Application of risk analysis in aquaculture

Melba B. Reantaso[1], Rohana P. Subasinghe[2]
and Raymon Van Anrooy[3]

Risk and hazard

As a food-producing sector, aquaculture has surpassed both capture fisheries and the terrestrial farmed meat production systems in terms of average annual growth rate. However, like other farming sectors, aquaculture is associated with environmental concerns that pose a number of risks and hazards to both its development and management, and to the aquatic environment and society.

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[1]'*. No matter how well managed a system is, there will always be associated risks and hazards.

Aquaculture faces risks similar to those of the agriculture sector. However, as aquaculture is very diverse (in terms of species, environments, systems and practices), the range of hazards and the perceived risks are much greater. These are coupled with the intensified transboundary movement of aquatic species as part of increasing trade and globalization, the sector's vulnerability to natural disasters and on-going climate changes, and other management and operational issues.

During the last few years, we have seen a number of significant biological and environmental hazards, causing considerable damage and affecting thousands of households depending on aquaculture for livelihood. These include oil spill pollution in Ireland (2003); super chill in the east coast of Canada (2003); *Chatonella* bloom in the west coast of Canada (2002); tsunami in Indonesia, Thailand, Sri Lanka and India (2004); disease outbreaks affecting finfish, molluscs and crustaceans in many regions; storms (including hurricanes); red tides and algal blooms.

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, United Nations Environmental Programme's (UNEP) Convention on Biological Diversity and the supplementary agreement Cartagena Protocol on Biosafety, the Codex Alimentarius).

Of equal importance, the other drivers of risk analysis are:

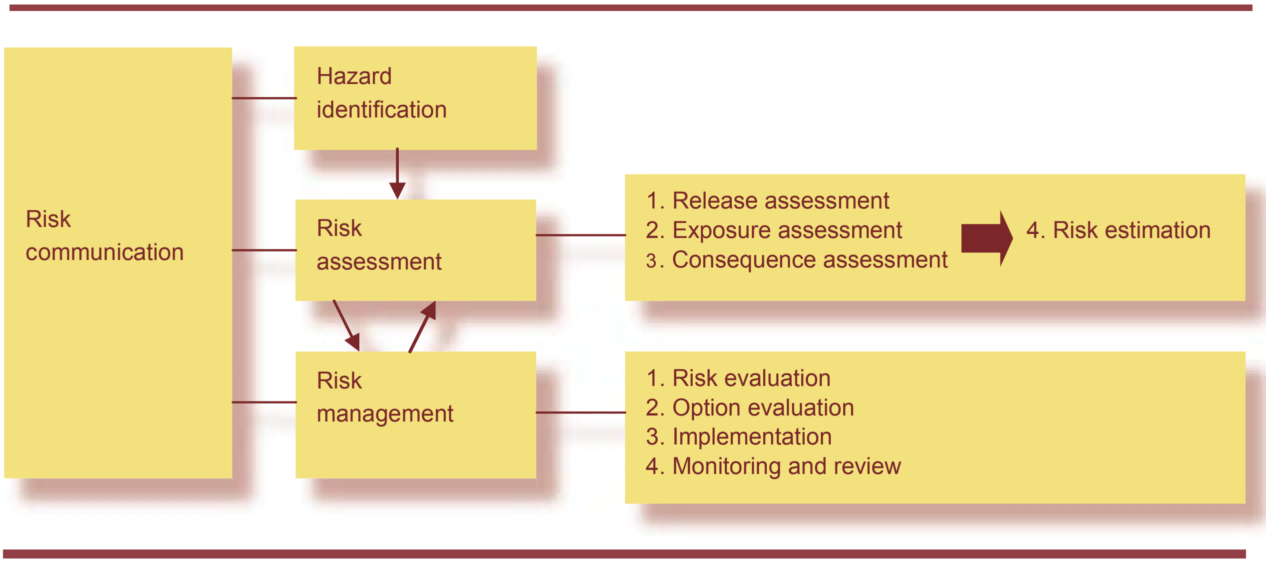
- food security
- trade
- consumer preference for high quality and safe products
- production profitability, and
- other investment and development objectives.

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

What is risk analysis?

MacDiarmid (1977)[2] defined 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 it is 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.

The process

The principal components of the risk analysis process, as illustrated above[3,4], are:

- hazard identification
- risk assessment
- risk management and
- risk communication (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.

