to reduce the risk from an unacceptable level to one that is acceptable. Aside from using risk analysis procedures as basis for assessing requests to import live aquatic animals, more efforts should be directed towards prioritizing risks and looking at ways to reduce them effectively by drawing on the entire arsenal of risk management measures that are available.

4) National frameworks to regulate, manage and control biosecurity

Responsible and good health management will be key to healthy and sustainable aquaculture production. The development and implementation of national strategies on aquatic animal health within the broader national aquaculture development plans and biosecurity frameworks must be be continuously pursued. The model for a national strategy is comprehensive enough and provides a good entry point for capacity building for many countries, at whatever level of national economic development they may currently be. The focus should be centered on prevention, responsible and better health management practices and ensuring and maintaining healthy aquatic production. A clear strategy is required; policy decisions should be based on best available science. Involvement of partners (stakeholders) at all levels will be necessary. Essential components of a biosecurity and national strategy framework are shown in Box 1 below:

In many countries, efforts are being made to improve biosecurity and reduce risks of aquatic diseases. However, the required trained expertise, human capacity, institutional capacity and arrangement, and adequate allocation of resources is significantly lacking. This shortfall needs to be clearly addressed and rectified to make any meaningful improvements in national aquatic biosecurity. In order for the national framework to be effective, it needs an implementation plan, the authority and necessary resources required for its implementation. Therefore, strong national commitment from concerned authority is necessary.

4.3. Empowering farmers to manage disease and other risks through implementation of better management practices

Farmers, small-scale farmers in particular, are key players in aquaculture production. Pond/farm health management is crucial in

Box 1. Essential components of a biosecurity and national strategy framework (FAO 2007b).

Policy, legislation and enforcement	Zoning
Risk analysis	Emergency preparedness
Pathogen list	Research
Information system	Institutional structure
Health certification and quarantine	Human resource development
Surveillance, monitoring and reporting	Regional and international cooperation

order to deal with day-to-day situations in farms in preventing and controlling serious disease. Inequities in aquatic animal medicine and/or husbandry education as well as inaccurate information dissemination are core issues. Empowering farmers with information and tools such as better aquaculture management practices or BMPs (e.g., good farm hygiene such as hand washing between tanks, separation of nets/tanks/stocks, maintaining good water quality, proper handling of fish; good record keeping, for example, gross and environmental observations and stoking records including movement records of fish in and out of facility) or simple and practical biosecurity measures at farm level (e.g. proper quarantine of incoming fish; removal of dead fish from ponds; drying and liming of ponds; regular and correct disinfection procedures; exclusion of wild fish) are all essential in understanding the disease situation at the farm level. Education of farmers and hobbyists on good health management is the key to disease prevention and early warning/reporting is the key to minimize disease spread (Bondad-Reantaso and Subasinghe 2005).

FAO's global guidelines on health management for responsible movement of live aquatic animals (FAO 2007b) have included guidance for health management at the farm and farm-cluster level. Box 2 lists a number of essential elements on health management which need to be addressed at the farm level.

Situation-specific BMPs developed with farmers and tailored to their farming systems and the investment capacity of individual farmers is an effective way to ensure farm level biosecurity. The cluster management approach is an effective way of addressing biosecurity concerns at the farm level since it involves direct and active participation of a group of small-scale farmers, whom involvement individually will otherwise not be effective. Cluster management provides an opportunity for addressing a common biosecurity issue and finding a common solution which at the individual level may either not be possible or extremely difficult.

4.4. Scientific research and advice

Generating scientific information to support biosecurity assessments will be indispensable. Bondad-Reantaso *et al*. (2005) made an exhaustive list of research areas that will support aquaculture biosecurity. These include research on pathways of pathogen spread, methods for inactivation of infectivity, and "barrier" vaccination strategies. In addition, epidemiological research need to be carried out on biological factors (identification of at-risk populations, hazards, pathways, pattern of spread, incubation period, nature of the pathogen), risk factors, interventions and methodologies (e.g., surveillance techniques, disease outbreak modelling, use of geographic information systems). Other essential research areas identified include pathogen studies, information on trade and most importantly, biological pathways for the introduction (release assessment), establishment (exposure assessment) and spread (consequence assessment) of a pathogen, host susceptibility, modes of transmission, infectivity, virulence and stability, intermediate hosts and vectors, and effects of processing, storage and transport. Research on bioremediation and other related aquatic

Box 2. Elements on health management which need to be addressed at the farm level.

Compliance with national legislation	Cluster management
Better management practices	Surveillance and reporting of disease outbreaks
On-farm disease prevention	Emergency preparedness
Certification	Information sharing and farmer education

husbandry management tools will assist in implementing better management practices. For newly emerging diseases as well as some diseases in poorly studied aquatic animal species, basic studies on their pathology and methods for rapid and accurate diagnosis (including standardization, validation and inter-calibration) are essential to facilitate accurate risk assessment and biosecurity management. Increased surveillance of wild fish to detect significant disease problems at an early stage will also be required.

