Risk Analysis in Aquaculture

Melba G. Bondad-Reantaso
Food and Agriculture Organization of the United Nations (FAO)
Viale delle Terme di Caracalla, 00153 Rome, Italy
E-mail: Melba.Reantaso@fao.org

Abstract

The information presented in this paper were taken from several key FAO documents. The objective is to continuously raise awareness about the concept of risk analysis and its application to the aquaculture sector.

The paper provides information in response to several key risk questions, e.g.: (1) what is risk versus hazard, (2) what is risk analysis, (3) who uses risk analysis, (4) why do countries need to be able to use risk analysis? An overview of the risks in aquaculture is also provided in terms of the process and approaches; and the different risk sectors in aquaculture.

The paper concludes with some key points and challenges. Risk analysis is a decision-making tool that contributes to protecting national health and welfare. It can also contribute to sustainable aquaculture and the success of individual aquaculture businesses and operations. Risk analysis does not stand alone – it supports and is supported by other components of a National Strategy on Aquatic Animal Health. A basic strength of the risk analysis process is its flexibility - it is adaptable to almost any sector/system where risk and uncertainty occur.

Countries will often be confronted with a lack of scientific information, both quality and quantity, to support the risk analysis process. Nevertheless, governments must often act under these uncertainties as well as make decisions in the face of a great deal of complexity, significant variability, and multiple management goals.

Introduction

Aquaculture, as a food-producing sector, has surpassed both capture fisheries and the terrestrial farmed meat production systems in terms of average annual growth rate. Like other farming sectors, aquaculture is associated with environmental concerns that present a number of risks and hazards to both its development and management, and to the aquatic environment and society. The information presented in this paper were taken from several key FAO documents (e.g. Arthur and Bondad-Reantaso [2012]; and Bondad-Reantaso et al. [2008]).

The objective of this paper is to continuously raise awareness about the concept of risk analysis and its application to the aquaculture sector.

Risk versus hazard

In general terms, 'risk' is defined as 'a combination of the *likelihood* of occurrence of undesired outcomes and the *severity* of consequences; while a 'hazard' is 'the presence of a material or condition that has the potential to cause loss or harm (Johnson, 2000). No matter how well managed a system is, there will always be associated risks and hazards.

The concept of risk varies somewhat depending on the sector. Most definitions incorporate the concepts of:

- uncertainty of outcome (of an action or situation), and
- probability or likelihood (of an unwanted event occurring) and
- consequence or impact (if the unwanted event happens)

Thus, "risk" is the potential for realization of unwanted and adverse consequences to human life, health, property, and/or the environment. Its estimation involves both the likelihood, or probability, of a negative event occurring as the result of a proposed action and the consequences that will result if it does happen.

As an example, taken from pathogen risk analysis, the Aquatic Animal Health Code (OIE, 2010) defines risk as:

"...the likelihood of the occurrence and the likely magnitude of the biological and economic consequences of an adverse event or effect to animal or human health."

While some sectors incorporate consideration of potential benefits that may result from a risk being realized (e.g. financial risk analysis), others specifically exclude benefits from being taken into account (e.g. pathogen risk analysis).

Risk involves the concept of a hazard. Hazard is something with the potential to cause negative consequences. Examples of hazards include:

- ecological hazards: the aquatic animal or an accompanying organism (a "fellow traveler" or "hitchhiker");
- pathogen: infectious agent;
- genetic hazards: the aquatic animal being moved;
- human health/food safety hazards: a "contaminant" in the product; and
- financial hazard: a decision that might cause business loss or failure

The risks faced by the aquaculture sector is similar to those of the agriculture sector. Since aquaculture is very diverse (in terms of species, environments, systems and practices), the range of hazards and the perceived risks are much greater. In addition, the intensified transboundary movement of aquatic species as part of increasing trade and globalization is now recognized as a pathway for disease introduction. The sector is also vulnerable to natural disasters and on-going climate changes, and there remain many other management and operational issues.

What is risk analysis?

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.

There are several definitions of 'risk analysis,' according to Society for Risk Analysis (http://www.sra.org/), as presented below:

1. A detailed examination including risk assessment, risk evaluation, and risk management alternatives, performed to understand the nature of unwanted and negative consequences to human life, health, property, or the environment.
2. An analytical process to provide information regarding undesirable events.

