PART 2

PROCEEDINGS OF THE FAO/NACA EXPERT WORKSHOP ON UNDERSTANDING AND APPLYING RISK ANALYSIS IN AQUACULTURE

Rayong, Thailand, 7–11 June 2007

Proceedings of the FAO/NACA Expert Workshop on Understanding and Applying Risk Analysis in Aquaculture

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BACKGROUND

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, it has a number of *biosecurity concerns* that pose risks and hazards to both its development and management, and to the aquatic environment and society.

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

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. The other drivers of risk analysis are: (i) food security, (ii) trade, (iii) consumer preference for high quality and safe products, (iv) production profitability and (v) other investment and development objectives.

FAO initiatives in risk analysis for aquaculture and aquatic species

FAO has been actively involved in the area of risk analysis for the safe movement of aquatic animals in cooperation with the Asia-Pacific Economic Cooperation (APEC) and the Network of Aquaculture Centres in Asia and the Pacific (NACA), through the APEC FWG 01/2002 "Capacity and Awareness Building on Risk Analysis (IRA) for Aquatic Animals" and the FAO Technical Cooperation Project (TCP) TCP/RLA/0071 "Assistance to health management of shrimp culture in Latin America," which jointly trained, in 2002, about 130 participants representing 37 countries comprised of regulatory authorities, administrators and aquatic animal health specialists responsible for trade of aquatic animals and produced a Manual on Import Risk Analysis (IRA) In the same area, a number of TCPs have small components aimed to build capacity on risk analysis: TCP/BZE/3003 "Strengthening the Biosecurity 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."

Since 2001, FAO has supported GESAMP Working Group 31 (WG31) on its specific task on Environmental Risk Assessment and Communication in Coastal Aquaculture, and facilitated the preparation of a related background and discussion paper for WG31.

GESAMP WG31 held a scoping and planning meeting in 2003 and in November 2006, it held a workshop at the FAO Headquarters to discuss and finalize its study report on Environmental Risk Assessment and Communication in Coastal Aquaculture, which contains six case studies on the application of environmental risk assessment and communication methods in six different contexts of coastal aquaculture. The work of WG31 has benefitted from contributions by experts of the ICES Working Group on Environmental Interactions of Mariculture.

FAO also completed a world review of aquaculture insurance and recognizing the importance of risk management in aquaculture and responding to needs for advice on this subject that have been expressed mainly in Asia, organized a regional workshop on the promotion of fisheries and aquaculture insurance for sustainable development of the sector, held in Bali, Indonesia, from 29 April to 3 May 2007.

There is also an on-going effort in the development of Technical Guidelines on Genetic Resource Management in Aquaculture with a section on risk assessment and monitoring. As well, FAO's contribution to the risk analysis work (including capacity building activities) in the realm of food safety in fish and fishery products within the Codex Alimentarius framework is well recognized.

The current project: "Application of risk analysis in aquaculture production"

Responding to requests emanating from the second and third Sessions of COFI's Sub-Committee on Aquaculture (SCA) (SCA II, Norway, 2002; SCA III, India, 2006) to undertake studies on risk assessment, with funding from the our Regular Programme and under FAO's New Cooperation Agreement with Norway, the current project was undertaken to: (1) review the (a) current state of knowledge and understanding on the risks involved in aquaculture development and management, and (b) application of risk analysis (hazard identification, risk assessment, risk management and risk communication) in aquaculture; (2) to prepare and compile a technical document that will provide practical guidance for policy-makers and interested individuals on the use of various types of risk analysis in aquaculture as a useful decision-making tool for the sustainable development of the sector; and (3) organize an expert workshop to contribute to the process of better understanding the various risks involved in aquaculture so that they can be communicated well, more accurately assessed, and risk management measures appropriately identified to reduce the vulnerability of people who depend on aquaculture for their livelihoods and so that improvement in sector sustainability, profitability and efficiency can be achieved.

Seven major risk sectors in aquaculture have been identified. These are: (i) pathogens, (ii) food safety and public health, (iii) ecological risks (pests and invasives), (iv) genetic issues (v) environmental issues, (vi) financial risks and (vii) social risks. While the hazard and risk elements in some of the sectors are clearly recognized (i.e. pathogens and food safety) and methodologies (as well as standards) for their assessment have been developed and applied, the hazards and risks in many of these areas of concern are still vaguely understood and methods for their assessment are not yet clearly defined. Nevertheless, all these sectors are *inextricably linked* and pose serious biosecurity threats if the risks are not reduced and managed responsibly. Therefore our attempt to "demystify" the concept first before being discouraged by the anticipated complexity of the process requires a good *cross-sectoral* and an *inter-disciplinary* approach to better understand the risk analysis process and how it can be applied to sustainable aquaculture development.

The current *global focus on biosecurity* is driven by such factors as: (i) increasing volume and diversity of trade, (ii) changing agricultural practices and climate, (iii) changing human behaviour and ecology, (iv) greater demands for public health and preserving environmental integrity, (v) increasing public perceptions on food safety and quality and (v) more sophisticated detection and management of hazards. Fisheries and aquaculture are now considered as an *"emerging new agriculture"* and will be affected by major development issues such as trade, international property rights, global diseases, climate change, etc. Enhancing biosecurity through cross-sectoral and multi-thematic/disciplinary coordination of the application of risk analysis and risk management measures will benefit the aquaculture sector and in general terms lead to the following benefits: (i) sustainable development of the sector, (ii) improved food safety and quality, (iii) improved human health, (iv) environmental protection, (v) increased trade, (vi) minimized impacts on biodiversity, (vii) genetic improvement and (viii) freer market access.

FAO is cognizant of initiatives by a number of national, regional and international institutions tackling the various risk issues affecting aquaculture. FAO's intent is to *begin the process* of bringing together these *parallel initiatives* in a consultative and participatory way aimed at a productive outcome. It is expected that this project through the desk study, the expert workshop and the outcomes of such initiatives will further elaborate on: (i) which risk sectors can be analysed using the RA framework as used for biological hazards and which cannot, (ii) what other appropriate approaches can be used or are already being used, (iii) which risk sectors are lacking in methodologies for their assessment, and (iv) which risk sectors require development of methods for assessment or need to be analyzed differently beyond the pathway analysis approach of the RA framework used for biological hazards.

TECHNICAL WORKSHOP

The FAO/NACA Expert Workshop on Understanding and Applying Risk Analysis in Aquaculture was held in Rayong, Thailand from 7 to 11 June 2007.

Purpose

The objectives of the expert workshop were:

(a) to present the desk-top study of the same title focusing on seven major risk sectors:
- pathogen risks,
- food safety and public health risks,
- ecological (pests and invasives) risks,
- genetic risks,
- environmental risks,
- financial risks, and
- social risks.

(b) to discuss the unifying principles for analysis of the various risks and identify:
- the inherent differences in approaches between sectors, and
- what risk analysis methodologies/procedures are available for the particular hazard/s being addressed; and

(c) to provide a platform for better understanding the hazards, vulnerabilities, uncertainties and risks affecting the aquaculture sector, as well as the connections between the different risk events and patterns and to identify integrated approaches to risk management and perspectives on how to share risks and responsibilities.

Participation

Forty-two aquaculture experts (policy-makers, risk analysis practitioners and technical experts in various aspects, e.g. diseases, food safety, genetics, environment, socio-economics, aquaculture insurance) representing various international, regional and national organizations and institutions in Asia, the Pacific, Oceania, Europe and North America, participated in the expert workshop. The list of experts and their profiles are presented as Annex 5.1.

Process

Annex 5.2 provides the programme of work during the workshop.