5. Emerging Issues

5.1. Responsible use of chemotherapeutants in aquaculture

As in other food producing sector, the use of chemicals in aquaculture is essential for a successful production (Subasinghe 2004). They are used in various ways (e.g. pond and tank construction, soil and water management, enhancement of natural aquatic productivity, feed formulation, growth promotion, health management, etc.) and there are many benefits in the use of chemicals in aquaculture. However, their use also presents a number of potential risks (e.g. risk to the environment, risks in human health and risks to production systems, etc.). Particularly important is for farmers to be informed of the benefits and the risks of chemical usage in aquaculture so that chemicals can be used in a responsible and prudent way.

5.2. Climate change and disease ecology

Very few studies have direct links on the impact of climate change on aquatic animal diseases. In general terms, changes in rainfall and weather patterns triggered by global warming may affect the distribution of disease vectors and thus change the distribution of diseases that they transmit. In order to understand the correlation of climate change and disease ecology, it will be necessary to direct some of current research efforts in doing retrospective analysis/case studies that can illustrate the potential effects of climate change on disease dynamics and any link between climate and disease.

5.3. Fish welfare and fish health

There is now a growing interest in fish welfare. One of the so-called "five freedom" is freedom from pain, injury or disease—by prevention or rapid diagnosis and treatment (Damsgard *et al*. 2006). In practical fish farming, fish reared under poor welfare conditions are more prone to disease. Studies on fish welfare and its integration with fish behaviour, fish physiology and fish health are now used as tools in better understanding fish welfare in farmed fish. As well, guidelines for health and welfare monitoring of fish used in research will also be forthcoming. The issue of fish welfare and health will become more prominent in the future and the aquatic animal health community should be prepared to tackle this.

5.4. Improving and strengthening fisheries-veterinarian dialogue and cooperation

This is an area where joint efforts are required to achieve tangible outputs. As fisheries and veterinary authorities are the focal points dealing with aquatic animal health issues, a concerted effort is required to enhance the dialogue and to improve capacity of appropriate authority/ies particularly in, for example, in complying to the OIE standards, FAO guidelines and other related international treaties and agreements. At the corporate level, there is limited experience in sharing responsibilities. Animal health has been and still is the mandate of the veterinary administration. For example, the use of "competent authority" vs "veterinary authority" in the OIE Code is quite recent. At the corporate level, aquaculture is a new area of animal production for veterinarians. For

example, "aquatic veterinary surgeons" do not have the same image as that of "veterinary surgeons" for dogs or other farm animals. The study and practice of aquatic animal disease and health management has been with biologists using the science approach and not the medical approach. The veterinarian legacy is needed by the aquaculture sector. In order to move forward, the current challenge for veterinarians will be to position themselves on aquatic animals as they have done for farm animals two hundred years ago. A restructuring of the veterinary curricula to include aquatic species will be of central importance. The challenge for fishery biologists will be to embrace the veterinary knowledge. Mutual respect for each profession, more dialogue and real cooperation will be desirable.

5.5. Certification of aquatic animal health service providers

A professional standards mechanism that promotes and authorizes a certification protocol for aquatic animal health providers will be useful in improving issues related to disease diagnosis, aquatic animal medicine, and information dissemination. Certified aquatic animal health service providers can offer farmers an opportunity to identify and choose qualified individuals; they will also provide credibility to importers and consumers regarding product quality; such standards will also lead to production of valid health certificates and ensure the competence of those who are involved in providing and interpreting information on the health status of aquatic animals. As aquaculture continues to expand as the fastest food producing sector, we can expect an increasing demand in certification schemes for aquatic animal health service providers, particularly in countries or regions where disease diagnostic services are provided by non-veterinarians.

6. Conclusions

Aquaculture development will continuously bring new challenges to aquatic animal health. A variety of strategies, approaches and options have been proposed, experimented and implemented. This is happening within the context of increasing social scrutiny. International and regional guidelines continue to be improved and added. National strategies enable ad hoc compliance to these standards with due respect to national priorities, objectives and means. Increased cooperation between fisheries and veterinary authorities provides timely support to national plans. Certification is certainly one critical issue, currently, because of its multiple and significant implications. Empowering farmers to manage disease and other risks is seen as the key to success under reducing public funds. Global aquaculture development therefore calls for innovative response in health management.

Diseases do matter. It requires major response by the government. Diseases can disrupt the sector, international trade and food supply but the impacts go beyond these as it has social and financial consequences as well, and in some cases, may have human health issues. The credibility of the government/country is at stake and failure to control will be a major risk. No amount of effort can eliminate the risk of danger from diseases. Aside from the technical challenge, the other challenges in dealing with disease control are resource management, public relations, communication, information management and endurance challenge. Dealing with disease emergencies require the following: (a) speed of response, decision-making and action; (b) systems of management, of information and of communication; and (c) good science. The overall objective must be to minimise the risk of disease entering a country; maintaining alertness or vigilance will be essential to achieve this.

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