3. The process of quantification of the probabilities and expected consequences for identified risks.

Risk analysis is a 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. It is a formal method of dealing with hazards and risks. In simple terms, it is science-based decision-making; but not science *per se*.

The risk analysis approach permits a defendable decision to be made 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. It includes both objective and subjective components. Transparency assures that stakeholders can understand the entire process and the points where subjective decisions are made.

Who uses risk analysis?

People (individuals, private companies, non-government organizations, government agencies at various levels, policy-makers, etc.) or basically anyone who has to deal with uncertainties are users of the risk analysis process. Examples of such uncertainties are provided below.

Aquaculture risks can be viewed in several ways including:

- risks to economic well-being
- risks to human health
- risks to social well-being
- risks to the physical environment
- risks to the biological environment (biodiversity)

Examples of risks to assets (destruction or loss of infrastructure and/or stocks) due to natural and man-made disasters, such as:

- toxic algal blooms
- epizootic disease outbreaks
- chronic disease losses
- vandalism & theft
- power failure
- predation
- unusual weather events
- war

Human health risks may affect public health due to the following:

- pathogens and contaminants in live fish and their products (e.g. bioaccumulation of heavy metals, organophosphates, etc. from feeding trash fish, parasitic infections such as anisakid nematodes, and larval trematodes, algal toxins, etc.)
- post-harvest changes (spoilage bacteria, histamines)
- contamination of drinking water (by antibiotics, chemicals, feeds used in aquaculture)
- breeding of resistant strains of bacteria (via misuse of antibiotics, e.g. chloramphenicol)

Occupational risks may include the following:

- risk of physical injuries (cuts, diving accidents, boating accidents, electrical shocks, etc.)
- chemical poisoning (breathing, skin contact, consumption of caustic chemicals, poisons)
- bites and stings
- post-harvest infections (bacterial infections - e.g. from handling tilapias)

Risks to the physical environment, may be in terms of:

- risk of environmental degradation (by nets, garbage, siltation, other forms of pollution, escapees)
- risk of decreased esthetics or quality of life ("not in my backyard" syndrome - frequent in developed countries where aquaculture and residential areas are in close proximity)

Examples of risks to the biological environment (biodiversity), include:

- unintentional introduction of pests and "fellow travelers" (tilapia fry in milkfish shipments, many other examples)
- intentional introduction of species that become invasive (Invasive aquatic species, IAS) (e.g. golden apple snail)
- risk of potential genetic impacts on native stocks due to use of new species or strains

- risk of potential ecological impacts on local ecosystems
- risk of potential pathogen introductions

In terms of introductions and transfers, pathogen risks may be in the form of introduction of exotic pathogens [e.g. transboundary aquatic animal diseases (TAADs) including highly pathogenic and untreatable viruses, and species that are non-pathogenic in the normal host may be highly pathogenic in new hosts] and introduction of new strains of existing pathogens (bacteria and viruses, e.g. *Vibrio parahaemolyticus* causing Acute hepatopancreatic necrosis diseases).

Ecological risks associated with introductions and transfers includes the following: competition (food, breeding, and habitat e.g. Asian catfishes); predation (Nile perch, rainbow trout, and other carnivorous species); and habitat destruction/alternation (janitor fish in Philippines and Malaysia, and zebra mussel in the Great Lakes).

On a global scale and across all aquaculture production systems, some of the major areas of environmental concerns are as follows:

- eutrophication of water: due to accumulation of nutrients from the release of uneaten food, feces and metabolites that damage the water column and generate unwanted algae.
- biological pollution: introduction of exotic species, biodiversity loss; escape of genetically modified organisms (GMOs) from production facilities – possibility of cultured species becoming voracious predators or competitors; interbreeding causing loss of genepool; transmission of diseases to native stocks from cage and pen facilities; increased abundance of pathogens in the water due to their reproduction in farmed stocks.
- chemical pollution: release of drugs and other substances used for treatment of disease and parasitic infections into the environment.
- habitat degradation: destruction of productive coastal marshes and other physical impacts (chance or loss) on habitat.

Drivers of the risk analysis process and the benefits

Multiple objectives are driving the application of risk analysis to aquaculture. Foremost is for resource protection (human, animal and plant health; aquaculture; wild fisheries and the general environment) as embodied in international agreements and responsibilities [e.g. the World Trade Organization's (WTO) Sanitary and Phytosanitary Agreement[1], United Nations Environmental Programme's (UNEP) Convention on Biological Diversity and the supplementary agreement Cartagena Protocol on Biosafety[2], the Codex Alimentarius]. Of equal importance, the other drivers of risk analysis are food security, trade, consumer preference for high quality and safe products, production profitability, and other investment and development objectives.