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.

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

- eutrophication of water: 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, 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; and

- habitat degradation: destruction of productive coastal marshes and other physical impacts (chance or loss) on habitat.

Although these problems are well recognized, the elements of risk in many of these areas of concern are vaguely understood. For example, the risks associated with introductions and transfers of live aquatic animals due to their potential ecological or genetic impacts need long term evaluation, yet the methods for their assessment are not yet clearly defined.

Other areas of risk in aquaculture that have received less attention include:

- risks faced by poor aquafarming communities;

- occupational risks (e.g. physical (injuries), chemical (burns, irritations, allergies), and biological hazards (parasites, diseases) faced by workers; and

MB REANTASO, FAO

MB REANTASO. FAO

Photos above: Out of desperation, aquafarmers will use anything in order to prevent losses from diseases, e.g., even using antibiotics for viral infection

MB REANTASO. FAO

One of the authors (MB Reantaso) during an investigation of Asia's first major outbreak of suspected Koi herpes virus (KHV) in Indonesia in 2002

- financial risks such as market (e.g. changes in prices of outputs/inputs, increases in interest rates) and asset (e.g. losses due to predation, power failures, etc.) risks.

On the other hand, the areas 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[5],
- hazard analysis and critical control point (HACCP) for food safety and public health hazards[6], and
- geoinformatics/risk mapping for natural disasters[7].

The levels of risk assessments used in these areas of concern range from qualitative (most common) to 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.

Disease is considered a high risk due to the frequency of occurrence and the magnitude of spread and effects experienced by the sector, not only in terms of economic and social impacts but as well as investment costs for disease control and other development programmes. Some examples of the economic and other impacts of aquatic animal diseases are shown in Table 1; while Table 2 presents examples of investments in aquatic animal health programmes. Most studied risk analysis[9,10] in aquaculture include its application to avoid pathogen incursions and other ecological impacts resulting from the movement of live aquatic animals or animal products and assessment of antimicrobial resistance[11].

Can we manage the risks?

Some risk management measures currently applied in the aquaculture sector are highlighted in Box 1 (see page 25). Aquaculture stock insurance[12] 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

Table 1. Examples of socio-economic and other impacts of diseases in finfish, shrimp and molluscan aquaculture in selected countries (from Bondad-Reantaso *et al*. 2005)[8]

COUNTRY/YEAR	DISEASE/PATHOGEN	LOSSES AND OTHER IMPACTS
FINFISH		
Japan (1994-1998)	Marine fish disease	US$ 114.4 M
China (1990-1992)	Bacterial diseases of fish (*Aeromonas hydrophila*, *Yersinia ruckeri* and *Vibrio fluvialis*)	>US$ 120 M annual losses
Indonesia (2002)	Koi herpes virus (KHV)	US$ 15 M
UK (1998-1999)	Infectious salmon anaemia (ISA)	US$ 37 M (approximately)
CRUSTACEAN		
Ecuador (1999)	White Spot Disease (WSD)	US$ 280.5 M in 1999 equivalent to 63 000 tonnes; closing of hatchery operations; 13% laying off of labour force (26 000 people); 68% reduction in sales & production of feed mills & packing plants
Thailand (1994)	Yellowhead Disease (YHD) & WSD	US$ 650 M in 1994; 12% production decline from 250 000 tonnes in 1994 to 220 000 tonnes in 1995; shrimp losses for 1997 reached nearly 50% of total farm output value. (Excludes losses in related businesses such as feed production, processing & exporting, ancillary services & lost income for labourers
China (1993)	Shrimp Diseases	US$ 420 M in 1993
MOLLUSC		
USA (since 1959)	*Haplosporidium nelsoni* of Eastern oyster	>90% of oysters grown in the Bay
Japan (1994-1996)	Mass mortalities associated with a viral disease of pearl oyster	1996-1997 – annual mortality in all western regions, >400 M oysters equivalent to 50% of oyster production in Japan. Total economic loss: >30 000 million Japanese yen (mortalities & decreased quality of pearls produced)

Table 2. Examples of economic investments in aquatic animal health programmes (from Bondad-Reantaso *et al*. 2005)[8]