Opening session

The opening session was held in the afternoon of June 8. The opening speakers were Prof. Sena de Silva, Director General of NACA and Dr Rohana Subasinghe, Senior Fishery Resources Officer, FAO Rome.

Presentation highlights

Dr Melba Reantaso (FAO) presented a backgrounder on risk analysis (RA), its various definitions, its application outside of aquaculture and the drivers for risk analysis in aquaculture. She presented the main objectives of the current project, which included: (i) to review the current state of knowledge and understanding on the risks involved in aquaculture development and management; (ii) to review the application of risk analysis in aquaculture and (iii) to prepare a technical document that will provide practical guidance to policy-makers and interested individuals on the use of various types of risk analysis in aquaculture as a useful decision-making tool for the sustainable development of the sector. She emphasized the need to demystify the whole process and produce a 'simple and crisp' technical document.

Dr J. Richard Arthur (FAO Consultant) examined the definitions and nature of risk, with a focus on the nature of hazards. He examined the different components of risk analysis and emphasized the need to factor in uncertainty. He then provided a series of general principles to risk analysis, including the use of common sense, precaution, transparency, consistency, stakeholder consultation, stringency, minimal risk management, unacceptable risk and equivalence.

Dr Iddya Karunasagar (FAO) emphasized that FAO is recommending the *food chain approach* that encompasses all sectors from primary production to final consumption, with emphasis on preventive steps. Risk analysis is an important tool to determine the level of risk against often statutorily accepted thresholds for food safety. Risk analysis has three components, namely: (i) (quantitative) risk assessment, (ii) risk communication and (iii) risk management. Food safety RA has four specific steps: (i) hazard identification, (ii) exposure analysis, (iii) dose-response analysis and (iv) risk characterization. He then looked at the different levels of risk assessment, e.g. qualitative, semi-quantitative and quantitative risk assessment.

Dr Melba Reantaso (FAO) considered what a pathogen RA is, the drivers and principle components of a pathogen RA. She went through the different steps in risk analysis in some detail. She also looked at other issues, including pathway analysis and scenario diagrams, the principles of acceptable level of risk (ALOR) and appropriate level of protection (ALOP), the precautionary principle (*cautious interim measures*) and future challenges and opportunities (especially the high levels of uncertainty involved). She presented the OIE approach to risk analysis. She concluded that despite the best risk analysis and risk mitigation measures, serious pathogens will be introduced and cause major disease problems. This is due to limitations in diagnostic techniques, existence of cryptic pathogens, and the ability of "benign organisms" (normally non-pathogenic) to become pathogenic when introduced to new hosts and environments. Therefore, good disease surveillance, reporting and well- designed emergency plans will be necessary. Disease is considered a risk sector with high uncertainty. Especially in developing countries, where there is a general lack of basic knowledge on the ecology and pathogens of aquatic animals, it is necessary to establish appropriate research capacity and to conduct targeted studies and particularly, research that will support aquaculture biosecurity.

Dr Eric Hallerman (Virginia Polytechnic Institute and State University) started looking at scoping of risk analysis, the processes of harm (consequence) and hazard identification, various likelihood assessments (release, exposure and harm resulting from exposure). He then looked at risk management (focusing on confinement and operational management), risk communication and future challenges (e.g. understanding of some fundamental issues, incompleteness of quantitative risk assessment, especially regarding likelihood of harm given exposure to hazard, etc.). In closing, he identified the following future challenges in dealing with genetic issues in aquaculture. On risk assessment, there is a need for more genetic risk analysis case studies, especially in the aquaculture context; better understanding of the fundamental issues (e.g. likelihood of outbreeding depression, fitness of transgenics) and development of quantitative risk assessment methodologies. On risk management, there is a need to develop and demonstrate cost-effective confinement for small aquaculture operations. Since most of the theories on risk analysis are already established, what is needed now is to apply it. The adaptive management framework would be appropriate in most cases, not only for genetic risk issues. Communication of risk analysis principles and application is needed, as well as capacity building, especially in the public sector.

Dr Kenneth Leung and Dr David Dudgeon (University of Hong Kong) presented the guidelines on Ecological Risk Assessment (ERA) by the US Environmental Protection Agency and proceeded with listing the seventh ecological risk associated with aquaculture activities, i.e. introduction of exotic species; the other six include habitat alteration/destruction, organic pollution and eutrophication, chemical contamination, infection with disease organisms, genetic risks of escaped cultured animals and depletion of wild fish stocks to provide food for cultured carnivorous fish. He emphasized the importance of understanding the processes of introduction, establishment and spread of an exotic species in aquaculture industries before beginning risk analysis. Future challenges include conducting biological and ecological studies on new cultured species; making risk assessment of biological invasion a legally binding procedure in aquaculture industries and improving international network and surveillance systems for the prevention and control of invasive aquatic species through aquaculture. The presentation was concluded with a note that aquaculture activities are important pathways for the introduction of exotic aquatic organisms. Implementing risk assessment before introduction will reduce the invasion risk and minimize ecological/economic impacts. More effort and funding should be channelled towards basic biological and ecological research, better biological invasion information systems and education of both consumers and industries.

Dr Michael Phillips (NACA) presented three major points, namely: the purpose of environmental risk analysis for aquaculture, its applications and environmental issues. Many environmental hazards overlap with those considered by other papers; the challenge therefore is to integrate these overlaps and complementarities into the manual. Environmental interactions in aquaculture include impacts of environment on aquaculture, impacts of aquaculture on the environment and impacts of aquaculture on aquaculture. Impacts can both be positive and negative; aquaculture heavily relies on a healthy aquatic environment. If broadly applied, risk analysis can support sector development. He then presented the eight principles for responsible shrimp farming (i.e. farm siting, farm design, water use, broodstock and postlarvae, feed management, heath management, food safety and social responsibility). With regard to risk communication, he noted that the most important issues are: ownership, building trust, stakeholder knowledge and priorities, transparency, dealing with "grey areas" and acceptable levels of change, clear communication of results to users for decision making and implementation; and lastly, the risk analysis "jargon" as a major communication concern. The presentation was concluded by listing a number of implementation challenges, e.g. uncertainties – the lack of science-based information for many aquaculture systems, widely scattered data, large number of small-scale farmers, the need for cost effective systems for risk analysis, the need for skilled people and resources for doing risk analysis, communications, institutional responsibilities and implementation of management measures.

Dr Rohana Subasinghe (FAO) gave the background to the IMO/FAO/UNESCO-IOC/WMO/IAEA/UN/UNEP/UNIDO Joint Group of Experts on Scientific Aspects of Marine Environmental Protection or GESAMP. GESAMP is an advisory body consisting of specialized experts nominated by Sponsoring Agencies; it establishes Working Groups that are tasked to review given issues and themes. Working Group 31 looks at the environmental impact of coastal aquaculture. He described the ongoing work of GESAMP Working Group 31, which is developing an integrated risk assessment/communication protocol that fits within a risk analysis structure for resource management. He then briefly enumerated the six case studies, drawn from temperate and tropical coastal aquaculture activities concerned with salmon, shrimp and bivalve culture, which were developed to illustrate the use of the risk assessment protocol. The case studies were: (i) fish farming effects on benthic community changes due to sedimentation; (ii) risk assessment of the potential decrease of carrying capacity by shellfish farming; (iii) risk analysis of the potential interbreeding of wild and escaped farmed cod; (iv) risk analysis of the decline of laminariales due to fish farming waste; (v) risk analysis of the soil salinization due to low-salinity shrimp farming in central plain of Thailand; and (vi) risk analysis of coastal aquaculture: potential effects on algal blooms.