The benefits of applying risk analysis in aquaculture are, thus, now slowly better understood and recently recognized as important to improve the sector's sustainability, profitability and efficiency.

The process

The risk sectors which have been afforded adequate attention and where hazards are clearly defined and risk assessment methodologies are better developed include import risk analysis (IRA) for pathogens/infectious diseases (Bondad-Reantaso et al., 2004), hazard analysis and critical control point (HACCP) for food safety and public health hazards (Sumner et al., 2004), and geoinformatics (GIS) or risk mapping for natural disasters[3]. The levels of risk assessments used in these areas of concern are considered as qualitative (most common), semi-quantitative or quantitative. Such categories provide useful information and the choice of assessment methodology will depend on the scope of the analysis required and the availability of information that will support the analysis.

The most studied risk analysis in aquaculture include its application to avoid pathogen incursions and other ecological impacts (Bondad-Reantaso et al., 2005; Arthur et al., 2005) resulting from the movement of live aquatic animals or animal products and assessment of antimicrobial resistance (Hernandez-Serrano, 2005).

[1]WTO. 1994. Agreement on the Application of Sanitary and Phytosanitary Measures. p. 69–84. In The results of the Uruguay Round of multilateral trade negotiations: the legal texts. General Agreement on Tariffs and Trade (GATT), World Trade Organization, Geneva.
[2]CBD. 1992. Convention on Biological Diversity. 5 June 1992, 29 p. (http://www.biodiv.org/convention/articles.asp)
[3]http://mrnathan.munichre.com/

MacDiarmid (1977) considers risk analysis as a tool that provides decision-makers with an objective, repeatable and documented method for assessing the risks posed by a particular action or event; it is intended to answer the following questions:

What can go wrong?
How likely is it to go wrong?
What would be the consequence of its going wrong?
What can be done to reduce either the likelihood or the consequences of its going wrong?

Risk analysis makes use of sound scientific and technical data; the process is transparent, iterative and uses a defensible methodology upon which to base policy development and decisions.

In general terms, the principal components of the risk analysis process (World Organisation for Animal Health, 2003) are as follows: (a) hazard identification; (b) risk assessment e.g. release, exposure, consequence assessments, and risk estimation; (c) risk management e.g. risk and option evaluation, implementation, monitoring, and review; and (d) risk communication or a continuous activity that takes place throughout the entire process. This framework is commonly used for pathogen risk analysis, a similar process is used for assessing food safety and public health hazards (see Figure 1).

Regardless of the type of risk analysis, the pathway analysis approach provides a risk assessment framework that facilitates detailed and transparent examination of the key factors that contribute to the overall risk.

Risk analysis can be qualitative or quantitative. In qualitative risk analysis, risk is described in words; likelihood and consequences are described in non-numerical terms (e.g. low, medium, high). It is often the first step in the risk analysis process. In quantitative risk analysis, risk is estimated numerically; likelihood and consequences are described in numerical terms (i.e. probabilities); analyses are more in-depth and more time consuming; and it needs available reliable data. Both approaches are transparent, fully documented and valid.

Can we manage the risks?

Some risk management measures currently applied in the aquaculture sector are highlighted in **Box 1**. According to Van Anrooy et al. (2006), aquaculture stock insurance can provide protection against disease incursions and natural hazards; secure incomes, greater stability and welfare in the farming communities; improve access to investment and credit; and increase incentives for farm improvements. However, access to such insurance is still lacking for small- and medium-scale farmers. GIS is another risk management tool that will become essential in the near future.

Key points and challenges to managing risks in aquaculture

Risk analysis is a decision-making tool that contributes to protecting national health and welfare. It can also contribute to sustainable aquaculture and the success of individual aquaculture businesses and operations.

