Drivers and Pathways for Aquatic Animal Disease Emergence

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Extended Summary

The growth of aquaculture - which has been pivotal in addressing aquatic protein production when there has been decline or no growth in major wild fisheries - has, however, been fraught with challenges from emergent and devastating diseases.

In 2000 and 2001, FAO undertook a millenial review of the disease challenges faced by aquaculture in both developed and low-income-food-deficit (LIFDC) countries[1]. (Subasinghe *et al.,* 2001).

"*…the difficult options available for health management, present a truly big challenge to all concerned. If maintained at present levels, major epidemics will continue to threaten many sectors, breakout and impact the ultimate goal of aquaculture sustainability.*"

"*… addressing aquatic animal health issues has… become an urgent requirement for sustaining growth of aquaculture… Harmonizing health protection approaches… and effective cooperation at national, regional and inter-regional levels are needed to maximise the effectiveness of limited resources".*

Recommendations from the 2000 Aquaculture Third Millenium conference[2] included the following:

- *developing appropriate policies and regulatory frameworks on introduction and movement of live aquatic animals and product…;*
- *capacity building at both the institutional and farmer levels through education and extension;*
- *developing and implementing effective disease reporting systems, databases and other mechanisms for collecting and analysing aquatic animal disease information;*
- *improving technology through research to develop, standardize and validate accurate and sensitive diagnostic methods, safe therapeutants, … through studies into emerging diseases and pathogens;*
- *promoting a holistic systems-approach to aquatic animal health management; emphasising preventative measures… maintaining a healthy culture (sic. farm) environment; and*
- *developing alternate health management strategies, such as use of disease resistant domesticated strains of aquatic animals…*

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[1] Subasinghe, R.P., Bondad-Reantaso, M.G. and McGladdery, S.E. 2001. Aquaculture development, health and wealth. In R.P. Subasinghe, P. Bueno, M.J. Phillips, C. Hough, S.E. McGladdery & J.R. Arthur, eds. Aquaculture in the Third Millennium. Technical Proceedings of the Conference on Aquaculture in the Third Millennium, Bangkok, Thailand, 20-25 February 2000. pp. 167-191. NACA, Bangkok and FAO, Rome.

[2] Bangkok Declaration and Strategy for Aquaculture Development Beyond 2000: http://www.fao.org/3/a-ad351e.pdf

Close to 20 years later, in 2018, all the risk factors identified with disease emergence and spread at the turn of the century remain, more or less, unchanged in scope and effect. Effective health management continues to be challenged by fragmented growth and industry integration, highly variable oversight and weak regulatory partnership, trade risk analysis, and poor communication/education/knowledge exchange for industry stakeholders, competent authority regulators and aquatic animal health professionals.

Health challenges to aquaculture that are considered for this objective are endemic and exotic pathogens, as well as emergent diseases of known or unknown origin or identity, that trigger disease outbreaks. An overview analysis of drivers and related pathways are summarized in Table 1 below for discussion purposes.

Table 1. Proposed drivers of aquatic animal disease emergence in aquaculture

Disease emergence factors (Morse 1995, 2004)[3]	**Proposed drivers of disease emergence in aquaculture**	**Examples of salient attributes/features and pathways to disease emergence in aquaculture**
Technology and industry; microbial adaptation and change	Knowledge of aquatic animal pathogens	• slow awareness on disease risk • weak knowledge about the pathogens, transmission route, susceptibility, and potential carriers/reservoirs. • weak knowledge of the immune response of many aquaculture species & related environmental and physiological factors that influence infection and disease progression • weak national surveillance programs that adequately define disease risks for the industry, due to lack of knowledge points outlined above • use of non-native food stocks such as live, fresh, or frozen materials as well as trash fish that represents the "silent sleeper" of aquaculture-related invasions • misuse of veterinary drugs that contribute to direct development of antimicrobial resistance (AMR) and other pest/pathogen resistance/tolerance; or indirect resistance via residues • lack of Specific pathogen free (SPF) stocks for most species cultured so vertical transmission of pathogens perpetuates infection • limited availability of vaccines (for a limited number of fish species and against few diseases) and other alternatives to antimicrobials • weak or lack of innovation, i.e. ability to harness the sanitary (health), nutritional and genetic dimensions to produce healthy, nutritious and disease-resilient species • emergent pathogens, with no research information background, have a higher prevalence in aquatic production environments than those subject to land or air-exposed systems.