Dr Marnie Campbell (co-authored with Dr Chad Hewitt, both of the National Center for Marine and Coastal Conservation, Australian Maritime College) in her presentation on Introduced Marine Species Risk Analysis – Aquaculture, explained the term marine biosecurity, which deals specifically with marine introduced species (includes animals, pathogens and diseases, plants and protests) and pre-border (quarantine and import health standards) and post-border (surveillance, monitoring and incursion response) measures. The basic risk analysis framework includes identifying the endpoint(s), identifying the hazards, determining the likelihood, determining the consequences and calculating the risk. In the risk analysis process, the following core values need to be included: environmental, economic, social and cultural values. The presentation was concluded with a note that: (i) the marine biosecurity risk framework is consistent with international standards; (ii) because of significant data limitations in the marine environment, semi-quantitative and qualitative assessments remain more tractable; (iii) the target species Organism Impact Assessment has proven extremely useful in identifying management options, even following an incursion event, however, the ability to predict which species will invade or the potential impact of a species once it is introduced remains poor and (iv) the use of non-native food stocks as live, fresh or frozen material represents the 'silent sleeper' of aquaculture-related invasions.

On behalf of Mr Colin Nash (NOAA), Mr Phillip A.D. Secretan briefly presented NOAA's Guidelines for the Ecological Risk Assessment of Marine Fish Aquaculture. He explained the purpose of the paper, which was to exemplify a basic set of guidelines for risk managers and other decision-makers to use all information available to assess the different ecological risks of marine fish aquaculture in a variety of marine ecosystems. He then presented the ten areas of substantive risk in the interaction between marine fish aquaculture perceived by the public and public administrators to be of most concern. These are: increased organic loading, increased inorganic loading, residual heavy metals, transmission of disease organisms, residual therapeutants, biological interaction of escapes with wild populations, physical interaction with marine wildlife, physical impact on marine habitat, using wild juveniles for grow-out, and harvesting industrial fisheries for aqua-feeds. Three examples were presented (i.e. increased organic loading, transmission of disease organisms, biological interaction of escapees) for their degree of potential adversity, together with its mitigation, in an identical step-by-step process. A flowchart helps identify the biological end points or entities and their attributes, both locally and far field, that might be affected for that respective area of risk. It also identifies appropriate methodologies that can be used for measuring or monitoring the effects of exposure to each specific risk.

Dr Lotus Kam and Dr Pingsun Leung (University of Hawaii), in a joint paper entitled Financial Risk Analysis in Aquaculture, introduced the topic by saying that in aquaculture, financial risk refers to the potential loss associated with an aquaculture investment. Aquaculture investments may be public or private and made on behalf of stakeholders, including individual farmers, shareholders, farm enterprises, financial institutions, and/or government institutions. Two types of sources of financial hazards, i.e. production uncertainty (e.g. environment/weather, equipment failure, disease outbreak, pest infestation, etc.). and market uncertainty (e.g. price, demand, availability of input, etc.) were presented. Financial risk analysis methods were compared with the standard components of a risk analysis (hazard identification, risk assessment, risk management and risk communication). She emphasized that methodologically, the linkage between financial risk and traditional risk analysis is weak. While many studies and techniques are available to analyze financial risk in aquaculture, the methods are not necessarily linked to the traditional components of a risk assessment. While the structure presented in this paper is not commonly used in assessing financial risk in aquaculture, it highlights the relationship between financial risk and biological, ecological, and environmental hazards in aquaculture. The presentation was concluded with a remark that financial risk analysis relies on financial analysis principles; utilizes the release and exposure methods for other disciplines; incorporates financial, economic and socio-economic criteria; considers farm-level, industry-level and regional impacts and mature quantitative evaluation methods; and integrates analytic methods into commercial software packages.

Mr Pedro Bueno (NACA) started his presentation on "Social Risks in Aquaculture" with an adapted definition that social risks in aquaculture are challenges by society to the practices of the sector, industry, company or farm over the perceived or real impacts of these practices on issues related to human welfare (e.g. working conditions, environmental quality, health or economic opportunity) and the consequences, which may include brand and reputation damage, heightened regulatory pressure, legal action, consumer boycotts and operational stoppages – jeopardizing short- and long-term shareholder value. Such a definition of social risk can be suitably adapted at the sector, industry, company, farmer group or individual farm level. He then proceeded with elaborating on the components of social risks, i.e. issues, stakeholders, perceptions and means. He defined aquaculture's spheres of social responsibility (internal, immediate external, global) and identified the stakeholders to which it has to be responsible. From, codes of conduct, codes of practice, ecolabeling and certification schemes, labour standards, food safety standards and environmental standards, he drew up a list of hazards that could turn into social risks. Borrowing from ecological risk assessment, he illustrated the process of social risk estimation, the practical application of which is to predict the types of challenges and their degrees of severity so that an early and cost-effective response can be devised to address them. He emphasized that the difference between social and other risks is that social risks are strategic risks. The presentation was concluded with the proposition that a social risk-free environment that is predicated on socially responsible behaviour promotes sustained growth and development.

Mr Phillip A.D. Secretan (AUMS Limited, Aquaculture Underwriting and Management Services) provided an overview of the insurance risk analysis in aquaculture that focussed on stock insurance. An underwriter's approach to risk analysis is not scientific and very arbitrary, He emphasized an important factor to bear in mind, i.e. insurers use substantial deductibles of 10, 15, 20 and even 30 percent (in some cases) of the total amount of risk. The risk analysis process in the insurance industry is an ongoing process during a policy's term because farms, their surroundings, people and farming processes all change. The analysis process relies on information obtained through the completion of specially designed proposal forms that have to be completed by applicants seeking insurance. Different forms are used for different types of aquaculture. Site surveys are essential to risk assessment at all phases of the insurance process. These are carried out by skilled surveyors, each of whom is experienced in risk assessment appropriate to the type of operation involved and its component parts. This particularly applies to marine installations and operations that include electrical and mechanical life support components. Fish health surveys are also carried out by specialist experts. The processes involved are professionally applied, thorough, on-going and enforced through policy conditions. He concluded the presentation by emphasizing that the end results of insurance are reduced losses, empowered risk profiles, reduction of financial loss (and thus hardship) and increase in wealth.

Mr N.R. Umesh (MPEDA/NACA) in a presentation on "Risk analysis in aquaculture – experiences from small-scale shrimp farmers of India" presented the outcomes of a project aimed at supporting Indian small-scale shrimp farmers in adopting better management practices (BMPs) for sustainable fish farming. The 10 BMPs used include: good pond preparation, good quality seed selection, water quality management, feed management, pond bottom monitoring, health monitoring/biosecurity, food safety (no use of antibiotics), better harvest and post-harvest practices, record keeping/traceability, and environmental awareness. Although the initial work was not planned to follow a formal risk analysis approach, the experiences gained provided valuable lessons in the application of risk analysis in small-scale aquaculture farming. Epidemiological studies lead to the identification of risk factors (infected seed, stocking at different periods, soil conditions, use of chemicals etc.), while epidemiological tools measured the statistical associations (= risk assessment) between the identified hazards and the risks (= bad outcomes). Risk management constitutes the application of BMPs. Lessons learned included reduced disease risk, increased profit, increased cooperation among farmers, food safety, enhanced financial support (through good access to bank credit and insurance), and reduced risks to small farmers livelihoods.

Working group session

Dr Melba B. Reantaso (FAO) presented the guidelines for the working group discussion, after which the participants were divided into three working groups that tackled the following themes:

- Working Group 1: Development of the contents of the *Manual on Understanding and Applying Risk Analysis in Aquaculture*
- Working Group 2: Identification and grouping of hazard and assessment methodologies

- Working Group 3: Hazard identification with emphasis on social, financial/economic and cultural hazards aspects

Two full days were spent on working group discussions and presentations. The outcomes of the working group discussions are presented in section 3; general and specific recommendations are presented in section 4.