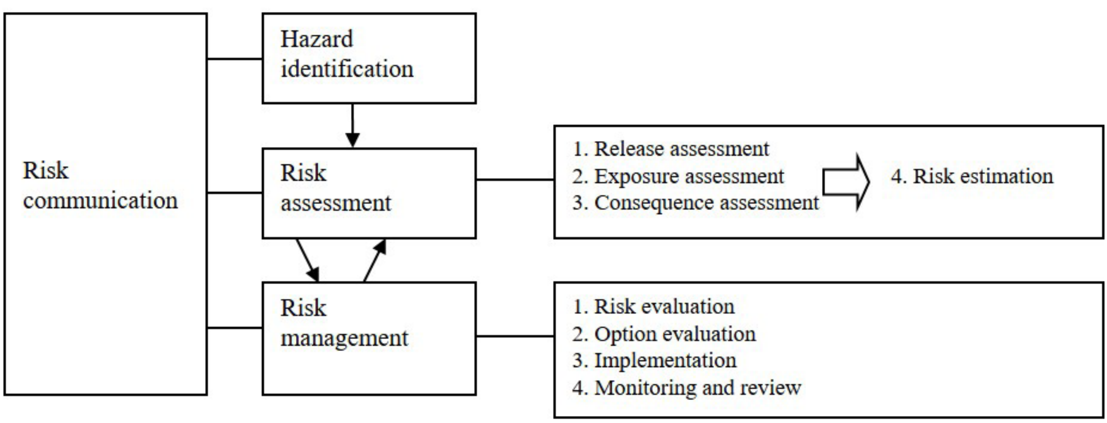

FIGURE 1. Principal components of risk analysis process

BOX 1. EXAMPLES OF RISK MANAGEMENT MEASURES APPLIED IN THE AQUACULTURE SECTOR.

Risk/Hazard	Risk Management Measures
Management and operational risks	Best Management Practices/ Standard Operating Procedures (e.g. good governance; good aquaculture practices at hatchery, nursery and farm levels; good practices for feed/drug and chemical suppliers; good practices for harvesting, marketing and processing; cluster management; other forms of risk-sharing mechanisms), aquaculture insurance
Aquatic animal pathogens/ diseases	Import risk analysis, national strategies on aquatic animal health, biosecurity, disease surveillance and reporting, early warning, emergency response and contingency planning, import risk analysis, good health management practices, vaccination, GIS risk mapping
Antimicrobial resistance	Regulatory interventions, vaccination, good husbandry practices to minimize use of antibiotics
Disease/ climate perils/natural hazards	Aquaculture insurance, GIS
Food safety and public health risks	HACCP; good management practices; good aquaculture practices (GAP), good hygienic practices (GHP), good manufacturing practices (GMP); food safety controls; consumer education; integrated approaches involving health education, vector control and selective population chemotherapy (for parasitic infections)
Occupational risks/hazards	Good orientation of employees and increasing their awareness on risks/ hazards and safety consciousness; use of protective gear; provision of first aid kits; traceability measures etc.
Environmental risks	Proactive policies and regulatory frameworks

Risk analysis does not stand alone – it supports and is supported by other components of a National Strategy for Biosecurity (National Aquatic Animal Health Strategy, Invasive Species Strategy, etc.).
Risk analysis is a framework whose structure and components vary depending on:

- the sector (e.g. technical, social, or financial);
- the user (e.g. government, company, individual);
- the scale (e.g. international, local, farm); and
- the purpose (e.g. to gain understanding of a system or to be implemented by legal measures)

A basic strength of the risk analysis process is its flexibility - it is adaptable to almost any sector/system where risk and uncertainty occur.

Countries will often be confronted with a lack of scientific information (both quality and quantity) to support the risk analysis process. Nevertheless, governments, must often act under these uncertainties, as well as make decisions in the face of a great deal of complexity, significant variability and multiple management goals. An important approach that needs to be considered when data are lacking and evidence of serious risk exists is the precautionary approach (Garcia, 1996). It must be applied responsibly and should be used as a temporary measure until such time that a more thorough risk analysis, supported by scientific information, can be undertaken. Another great challenge is deciding on the Appropriate Level of Protection (ALOP), a societal value judgement about how much a country is willing to pay in forgone trade for protection against incursions, versus the benefits of that trade. Deciding an ALOP will need to take into consideration the economic and social value of aquaculture and capture fisheries, the perceived value of natural biodiversity and the likely economic and social benefits of trade in cultured aquatic animals and their products.