[3] Morse, S.S. 1995. Factors in the emergence of infectious diseases. *Emerging Infectious Diseases*. 1995;1(1):7-15 Morse, S.S. 2004. Factors and determinants of disease emergence. Rev. Sci. Tech Aug 23(2): 443-51.

International Travel & Commerce; & Human demographics, behavior	Trade & commerce	• evolution of aquaculture from subsistence food production to a global trade commodity, with concurrent challenges for prevention of disease spread – especially for emergent diseases that have limited/no information • intensification of aquaculture, building larger farms in tighter aggregations that complicate surveillance and rapid disease responses. • increased movement of broodstock, eggs/larvae, fry, fingerlings, juveniles, post-larvae, for inter-regional and international trade. • introduction of new species (exotic or native) for aquaculture to support diversification • development and expansion of aquaculture of ornamental (non-food) species and trade
Breakdown in public health measures	Aquaculture Management & Health Control	• multiple institutions involved in aquaculture production and health management with unclear mandates and/or overlapping responsibilities • inadequate or poorly implemented biosecurity/disease response measures related to resourcing expertise & management infrastructure priorities & mandates • weak regulatory and public-private sector partnerships – related to both examples noted above – along with mismatch between trade/commerce goals and sustainable production goals (i.e., ecosystem, farmed animal & disease knowledge). • mismatch between farmer/commodity/sectoral needs and research agenda/motivation • genetic bottlenecking of farmed species. • monoculture – providing populations that fuel infection spread and magnification. • short production times – helping pathogen adaptation • weak understanding and/or implementation of international standards and other agreements (obligatory/mandatory or voluntary)
Ecological Changes	Ecosystem Changes	• unanticipated disease exchange between farmed and wild aquatic animal stocks/populations. • environmental stressors compromising aquatic stock immune systems; e.g., freshets in coastal water from extreme rainfall, snow/ice-melt or salinification of estuarine waters due to drought. • enhancement of aquatic habitats with restocking programs from hatchery production. • unpredicted microbial changes that trigger pathogenic strains from previously benign strains.

Experience during the last three decades showed the long time lapse (usually a couple of years) from the time that an outbreak is observed in the field to the time that the disease is diagnosed and management and control interventions are implemented. This situation needs to be rectified and a paradigm shift[4] or

[4] Stentiford, G.D., Flegel, T.W., Bass, D., Williams, B.A., Withyachumnarnkul, B., Itsathitphaisarn, O., Sritunyalucksana, K. (2017). New paradigms to solve the global aquaculture disease crisis. PLoS Pathogens 13(2): e1006160

fundamental change in dealing with aquatic animal disease emergence is now clearly recognized by almost all sectoral players[5]. This discussion paper aims to examine the drivers and pathways that persist and identify the 'critical control points' where possibilities for practical interventions and biosecurity improvement at all levels of management and regulatory partnership (farmers, local support services, and authorities and stakeholders responsible for sustainable development) can be made.

[5] FAO. 2012. *Report of the Global Conference on Aquaculture 2010 – Farming the waters for people and food. Phuket, Thailand, 22–25 September 2010*. FAO Fisheries and Aquaculture Report. No. 988. Rome, FAO. 2012. 84 pp. http://www.fao.org/docrep/015/i2501e/i2501e00.pdf (pp.29-30)

Health Management in Small-Scale Aquaculture: Opportunities for the Progressive Management Pathway (PMP) Approach

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Extended Summary

Fish is an important health food.

Malnutrition is a problem that affects one in three people worldwide. Today, more than 159 million children are stunted, 50 million are wasted and two billion people are overweight or obese. Although it is encouraging to note that the world has now committed to ending malnutrition in all its forms, reaching this ambitious target is certainly a daunting task. Malnutrition can't be eliminated by just increasing food supply. People should be fed with a balanced diet, which provides required daily intakes of nutrients, including essential amino acids, micronutrients, vitamins and minerals. In this regard, fish is an important health food. It has the potential to, significantly contribute to, eliminating malnutrition, while improving food and nutrition security, globally.

Fish provides more than 4.5 billion people with at least 15 % of their average per capita intake of animal protein. Fish's unique nutritional properties make it also essential to the health of billions of consumers in both developed and developing countries. The lipid composition of fish is unique, having LC-PUFAs, with many beneficial effects for child development and adult health while providing protection against diseases such as stroke, high blood pressure or coronary heart disease. Complementing its fatty acid content, fish is also known to be an important source of essential micronutrients, vitamins D and B, and minerals. Besides, fish is one of the most efficient converters of feed into high quality food and its carbon footprint is lower compared to other animal production systems. Fish contribute substantially to the income and therefore to the indirect food security of more than 10 % of the world population, essentially in developing and emergent countries. If sustainably produced, fish will make a significant contribution to humankind in the coming decades.