TYPE OF INVESTMENT	COUNTRY/ ORGANIZATION	AMOUNT	DETAILS/REMARKS
Aquatic animal health strategy	Australia	US$ 2.09 M	Over four years to develp AQUAPLAN (1998 - 2003)
	USA	US$ 375,000.00/year	Development of National Aquatic Animal Health Plan
Research	China	US$ 6 M	Research on aquatic animal diseases
	Thailand	US$ 5 M	Research work at the Aquatic Animal Health Research Institute (AAHRI) and universities
	Norway	US$ 50.1 M	Aquatic animal health research from Norwegian Research Council provided to National Veterinary Institute (2005), Marine Laboratory
Disease Control Programmes	USA	(a) US$ 8.3 M (b) US$ 11.7 M	(a) To combat Infectious salmon anemia (2002) (b) To combat spring viremia of carp (2003-2004)
	China	US$ 73 M	Disease control
	Canada	US$ 34 M	Reactive disease control
Development programmes	Food and Agriculture Organization (FAO)	(a) US$ 345,000.00 (b) US$ 395,000.00 (c) US$ 364,000.00	(a) FAO/TCP/RAS 6714 (A) and 9605 "Assistance for the Responsible Movement of Live Aquatic Animals", 1997-2000, regional programme, 21 governments in Asia-Pacific (b) FAO/TCP/RLA/0071 (A) "Assistance to health management of shrimp culture in Latin America", regional programme, 14 governments in Latin America (c) FAO/TCP/INS/2905 (A) "Health management in freshwater aquaculture", national programme, Indonesia
	Asian Development Bank (ADB)	US$ 290,000.00	RETA 5358, Fish Health Management in Asia-Pacific
	Asia-Pacific Economic Cooperation (APEC)	US$ 116,000.00	APEC FWG 01/2002 "Capacity and awareness building on import risk analysis for aquatic animals'', excludes contribution from other partner organizations such as FAO, OIE, private sector.

such insurance is still lacking for small- and medium-scale farmers (see related article on Aquaculture Stock Insurance on pages 10-12). Geoinformatics/GIS is another risk management tool that will become essential in the near future (see related article on Use of Geographic Information Systems (GIS) for Responsible Aquatic Resource Management on pages 13-19).

Key challenges to managing risks in aquaculture

Countries will often be confronted with the 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[13]. 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 or 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 values 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 (those most vulnerable [i.e. fishfarmers, people in poverty]) and their needs* be the focus of the 'first mile' of protection. Risk communication will play an essential role and is a critical step that will provide 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:

- better understand the risks, hazards and vulnerabilities;
- develop methods to assess them as well as study the connections between the different risk events and patterns; and
- identify integrated approaches to risk management,

will be necessary and should be considered as a matter of priority, especially for developing countries.

FAO's initiatives

FAO has been actively involved in risk assessment in the area of risk analysis for the safe movement of aquatic animals in cooperation with the Asia-Pacific Economic Cooperation (APEC) and NACA, through the APEC FWG 01/2002 "Capacity and Awareness Building on Risk Analysis (IRA) for Aquatic Animals" and the FAO TCP/RLA/0071 "Assistance to health management of shrimp culture in Latin America" which jointly trained in 2002, 130 participants representing 37 countries comprised of regulatory authorities, administrators and aquatic animal health specialists responsible for trade of aquatic animals. On the same area, a number of TCPs have small component in building capacity on risk analysis, namely.

- TCP/BZE/3003 Strengthening the Bio-security Framework,
- TCP/LAT/3001 Improving Aquatic Animal Health and Quality and Safety of Aquatic Products,
- TCP/IND/2902 Health Management in Shrimp Aquaculture in Andhra Pradesh,
- TCP/BIH/3101 Strengthening Capacity of Aquaculture Health Management, and
- TCP/RAS/3101 (A) Sustainable Aquaculture Development in Pacific Micronesia (see related article on TCP/RAS/3101 on page 45).

FAO supports GESAMP's[14] Working Group 31, which has commissioned a background and discussion paper "Environmental Risk Assessment and Communication in Coastal Aquaculture" in preparation for its Second Session planned for November 2006 in cooperation with the ICES Working Group on Environmental Interactions of Mariculture.

FAO is also completing a world review of aqua-culture insurance. Recognizing the importance of risk management in aquaculture and responding to needs for advice on this subject, expressed mainly in Asia, a regional workshop on the promotion of fisheries and aquaculture insurance for sustainable development of the sector is being planned for 2007 (see related article on Aquaculture Stock Insurance pages 10-12).