Closing session

The closing session was held at 1300 hours on 11 June. Representatives of FAO and NACA thanked the participants and their institutions for an extremely productive workshop. The spirit that pervaded the exercise was marked by the collective desire and a strong commitment to accomplish an important and, it was felt, a challenging task; a large part of the challenge was to produce a practical guide and get it to be adopted.

WORKING GROUP FINDINGS

Working Group 1: Development of the contents of the *Manual on Understanding and Applying Risk Analysis in Aquaculture*

Working Group 1 reviewed the draft concept document for the preparation of a *Manual on Understanding and Applying Risk Analysis in Aquaculture*, and in light of the presentations and associated summary documents commissioned by FAO and prepared by the various experts, to attempt to develop an integrated approach and outline for the manual.

Working Group 1 members: Peter Applesford, Cheng Wo Wing, Jason Clay, Tim Huntington, Iddya Karunasagar, Zorana Mehmedbasic, Philip Secretan, Putt Songsangjinda and N.R. Umesh

Working Group 1 recommended that the outline of the manual should contain five major sections (Box 1) the contents of each section are briefly described in Table 1.

Working Group 2: Identification and grouping of hazard categories and risk assessment methodologies

Working Group 2 considered the "hazard identification" step for the manual. They were to identify hazards in coastal/marine aquaculture, group them as far as possible into hazard categories, list/identify methodologies that should be included for hazard identification, identify inherent similarities and differences between hazard identification sectors, and time permitting, to start to identify what risk assessment methodologies/procedures are available for the particular hazards being addressed and to identify examples of risk assessments that have been conducted.

Working Group 2 members: Richard Arthur, Puttharat Baopraserkul, Ingrid Burgetz, Marnie Campbell, Jim Chu, Eric Hallerman, Matthias Halwart , Chad Hewitt, Kenneth Leung, Graham Mair, Sena de Silva, Yin Kedong, C.V. Mohan, Thuy Nguyen, Michael Phillips, Ben Ponia, Temdoung Somsiri, Rohana Subasinghe, Sanin Tankovic and Varin Thanasomwang

The Working Group divided itself into four subgroups dealing with (i) pathogens/disease risks (ii) food safety and public health risks, (iii) genetic risks and (iv) environmental and ecological risks.

BOX 1
Table of contents of the Manual on Understanding and Applying Risk Analysis in Aquaculture

Working Group 2.1 Pathogen/disease risks
Since the procedures for pathogen or import risk analysis are well established (OIE, 2007; Arthur *et al.*, 2004) and there are a number of relevant import risk analysis materials available (see Bondad-Reantaso and Arthur, this volume), Working Group 2.1 on pathogen/disease risks concentrated on listing actions for minimizing/managing risks associated with the following: (1) importation of live aquatic animals (import permitted following a risk analysis), (2) importation of aquatic animal products (import permitted following a risk analysis), (3) domestic movements of live aquatic animals and farm-level operations, (4) pathogen risk communication relevant to all of the above (Table 2) .

Working Group 2.2 Food safety and public health
Working Group 2.2 discussed the three steps in risk assessment for food safety and public health, i.e. (1) hazard characterization, (2) exposure assessment and (3) risk characterization; and the risk management framework using the Codex Principles for Risk Management and provided three examples of food safety and public health risks related to aquaculture.

(1) Hazard identification. Important considerations in the hazard characterization step is given in Table 3 below; while Table 4 shows three examples from the aquaculture sector.

TABLE 1
Suggested contents of the different sections of the Manual

Section title	Contents
1. Introduction	
1.1. Concepts of risk analysis	What is risk? Why is risk analysis used? When is risk analysis conducted? Who typically uses risk analysis (wider than just aquaculture)? Emphasis on the process being science-based and appropriately precautionary Relevance to aquaculture
1.2 General framework of risk analysis	Introduce the four steps: (1) hazard identification, (2) risk assessment, (3) risk management and (4) risk communication (cross-cutting) Provide examples of typical tools used (short and referenced to literature) Discuss uncertainty and the use of proxies
1.3 Purpose of the manual	Users: define target users as decision-makers but should consider regional, national, corporate and community levels (policy, investment, corporate) Scale: for use by FAO member countries; should contain both generic as well as specific information to be useful; the manual should serve as a high-level guiding document with resources to enable further development and provide guidance on the use of qualitative and quantitative approaches; need to cover site-specific risks vs cumulative risks, separately if appropriate Need to mention that risk analysis if still unknown in many countries, that there are many unique problems and scales of development occurring at different levels – all these have implications for the end use of the manual and its contents
1.4 Scope of the document	Introduce the seven "risk sectors" Present the structure of the manual Provide the boundaries of the manual, i.e. it addresses both the impacts of aquaculture to the environment (environmental, social and economic) and vice-versa Many of the hazards identified will be at the policy level, but will need to factor these hazards into the operational elements. For example, farm-level risk assessment will include development of better management practices (BMPs).
1.5 Definitions	Important terminologies used in the document
2. Operating Environment	
2.1. Overview of the regulatory frameworks	May include international and regional agreements; statutory frameworks; voluntary frameworks (e.g. codes of practice, BMPs, etc.) Examples: Pathogen risks (e.g. as elaborated in OIE, SPS Agreement, ISO) Food safety and public health risks (e.g. Codex, SPS, HACCP, TBTs, GMOs, ISO) Ecological (pests and invasive species) risks (e.g. CBD, CCRF, SPS, IPPC, WTO) Genetic risks (GMOs, Cartagena Protocol) Environmental risks (CCRF, CBD, ISO) Financial risks (WTO, Codex?) Social risks (ILO) (e.g. 1st Nations issues)
2.2 Overview of the key risk categories	Pathogen risks, food safety and public health risks, ecological (pests and invasive risks, genetic risks, environmental risks, financial risks and social risks Examples of national and local constraints (New Zealand Biosecurity Act) Review of the literature
3. Risk analysis process for aquaculture	Need to separate the risk against the mitigation options; latter need to be selected at an early stage and have to go through a cost-benefit analysis (note – costs might not be just monetary) Manual to be based on the four steps to risk analysis of GESAMP as this is still a reasonably robust approach; there might be slight variations, but this may be also just terminology issues.
3.1 Hazard identification	Environmental, economic, social/cultural hazards (to be informed by WGs 2 and 3) Prioritization of relevant hazards – need to categorize and aggregate hazards/risks using a hierarchichal process that will allow screening and methodology decision-making, mainly focused by data availability and scope requirements Forward thinking of hazard mitigation (e.g. an environmental hazard may result in an economic or social consequence; thus includes a time-scale issue (i.e. what happens now has consequences much later) To include boxes, e.g.: Box 1: Pathogens: VHS in finfish (or EUS in Botswana?) Box 2: Carbon miles (including fish feeds) Box 3: Mangrove usage Box 4: Social Box 5: Economic Boxes provide a snapshot. They should be short and referenced.