Since the contribution of capture fisheries to global fish production has been nearly stagnated for some time, aquaculture has been the main contributor of fish to keep the global fish supply growing. Aquaculture is the fastest growing food producing sector in the world, producing over 50 percent of the global fish supply. It is predominantly a smallholder activity and around 75 percent of the global production currently originates from small-scale aquafarms. Failing to increase aquaculture contribution to global fish supply in the coming decades will result in reduction in the global per capita fish consumption, which will be detrimental to global health, including malnutrition.

Disease is a threat to the aquaculture growth.

Although aquaculture is the fastest growing food producing sector, the threat of disease has now become a primary constraint and risk to the sustainable growth of the aquaculture sector, significantly impeding both economic and socio-economic development in regions dependent on aquaculture and fisheries. The importance of prevention and control of disease risks as a measure to reduce production losses in commercial, semi-commercial and small-scale aquaculture systems has thus received increased attention.

Many factors have contributed to the health problems currently faced by aquaculture, including those of the rural, small-scale sector. Over the past five decades, aquaculture has expanded, intensified and diversified, such that modern-day aquaculture practices often involve significant domestic and international movement of live aquatic animals and animal products. This has led to the movement and spread of associated pathogens. Such introductions have not only caused losses and mortalities in commercial systems, but also affected small-scale, rural aquaculture and fisheries operations. Not only diseases in small-scale aquaculture contributes to reducing global fish supply, it also affects the livelihoods of people involved in aquaculture and the communities in which they occur, through reduced food availability and loss of income and employment. Besides the apparent impacts of pathogen introductions and transfer, many other human activities (agricultural or industrial) can also have negative impacts on rural, small-scale aquaculture and enhanced fisheries that increase the risk of disease problems and stock losses.

Small-scale aquaculture requires targeted interventions to combat disease problems.

Rural, small-scale farmers are generally resource-poor and have little or no knowledge of health management. As a result, their ability to respond to such situations effectively is limited. It is therefore important to better understand how the rural, small-scale aquaculture sector is managed, both by the farmers themselves and the others involved in the sectoral activities, and to develop appropriate interventions which can assist resource-poor farmers to prevent and control disease outbreaks through better health management.

Some of these interventions that may improve the health management standards of the rural, small-scale aquaculture and enhanced fisheries sectors include:

- developing appropriate national policies, enforceable regulatory frameworks and legislation to prevent entry of pathogens and thereby safeguard farms from disease incursions;
- improving small-scale farmer access to basic aquatic animal health services;
- focusing on research that addresses the basic needs of the small-scale farmers and SMEs;
- creating opportunities for small-scale farmers to practice preventative health management, by improving basic production and management skills;
- incorporating basic health management messages into small-scale aquaculture extension programmes;
- ensuring that basic health management measures are incorporated into programmes for fisheries enhancement and small-scale aquaculture within rural livelihood projects; and
- improving extension services and enhancing communication exchange to enable quick response to disease situations.

Progressive Management Pathway (PMP) approach may offer hope.

Understanding the risks and impacts of diseases, not only on the rural, small- scale production systems, but also on the overall livelihoods of vulnerable communities, needs to be improved. Health management should not be considered as a separate entity within aquaculture and or rural development projects involving aquaculture or enhanced fisheries. It should be integrated within the overall context of rural development programmes. In this regard, more holistic, cross-sectoral and integrated approach such as Progressive Management Partway (PMP), might offer more hope to improve small-scale aquaculture health, than that from the conventional aquatic animal health management efforts and programmes, which we have so far failed to impact.