It is important that the people at risk, or those who are most vulnerable, and their needs be the focus of the first mile of protection i.e. fish farmers, people in poverty. Risk communication will play an essential role and a critical step that provides over-all system integrity. Civil society dialogues and partnerships should be widely and actively promoted to enhance risk prevention. Good science, and information dissemination should form part of an integral approach to risk management (e.g. early warning systems, studies on biological pathways, public education, preventative and risk management measures, surveillance, risk mapping). National level enabling legal and policy environments for risk assessments as well as economic incentives must be provided to prevent and mitigate risks in aquaculture. Awareness raising and capacity building to: (a) better understand the risks, hazards and vulnerabilities; (b) develop methods to assess them as well as study the connections between the different risk events and patterns; and (c) identify integrated approaches to risk management, as it will be necessary and should be considered as a matter of priority, especially for developing countries.

The process can be tedious but it is important to embrace the concept first before being intimidated by the process required in some risk scenario and the lack of scientific information for other risk scenarios.

Governments may need to enhance their capacities in understanding and applying risk analysis to aquaculture to support decision-making. With good understanding, they will be able to decide whether an introduction or transfer of an aquatic organism or application for an import permit, for example, will require a risk analysis. And if required, they will be able to provide technical oversight into the process, whether the process is done in-house, by proponents or by consultants, or by expert knowledge (FAO, 2018).

References

Arthur, J.R., Bondad-Reantaso, M.G., Baldock, F.C., & Edgerton, B.F. 2004. Manual on risk analysis for the safe movement of aquatic animals (FWG/01/2002). APEC/DoF/NACA/FAO, 59p. APEC Publication Number: APEC # 203-FS-03.1.

Arthur, J.R. and Bondad-Reantaso M.G. 2012. Introductory training course on risk analysis for movements of live aquatic animals. FAO SAP, Samoa. 167p. (http://www.fao.org/3/i2571e/i2571e00.htm)

Arthur, J.R., Hurwood, D., Lovell, E.R., Bondad-Reantaso, M.G., & Mather, P.B. 2005. Pathogen and ecological risk analysis for the introduction of giant river prawn, *Macrobrachium rosenbergii* from Fiji to the Cooks Islands. Secretariat of the Pacific Community, New Caledonia. 60p.

Bondad-Reantaso, M.G.; Arthur, J.R.; Subasinghe, R.P. (eds). Understanding and applying risk analysis in aquaculture. FAO Fisheries and Aquaculture Technical Paper. No. 519. Rome, FAO. 2008. 304p. (http://www.fao.org/3/i0490e/i0490e00.htm)

Bondad-Reantaso, M.G., Lovell, E.R., Arthur, J.R., Hurwood, D. & Mather, P.B. 2005. Pathogen and ecological risk analysis for the introduction of blue shrimp, *Litopenaeus stylirostris*, from Brunei Darussalam to Fiji. Secretariat of the Pacific Community, New Caledonia. 80p.

Food and Agriculture Organization of the United Nations (FAO). 2018. Tilapia Lake Virus Expert Knowledge Elicitation Risk Assessment (December 2018). FAO Animal Health Risk Analysis – Assessment, Issue No. 7. Rome, FAO.

Garcia, S. 1996. The precautionary approach to fisheries and its implications for fishery research, technology and management: an updated review. In Precautionary approach to fisheries. Part 2: scientific papers. Prepared for the Technical Consultation on the Precautionary Approach to Capture Fisheries (including species introductions). Lysekil, Sweden, 6-13 June 1995. FAO Fisheries Technical Paper No. 350, Part 2, 210p.

Hernandez-Serrano, P. 2005. Responsible use of antibiotics in aquaculture. FAO Fisheries Technical Paper. No. 469. Rome, FAO. 97p

Johnson, R.W. 2000. Risk management by risk magnitudes – Unwin Company Integrated Risk Management. 2p.

MacDiarmid, S.C. 1997. Risk analysis, international trade, and animal health. In Fundamentals of risk analysis and risk management (V. Molak, ed.). CRC Lewis Publishers, Boca Raton, 377-387.

Sumner, J., Ross, T., & Ababouch, L. 2004. Application of risk assessment in the fish industry. FAO Fisheries Technical Paper No. 442. Rome, FAO. 78p.

Van Anrooy, R., Secretan, P.A.D., Lou, Y., Roberts, R., & Upare, M. 2006. Review of the current state of aquaculture insurance in the world. FAO Fisheries Technical Paper No. 493. Rome, 82p.

World Organisation of Animal Heath (OIE). 2003. Aquatic Animal Health Code. 6th edn. Office International des Epizooties, Paris.