TABLE 1 (continued)
Suggested contents of the different sections of the Manual

3.2. Risk assessment	Qualitative, quantitative, scale, uncertainty
	Precaution in application (to reflect different perspectives and used in the context of lack of knowledge)
	Use of controls and baseline
3.3 Risk management	Prioritization
	Need to focus on key issues
3.4 Risk communication	Stakeholder engagement and consensus building
	General principles
	Risk analysis process
	Hazard identification
	Risk assessment
	Risk management
	Dissemination of results and outcomes
	Sectoral stakeholders
	External stakeholders (including transboundary responsibilities)
4. Synthesis	
5. Next steps	Implementation (especially at small-scale level)
	Information collection and management
	Capacity (knowledge, skills and attitude)-building needs, both in terms of numbers and skills availability.
	Needs to address risk analysis (access to skills and relevant (and often multidisciplinary) knowledge and on-going risk management (in-house expertise and capacity) capability.
	identification of sources of available knowledge and ability to distribute and share experience/information/knowledge.
Appendix 1	References
Appendix 2	Risk analysis case studies

(2) Exposure assessment. Exposure assessment is the qualitative and/or quantitative evaluation of the degree of intake likely to occur. It considers the level of the pathogen/chemical agent at the time of consumption and the quantity of particular food consumed. Table 5 below lists the relevant questions to be asked and the sources of information that may be useful.

Dose response assessment determines the relationship between the magnitude of exposure and the magnitude and/or frequency of adverse effects.

- Theoretical Maximum Daily Intake (TMDI) is based on the MRLs, and estimates of commodity intake are made based on a global diet. This calculation is known to greatly overestimate the exposure and is conducted for screening purposes. If the TMDI exceeds the ADI, the Estimated Maximum Daily Intake (EMDI) is calculated based on global and regional diets and may include correction factors to improve the accuracy of exposure estimates. For example, data on the edible portion of the food and the fate of residues during processing may be used to make a more accurate calculation of exposure.

Production to consumption pathway takes into account the relevance and concentration of the biological agent or the chemical agent. In aquaculture, the various sources of the biological or chemical agent (e.g. water, sewage contamination, feed, fertilizers, intermediate hosts (in the case of some parasites) and considered as well as the effects of various aquaculture practices on the biological or chemical agent (e.g. effect of sanitizers on pathogens, diatom blooms affecting bacterial pathogens).

(3) Risk characterization. The Codex Alimentarius defines the risk characterization step as the process of determining the qualitative and/or quantitative estimation, including attendant uncertainties of the probability of occurrence and the severity of the known or potential adverse health effect in a given population based on hazard

TABLE 2
List of risk management actions for minimizing risks of pathogens

Importation of live aquatic animals (import permitted following risk analysis)	Importation of fishery products (import permitted following risk analysis)	National movements and farm-level operations	Pathogen/disease risk communication
• legislation to support establishment and operation of quarantine facilities; • registering of importers; • setting up and registering of quarantine facilities (government or private); • ensuring that quarantine facilities meet biosecurity requirements; • allowing importation only with a valid health certificate issued by the exporting country; • ensuring that the imported stock (consignment) is held in quarantine for the specified period; • testing stock for World Organisation for Animal Health (OIE) listed or national-listed pathogens, as appropriate; • releasing imported stock only to an approved facility (e.g. a farm); • setting up surveillance programmes (active and/or passive, as appropriate) and using the OIE and national pathogen lists, as appropriate; • establishing mechanisms (e.g. stock destruction, farm closure, restrictions on stock movement) to deal with the pathogen in the event of its detection during active and passive surveillance; and • notifying the OIE and following other regional disease reporting mechanisms if the disease in question is listed.	• registering importers; • approving importer facilities (e.g. processing plant, handling facility); • assuring that the processing facility meets hazard analysis critical control point (HACCP) or other (e.g. Better Management Practices (BMP), International Standards Organization (ISO)) requirements; • ensuring safe and effective disposal of effluents and wastes from the importer's facility (e.g. processing plant); • allowing importation of products only with valid health certificate from the exporting country; • conducting random checks on imported products for OIE or nationally listed pathogens, as appropriate; • ensuring implementation of appropriate measures in the event that samples test positive (e.g. from frozen product to cooked product); and • notifying the exporting country or OIE, as appropriate.	• registering farm facilities; • approving farm facilities (e.g. physical facility, sanitary conditions, biosecurity measures); • implementing or facilitating record keeping to ensure traceability; • ensuring implementation of active surveillance for pathogens listed in OIE and national pathogen lists, as appropriate for the cultured species; • ensuring establishment of mechanisms to gather disease information from all culture systems (passive surveillance); • ensuring implementation of better health management practices by the hatcheries and farmers (e.g. Good Aquaculture Practices (GAP), Codes of Conduct (CoC), BMPs); • setting up mechanisms (e.g. destruction, farm closure, restrictions on stock movement) to deal with disease outbreaks (active and passive surveillance); and • following OIE and other regional disease reporting mechanisms if the disease in question is listed.	• informing all stakeholders (e.g. importers, exporters, farmers, government) about hazards (e.g. diseases listed by the OIE and on national disease lists); • following the communication channels to provide and obtain all the information required for the purpose of conducting risk analysis and for taking decisions on national movements (adopting risk communication channels identified in typical risk analysis processes (e.g. OIE)); • communicating risk mitigation measures to be adopted to quarantine officers, processing plants, officers dealing with fishery products etc, in the event of detection of listed pathogens; • communicating (extending) better aquatic animal health management practices to farmers (e.g. on prevention and control methods); • implementing early warning systems for communicating risks to farmers, trading partners etc.; and • implementing notification systems (e.g. reporting to OIE).

identification, exposure assessment and hazard characterization. Risk assessments may be:

- qualitative: e.g. low, medium, high.
- quantitative: e.g. number of human illnesses likely to occur due to the biological or chemical agent per defined number of population.

Risk reduction scenarios include:

- Effect of mitigation steps (e.g. prevention of sewage contamination; treatment of intake water; growing shellfish in category A water; regulating number of bacteria in water, shellfish meat etc) on number of cases.
- Number of cases of illness which can be averted?
- Effect on aquaculture (e.g. water treatment costs, use of alternate feeds)?

Assumptions and uncertainties and data gaps must be documented.

TABLE 3
Hazard characterization for food safety and public health risks

	Key factors for these hazards	
	Biological agents	**Chemical agents**
In the hazard characterization step, a qualitative description is made of the severity and the duration of the adverse health effect that may result from the ingestion of a microorganism, a toxin or a chemical contaminant.	Ecology of the biological agent (natural habitat, likely mode of entry into aquaculture systems, probability of introduction). Virulence characters of the pathogen. Effect of food matrix on the organism at the time of consumption (factors of the food, e.g. high fat content that may protect the organism by providing increased resistance to gastric acids). Host susceptibility factors (immune-compromised individuals, pregnant women, AIDs patients). Population characteristics.	The chemicals in aquaculture products being considered include pesticides, polychlorinated biphenyls (PBCs), veterinary drugs and contaminants. They are often present in food at low levels – typically at a part per million or less. However, to obtain adequate sensitivity, animal toxicological studies must be conducted at high levels that may exceed, depending on the intrinsic toxicity of the chemical, several thousand parts per million. The significance that the adverse effects detected in high-dose animal studies have for low-dose human exposures is the major question posed in the hazard characterization of chemicals. Estimation of Provisional Tolerable Weekly Intake (PTWI) or Provisional Maximum Tolerable Daily Intake (PMTDI) is made, if possible. Maximum Residue Limits (MRLs) are estimated for individual pesticides in or on specific commodities. These MRLs are primarily based on the residue levels estimated in supervised field trials when the pesticide is used according to GAP.
	Wherever data are available, a dose response analysis is performed; data may come from outbreak investigations, human volunteer studies, vaccine trial studies or from animal studies	

TABLE 4
Examples of food safety and public health risks from the aquaculture sector