Effective extension services to support biosecurity systems

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Abstract

Effective aquaculture extension forms the bridge between the producers and the scientists. This role is most important for aquaculture industries that are primarily composed of small to medium size operations. Health issues often have immediate and critical impact on the success of an operation. Therefore, much of the effort of extension workers is in helping the producers maintain healthy populations. Success in health management advice builds trust and provides the opportunity to promote regional disease prevention measures. The aquaculture extension specialists have broad training in all aspects of aquatic system management and are familiar with common diseases that occur locally. They are on the front line and can recognize unusual events including unusual mortality events. Because they routinely interact with producers, veterinarians, diagnosticians and aquatic animal health researchers, they can facilitate the diagnosis and field research on new and emerging diseases. Furthermore they are often more aware of local changes in the aquaculture business than the diagnosticians. The critical factors that can influence health management and biosecurity include the availability and cost of medicated feed sources, chemicals, harvesting options and the movement of fish. The extension activities are heavily dependent on individual interactions and focused small group field presentations. Additionally, the extension service has the infrastructure and resources to occasionally arrange larger seminars and workshops to provide direct contact between the scientist and the producers.

When new disease situations do arise the extension personnel are critical for field research, epidemiology and economic evaluation of the impact of the disease and remedial measures. Because the aquaculture extension specialist is a trained biologist that sees the whole operation where disease outbreaks occur, they can often observe trends that scientist can use as leads to help resolve the underlying factors that lead to these outbreaks. When management options are discovered these extension specialists are often recruited to facilitate field trials and disseminate the findings and to promote the adoption of new proven management practices. Furthermore, when regional management and biosecurity measures are developed that involve new regulations, extension specialist are critical for informing the producers and helping the changes occur seamlessly.

For industries that consist of small to medium size operations, extension is a critical conduit, providing real-time contact between regional and national aquatic animal health experts and the industry. This provides a faster recognition of aquatic animal health threats, more rapid response and a better understanding of the process and buy-in to national action plans by the industry. This is essential for the bottom up approach proposed in the Progressive Management Pathway (PMP) to risk management in aquaculture systems.

Socio-economic impacts of aquatic diseases and economic drivers

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Abstract

Diseases are an integral part of any biological production process. This makes diseases a challenge to all three of the pillars of sustainability, environmental, societal and economic development. This is of course also true for aquaculture. In fact, some of the challenges appear even larger in aquaculture because of it´s recent rise as an important food producing industry.

This paper will discuss social and economic consequences of diseases. These come in a number of forms and tend to go hand-in-hand. A profitable company is sustainable, a highly profitable company grows and an un-profitable company closes down. While there is not a one-to-one relationship between production, employment and social benefits, the correlation will normally be high. Hence, in general a growing aquaculture sector provide more social benefits directly in the form of employment and indirectly as the companies themselves and their employees support the community by spending their wages and paying taxes that fund public activities.[6] In addition, if diseases influence the productivity of other sectors, it will have negative consequences also for companies and people who depend on these activities.

The economic consequences at the firm level they are relatively straightforward, as disease influence the firms cost structure and prices, and thereby profits and development with respect to growth. However, in most cases the effects of disease is more profound when regarded at the industry level, in particular since this is the level that are most important for the social impact of an industry. At this level, diseases will influence growth, types of companies and their capabilities with respect to addressing disease issues. This level is also where issues such as governance system, and capacity to prevent and/or treat disease are best assessed.

The governance system is also one of the links between social and economic effects, and is essential in influencing not only the type of firms (e.g. small-scale vs. large scale), how they operate, where they are located and which market they serve, but also the capacity to prevent and/or treat disease. Hence, the social impacts of disease are partly a function of the society where the aquaculture operations are located and how it facilitates the aquaculture operations. These vary from countries like the U.S..A. where the regulatory system largely prevent the creation of an economically sustainable aquaculture industry, and where the industry has few direct impacts (the indirect impacts is still substantial since U.S.A. imports most of it's seafood), to Taiwan which only had one significant shrimp crop due to no regulations and unfavorable microclimate. Moreover, the significant imports surplus to the developed world from an industry with environmental impacts is another good example of exports of negative environmental effects.

The social impacts are most obvious when a serious disease occur – there are numerous examples of aquaculture industries that fully or largely disappear or that experience substantial set-backs due to disease. This are strong examples where people lose their livelihoods, capital, saving and/or jobs. Furthermore it can have significant effects not only on suppliers and processors of the basic producers product in the direct

[6] There are also those who argue that the creation of an aquaculture industry lead to social disruption as competing users for land are harmed. Since these issues are not consequences of diseases they will not be further discussed here.

supply chain, but also for the community as the total economic activity is reduced endangering the livelihoods also in other sectors.

This paper is organized as follows. First, a brief discussion of the general development of aquaculture is provided, as well as some examples of the impacts of disease. In section 3, economic effects will be discussed before societal effects are discussed in section 4.