More recently, responding to a request emanating from the Second Session of COFI's Sub-Committee on Aquaculture (Norway, 2002) to undertake studies in risk assessment, a new biennial output has been included in the FI Department's Programme of Work and Budget (PWB) 2006–2007 to support the theme "Application of Risk Analysis in Aquaculture Production". With funding from the FI Regular Programme and under FAO's New Cooperation Agreement with Norway, a study will be undertaken to: (1) review the (1a) current state of knowledge and understanding on the risks involved in aquaculture development and management, and (1b) application of risk analysis (hazard identification, risk assessment, risk management and risk communication) in aquaculture with the view of reducing those risks; and (2) to prepare and compile a technical document that will provide advice and assistance to FAO Member Countries in the application of risk analysis in aquaculture as a decision-making tool for the sustainable development of the sector.

FAO is completing the FAO Technical Guidelines for Responsible Fisheries: Health Management for the Responsible Movement of Live Aquatic Animals developed to support sections of the FAO Code of Conduct for Responsible Fisheries (CCRF) addressing responsible fisheries management (Article 7), aquaculture development (Article 9), international trade (Article 11) and fisheries research (Article 12), with inputs from the recently concluded FAO Expert Workshop on Health Management held in Dambulla, Sri Lanka from 1-4 November 2005. The Technical Guidelines has a companion document, Compliance to FAO Technical Guidelines for Responsible Fisheries: Health Management for Responsible Movement of Live Aquatic Animals, which will provide more detailed documentation to assist countries and individuals in promoting health management for the safe movement of live aquatic animals.

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, 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, geoinformatics
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 risk/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

Under the Government of Japan Trust Fund (GCP/INT/936/JPN), a project is being implemented to address key issues in sustainable aquaculture, including food safety of aquaculture fish.

These initiatives will hopefully provide a better understanding of the risks involved in aquaculture so that they can be communicated well, assessed and risk management measures made available to reduce the vulnerability of people who depend on aquaculture for their livelihood and so that improvement in sector sustainability, profitability and efficiency can be achieved.

[1]Johnson, R.W. 2000. Risk management by risk magnitudes – Unwin Company Integrated Risk Management. 2 p.
[2]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.
[3]Subasinghe, R.P., McGladdery, S.E. and Hill, B.J. (Eds.) 2004. Surveillance and zoning for aquatic animal diseases. FAO Fisheries Technical Paper 451. Rome, FAO. 2004. 73 p.
[4]OIE. 2003. Aquatic Animal Health Code. 6th edn. Office International des Epizooties, Paris.
[5]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, 59 p. APEC Publication Number: APEC # 203-FS-03.1.
[6]Sumner, J., Ross, T., & Ababouch, L. 2004. Application of risk assessment in the fish industry. FAO Fisheries Technical Paper. No. 442. Rome, FAO. 2004. 78 p.
[7] http://mrnathan.munichre.com/
[8]Bondad-Reantaso, M.G., Subasinghe, R.P., Arthur, J.R., Ogawa, K., Chinabut, S., Adlard, R, Tan, Z. & Shariff, M. 2005. Disease and health management in Asian aquaculture. *Vet. Parasitol*. 132:249-272.
[9]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. 80 pp.
[10]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.
[11]Hernandez-Serrano, P. 2005. Responsible use of antibiotics in aquaculture. FAO Fisheries Technical Paper. No. 469. Rome, FAO. 97p.
[12]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. FAOA Fisheries Technical Paper No. 493. Rome, Italy. 82 p.
[13]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, 210 p.
[14]Joint Group of Experts on Scientific Aspects of Marine Environmental Protection (GESAMP) http://gesamp.imo.org/. Contact person at FAO, Uwe Barg, e-mail: Uwe.Barg@fao.org

MB REANTASO. FAO

Rice-fish farming in Lao PDR

For further information, please contact:
Melba B. Reantaso of FIRI at
Melba.Reantaso@fao.org

[1]Melba B. Reantaso,
Inland Water Resources and Aquaculture Service
e-mail: Melba.Reantaso@fao.org

[2]Rohana P. Subasinghe,
Inland Water Resources and Aquaculture Service
e-mail: Rohana.Subasinghe@fao.org

[3]Raymon Van Anrooy,
Fishery Development Planning Service
e-mail: Raymon.vanAnrooy@fao.org
FAO Fisheries Department, Rome