Examples from aquaculture	Characteristics
Vibrio parahaemolyticus in oysters eaten raw	Scientific data adequate for a quantitative risk assessment MRA conducted by the United Stated Food and Drug Administration (US FDA), FAO/WHO Management options: - cooling oysters immediately after harvest to prevent multiplication of *V. parahaemolyticus* (consider cost of this process) - control oyster harvesting based on levels of total *V. parahaemolyticus* in oysters at the time of harvest (what proportion of oysters have a high level of *V. parahaemolyticus*?) - subjecting oysters to high-pressure treatment - depuration (not very efficient for *V. parahaemolyticus*) - Food safety objective still under discussion (total *V. parahaemolyticus* 5 000/g?)
Listeria monocytogenes in smoked salmon	MRA conducted by US FDA, FAO/WHO (ready to eat products) Cases of listeriosis occur when foods with more than 10^6 *L. monocytogenes*/g are consumed. Control *L. monocytogenes* in smoked fish (100/g) Zero tolerance not practically achievable in smoked fish industry
Nitrofuran residues in prawns	Risk assessment conducted by Food Standards Australia and New Zealand Exposure (worst-case scenario in high consumers) is 1.5 percent of allowable daily intake (ADI) that existed earlier Public health and safety risk from nitrofuran residues in prawns very low No recalls ordered

With respect to risk management to food safety in aquaculture, the Codex Principles for Risk Management consisting of 8 principles are listed in Box 2.

Key reference documents pertaining to risk assessment for food safety and public health include:

- FAO/WHO 1995. *Application of risk analysis to food standards issues*. Report of Joint FAO/WHO Expert Consultation. 43 pp.

TABLE 5
Exposure assessment questions and information requirements

Exposure assessment questions	Information requirements
How many organisms are ingested by the consumer?	sources of contamination: frequency, concentration and an estimation of the probability and concentration that will be consumed
How often do they get ingested by the consumer?	distribution, growth, inhibition or inactivation from primary contamination, through processing, handling at retail and consumer preparation practices
	growth studies, predictive models
	food manufacturer data
	food surveillance data – primary processes and retail
	animal/zoonotic disease data
	food composition – pH, Aw, nutrient content, presence of antimicrobial substances and competing microflora
	population demographics
	consumption patterns

BOX 2
Codex principles for risk management

Principle 1: Risk management should follow a structured approach.
Risk evaluation,
Risk management option assessment,
Implementation of management decision, and
Monitoring and review.

Principle 2: Protection of human health should be the primary consideration in risk management decisions.

Principle 3: Risk management decisions and practices should be transparent.

Principle 4: Determination of risk assessment policy should be included as a specific component of risk management.

Principle 5: Risk management should ensure the scientific integrity of the risk

assessment process by maintaining the functional separation of risk management and risk assessment.

Principle 6: Risk management decisions should take into account the uncertainty in the output of the risk assessment.

Principle 7: Risk management should include clear, interactive communication with consumers and other interested parties in all aspects of the process.

Principle 8: Risk management should be a continuing process that takes into account all newly generated data in the evaluation and review of risk management decisions.

- FAO/WHO 2002. *Principles and guidelines for incorporating microbiological risk assessment in the* development of food safety standards, guidelines and related texts. 47 pp.
- FAO/WHO 2003. Hazard characterization for pathogens in food and water. Microbiological Risk Assessment Series No 3, 76 pp.
- Fazil, A. 2005. *A primer on risk assessment modelling: focus on seafood products.* FAO Fisheries Technical Paper No. 462, 62 pp.

Working Group 2.3 Genetic risks in aquaculture

Working Group 2.3 went through the whole process of assessing genetic risks in aquaculture starting from key questions which need to be asked to identify genetic hazards (Box 3), a process for prioritizing genetic hazards (Table 6), the risk assessment

BOX 3

Key questions for identifying genetic hazards in aquaculture

What are the hazards?
How do we identify genetic hazards in aquaculture?
What is the process for prioritization of genetic hazards?
What is the risk assessment process?
How do we identify or characterize the consequence of the hazard?

Key questions concerning genetic hazards from cultured organisms:

What is the organism being cultured?
Is it indigenous?
Is it being cultured in an environment with conspecifics or reproductively compatible species?
Is it genetically changed from local stocks?
Is it a composite of genetically distinct stocks?
Is it selectively bred?
Is it an inter-species hybrid?
Is it a genetically modified organism?
Is it triploid/sterile?

Key questions concerning genetic hazards from wild organisms:

What wild organisms are interacting with the cultured stocks?
Is it a reproductively compatible species?
Is it conspecific?

process using a conceptual approach for conducting assessment of the probability of gene flow from aquaculture systems into the receiving environment (Table 7), a matrix for identifying consequences and mechanisms for assessment of that consequence (Table 8), important considerations for risk management and risk communication, a case study example (Hallerman, 2008, this volume) and key references (Box 4).

The risk assessment process

Tools for risk assessment have been developed for transgenic fish (see references listed in Box 4). These can be readily adapted for characterizing the probability of gene flow from cultured stocks to wild stocks. The approach indicated below Table 8) can apply for assessing risks identified above that are related to gene flow, with the exception of the risk associated with the escape/release of sterile triploid organisms, which is related to loss of reproductive investment rather than gene flow[1].

Important considerations with respect to risk management (Table 9) and risk communication are provided below.

In the case of deliberate release of cultured stocks as part of a stock enhancement programme, it is necessary to effectively monitor and evaluate the impact of the stocking programme to ensure it is consistent with its objectives. Such objectives may include increased population size, yield to fisheries, maintenance of genetic diversity of the receiving population and fitness of the wild stock. The main risk management strategy in relation to stock enhancement is to adhere to genetic management guidelines in the foundation and subsequent maintenance of the hatchery stock.

Monitoring and evaluation would be required under both circumstances (accidental and deliberate release) to reassess risk likelihoods and severity of consequences. Control

[1] A separate conceptual approach can be developed for triploid organisms.

TABLE 6
A process for prioritization of genetic hazards

Hazard component	Degree of concern for genetic impacts			Genetic consequence
	Low	Med	High	
A. From cultured organisms				
Indigenous			X	Loss of adaptation Outbreeding depression Decreased Ne
Non-indigenous				
Reproductively compatible			X	Introgressive hybridization
Not reproductively compatible	X			None
B. From local stock				
Domesticated?	X			Loss of adaptation Outbreeding depression Decreased Ne
Selectively bred		X		Loss of adaptation Outbreeding depression Decreased Ne
Interspecific hybrid			X	Introgressive hybridization
Triploid/sterility	X			Loss of reproductive investment
GMO			X	Loss of adaptation Outbreeding depression Decreased Ne Unanticipated effects
C. From non-local stocks				
Composite of distinct stocks		X		Loss of adaptation Outbreeding depression Decreased Ne
Selectively bred		X	X	Loss of adaptation Outbreeding depression Decreased Ne
Interspecific hybrid			X	Introgressive hybridization
Triploid/sterility	X			Loss of reproductive investment
GMO			X	Loss of adaptation Outbreeding depression Decreased Ne Unanticipated effects
D. From wild organisms (reproductively compatible)				
Conspecific[1]		X		Loss of adaptation Loss of performance
Non-conspecific			X	Introgressive hybridization Loss of adaptation Loss of performance
Non-reproductively compatible	X			None

[1] Level of risk depends on the genetic status of the cultured stocks and the purpose of the operation. Invasion of wild or feral aquatic organisms into the culture system containing genetically improved stock carries higher risk than for facilities stocked with non-improved stock. Likewise the risks associated with invasion are higher in hatcheries than they are for grow-out systems.

actions need to be documented and continually assessed. Monitoring indicators need to be developed (e.g. regular sampling of threatened indigenous stocks for detection of introgression or stock assessment to determine impacts of releases) and monitoring implemented. Programme design and implementation may need to be adjusted.

With respect to risk communication concerning genetic risks, the following considerations are important: (1) actively engaging stakeholders' to agree on the scope of the risk analysis, (2) an educational component regarding principles and practices for evaluating and characterizing genetic hazard and consequences on genetic aspects of a project, (3) stakeholder agreement on hazards and validation of the prioritization of the hazards, (4) stakeholder agreement of consequences and validation of risk likelihood analysis, and (5) agreement on an acceptable level of risk and risk management options on a case-by-case basis.

BOX 4

Example of case study on a genetic risk analysis and key references

Case study

- Risk analysis for triploid oysters in Chesapeake Bay, United States of America (see Hallerman, 2008, this volume)

References

- ABRAC (Agricultural Biotechnology Research Advisory Committee) Working Group on Aquatic Biotechnology and Environmental Safety. 1995. *Performance standards for safely conducting research with genetically modified fish and shellfish. Parts I & II.* United States Department of Agriculture, Office of Agricultural Biotechnology. Document Nos. 95-04 and 95-05. (available at: http://www.isb.vt.edu/perfstands/)
- Kapuscinski, A., Sifa, L. & Hayes, K. eds. In press. Environmental risk assessment of genetically modified organisms, Vol. 3. *Building scientific capacity for transgenic fish in developing countries.* CABI Publishing.
- Mair, G.C., Nam, Y.K. & Solar, I.I. In press. Risk management: reducing risk through confinement of transgenic fish. *In* A. Kapuscinski, L. Sifa & K. Hayes, eds. *Environmental risk assessment of genetically modified organisms: methodologies for transgenic fish*. CABI Publishing.

TABLE 7

A conceptual approach for conducting assessment of the probability of gene flow from aquaculture systems into the receiving environment

Knowledge requirement	Action steps to be taken	Comments
Baseline data on escapees from aquaculture systems	Assess the probability of escape of sexually mature and immature organisms from aquaculture systems	If organisms are farmed in open aquaculture systems especially in an area where conspecifics live, an option is to assume escape will occur and focus assessment resources on next step.
Baseline data on the habitat conditions into which farmed fish are likely to escape	Assess the probability that immature escaped aquatic organisms would survive to sexual reproduction in the wild	If aquatic organisms can escape into habitat where conspecifics or closely related species survive and reproduce, an option is to assume some escapees will survive and focus assessment resources on the next step.
Baseline data on the population ecology of aquatic organisms in the receiving environment	Assess the probability of encounter between sexually mature escapes/ releases from aquaculture and reproductively compatible wild species	If cultured organisms can escape into an area where conspecifics (or reproductively compatible species) are known to exist, an option is to assume encounters will occur and focus assessment resources on the next step.
Baseline data on the reproductive behaviour of the species	Assess the probability of successful mating occurring between escapes/ releases from aquaculture and reproductively compatible wild species	
	Assess the probability of F1 offspring surviving and successfully reproducing	
	Assess the probability of survival and reproduction in the subsequent generations of introgressed stocks.	

Working Group 2.4 Risk assessment process for environment and ecology

Working Group 2.4. looked at the process which can be used for environmental and ecological risks. The process involves nine steps. This process can be applied for example to the release of effluent. Intensity, extent, geographical extent, frequency and duration must be assessed on a case-by-case basis with the particular circumstances

TABLE 8
Table identifying consequences of hazards from cultured organisms (risks from aquaculture) and from wild organisms (risks to aquaculture) and mechanisms for assessment

Risks from aquaculture			Risks to aquaculture		
Consequence of hazard from cultured organism	**Description**	**Mechanisms of assessment**	**Consequence of hazard from wild organisms**	**Description**	**Mechanisms of assessment**
Loss of adaptation	Loss of capacity of affected stocks to adapt to environmental changes/ challenges	Loss of population structure (identified through changes in genetic markers, which are used as proxies for fitness-related loci)	Interbreeding and loss of adaptation to culture conditions	The interbreeding of wild fish with cultured stocks in the culture environment, resulting in the partial loss of adaptation of the stock to the culture environment and/ or the benefits of genetic improvement	Loss of stock purity detected through analysis of genetic or phenotypic markers
Outbreeding depression	Loss of fitness upon interbreeding of differently adapted populations	Observation of reduced fitness upon interbreeding of cultured and wild stocks	Hybrid introgression of cultured stocks	The mixing of gene pools from two or more species under culture conditions, resulting in characteristics of pure species	Loss of species purity detected through analysis of genetic or phenotypic markers
Decreased effective population size	Reduction in number of breeding individuals contributing to the next generation. Also may result in increased levels of inbreeding	Detected through loss of rare alleles or by direct estimation of effective population size in suitably designed experiments	Of feed species & hitchhikers		
Introgressive hybridization	The mixing of gene pools from two or more species, resulting in change of characteristics of pure species.	Loss of species purity detected through analysis of genetic or phenotypic markers			
Loss of reproductive investment	The disruption of reproduction in natural stocks through the participation of non-fertile individuals in breeding. (especially triploid sterile males)	• Reduction in recruitment characterized through stock assessment • Reduction in number of breeding individuals contributing to the next generation; detected through loss of rare alleles • Experimental verification of participation of triploid/sterile in wild spawning			

of the production system and the surrounding environments (including biological components) being described and assessed in detail. Gaps in the available information on the surrounding environments and their biological components, trophic interactions etc. are inevitable. It may not be feasible to address these gaps in full or in part or within an acceptable time frame. This results in an increase in the uncertainty level for each determination.

TABLE 9
Important considerations concerning risk management and operations management of genetic risks

Risk management	Operations management
Acceptable level of risk needs to be defined on a case-by-case basis by consequence and informed by expert opinion and stakeholder consultation. The options for management of risk in relation to escapes from aquaculture are well defined (and published). They are: • Physical confinement - Physical barriers to escape - Geographic/physiological (e.g. tropical species in a temperate environment) • Biological confinement - Triploidy/sterility - Monosex • GURT (Genetic Use Restriction Technologies – currently only at R&D stage)	Activities consistent with goal of confinement (e.g. strong record keeping) Prevention of unauthorized access Regular inspection and maintenance of physical confinement systems Effective supervision of project personnel and implementation of policy Redundancy of measures is necessary to minimize probability of escape into the receiving environment

The steps involved in the process are:

1. Risk is derived from likelihood x consequence.
2. Once hazards are identified (hazard identification process for environment/ ecology issues) the risk assessment process begins (Stage II).
3. Identify likelihood using Table 10. Ask questions such as "is it likely that this farm will release effluent?" – this will determine the level/descriptor of likelihood. Likelihood may need to be determined from past records, expert input or through comparison with existing practices. Uncertainty at this stage should be captured as best possible by considering intensity, frequency and duration.
4. Develop a basic consequence matrix for the receiving environment (policy/ expert derived; e.g. Table 11). In this example, we are using an endpoint of disturbance to the surrounding environment from aquaculture practices.
   - Terminology within the consequence matrix must be defined and can be altered to meet stakeholder expectations
   - The consequence table must incorporate:
     – intensity or degree of change,
     – geographical extent, and
     – permanence or duration.
   - A basic consequence matrix (Table 11) can be presented to focus groups for threshold values to be determined and the matrix to be refined. This occurs following a heuristic process involving scientific experts (government, industry and independent scientists) and stakeholders' (including indigenes, government and industry representatives, conservationists, interested public) working groups.
     – The threshold values (percentages and levels within the consequence matrix representing categorical descriptors, e.g. "significant") were derived from legislative and policy obligations in the first instance, with subsequent adjustment through stakeholder consultation.

TABLE 10
Likelihood matrix

	Descriptor	Description
1	Rare	Event will only occur in exceptional circumstances
2	Unlikely	Event could occur but not expected
3	Possible	Event could occur
4	Likely	Event will probably occur in most circumstances
5	Almost Certain	Event is expected to occur in most circumstances

TABLE 11
Consequence example: effluent release from the farm to the surrounding environment

Level	Descriptor	Effluent release impacts
1	Insignificant	Biodiversity change is minimal (<xx%) compared to natural fluctuations in the ecosystem No significant change in nutrient levels detected If the effluent was removed, recovery is expected within a diel cycle
2	Minor	Biodiversity change is measurable (<xx%) compared to natural fluctuations in the ecosystem, and is apparent at point source Minor increase in nutrient levels detected (xx%) If the effluent was removed, recovery is expected within days
3	Moderate	Biodiversity reduction is <xx% compared to natural fluctuations in the ecosystem, and is apparent at point source and x km downstream Increase in nutrient levels are detected (>xx%) at x km downstream If the effluent was removed, recovery is expected in days to months
4	Major	Biodiversity reduction is <xx% compared to natural fluctuations in the ecosystem, and at x km downstream (<yy%). Eutrification has occurred near point source (>xx%) and nutrient levels are increased (>xx%) at x km downstream. If the effluent was removed, recovery is expected in years or generations
5	Catastrophic	Biodiversity reduction is <xx% compared to natural fluctuations in the ecosystem, and is apparent throughout the system Eutrification has occurred throughout watershed/system If the effluent was removed, recovery is not expected

   – The exact threshold values are subject to adjustment within constraints of the legal and policy frameworks.
   – Thus threshold values are based on consensus opinion and do not represent a fixed value but rather a perceived consequence at the scale of assessment (river, farm, region, country, etc).

5. Data collection occurs via literature review, heuristic process or undertaking monitoring, research etc. The steps for undertaking this analysis are as follows and can be applied singularly or in combination:
   - Undertake a literature review to ascertain available information. If information is lacking or incomplete, undertake a heuristic process.
   - The heuristic process captures input from experts to clarify information/data. If data are still lacking or incomplete, undertake further research.
   - Research can occur via extending existing monitoring or undertaking new research.
   - Data collection will inform the consequence matrix and identify uncertainty.
6. An estimated measure of risk is then derived by multiplying likelihood by consequence using Table 12.
7. The uncertainty must be determined at each level and data input. The degree of uncertainty may alter the risk matrix based on the application of the precautionary principle and stakeholder/expert perceptions and values.
8. Once risk is derived, risk management is applied. For consideration is the following example of possible approaches following the risk derivation (Table 13). The likely actions will be dictated by the level of acceptable level of risk (ALOR) (which is set through risk managers). Reporting will be case-by-case and aligned with national policies, international obligations, etc., as appropriate.

TABLE 12
Risk matrix (N = negligible; L = low, M = moderate; H = high; E = extreme)

	Consequence (impact)				
Likelihood event)	Insignificant	Minor	Moderate	Major	Catastrophic
Rare	N	L	L	M	M
Unlikely	N	L	M	H	H
Possible	N	L	H	H	E
Likely	N	M	H	E	E
Almost Certain	N	M	E	E	E

TABLE 13
Risk interpretation

Risk	Likely action	Reporting
Negligible	Nil	-
Low	None specific	-
Moderate	Specified management/science decision/activity required	+
High	Possible increases to science/management activities required	+
Extreme	Additional science/management activities required	+

Working Group 2 came up with Table 14 listing examples of different risks to aquaculture and from aquaculture under the 5 risk categories.

Working Group 2 also raised some issues and questions pertaining to hazard identification such as: socials risks can have environmental consequences; economic risks can have environmental and social consequences; social and environmental risk analysis need to be done early in the process and not after an industry has been

TABLE 14
Examples of different risks to aquaculture and from aquaculture under the five risk categories

Risk sectors	Examples	
	Risks to aquaculture	Risks from aquaculture
Pathogen risks	pathogens spreading from aquaculture to aquaculture	pathogens spreading from aquaculture to wild stocks
	pathogens spreading from wild stocks to aquaculture	multiplication of pathogens in wild stocks
Food safety and public health risks		food safety spreading of zoonotic pathogens to new areas chemical and drug contamination heavy metals biotoxins
Genetic risks	impacts of genetic improvement programmes risks from translocation of stocks	genetics and conservation trojan gene effects loss of reproductive investment hybrid introgression by mixing or domestication genetically modified organisms (GMOs) genetic changes of wild stocks
Ecological/environmental	changing/blocking water circulation/ current patterns harmful algal blooms changing risks over time with climate change risks to stocks during transportation	introduced species invasive species feed species hitchhiker species trophic cascades water quality, turbidity chemicals harmful algal blooms escapees ecosystem disruptions genetic introgression impacts on resident pathogens hazards to endemic species and/or species extinctions impacts on drinking water solid wastes watershed usage impacts of collection of seed from wild mangrove destruction alteration of currents/water flow patters
Social and economic risks	policy and planning aspects lack of capacity, information, education lack of legislation food security aesthetics and tourism	

established; how can social and environmental risks be quantified?; how can the different risk sectors be integrated into one complete risk analysis model?.

Considering the application of risk analysis at the farm level, the Working Group concluded that:

- risk analysis principles can be applied;
- application of release assessment and exposure assessment may be slightly difficult;
- risks can be identified and their likelihood assessed using other tools (epidemiological studies);
- risk can be prioritized;
- risk management measures can be developed around identified risks (better management measures);
- similar qualitative approach could be used for food safety, genetics and environmental risk assessments; and
- could be a good model for a research project.

Working Group 3: Hazard identification with emphasis on social, financial/economic and cultural aspects

Working Group members: Pedro Bueno, Jesper Clausen, Nihad Fejzic, Clayton Harrington, Lotus Kam, Thithiporn Laopraset, Pingsun Leung, Melba Reantaso, Susana Siar, Suda Tandavanitj and Montira Thavornyutikarn

Working Group 3 considered the definition of a "hazard" as an agent, event. material or condition that can cause potential loss or harm. Hazards include challenges by society to aquaculture practices.

The major outcomes of Working Group 3 include the following:

- free listing of social hazards to better understand the potential scope of hazards in aquaculture production that has a social dimension (Box 5);
- five major categorization of social-political hazards (Table 15);
- identification of factors which need to be considered when assessing social risks;
- identification of social hazards (Table 16); and
- identification of economic hazards (Table 17).

A number of factors need to be considered when assessing social risks. These include: (1) governance (e.g. clear property rights, presence of registration and licensing systems, governance indicators (e.g. using the human development index); (2) level of education and training (e.g. veterinary services, criteria for each indicator, how to measure knowledge and training). Social risk assessment methods (for projects) may be used.

Social hazards were identified and divided into 4 major areas as shown in Table 16 below. Cross-cutting issues which affect these broad categories include governance, political framework, legal framework and globalization.

With respect to social hazards, the Working Group came up with the following social hazards and examples of issues using four categories (resources, capacity, welfare and cross-cutting issues) categories (Table 17).

TABLE 15
Five major categorization of socio-political hazards in aquaculture

Category	Examples
Governance	poor governance, poor policies, unclear property rights, unsustainable national policies, lack of government support, widespread unemployment
Knowledge, education and information	low investment in human capital, poor people quality, negative views of aquaculture by consumers, lack of general education and training
Competition for resources	dislocation of some sectors
Civil unrest/terrorism	political/social instability
Globalization	

TABLE 16
Social hazards in aquaculture

Social hazard categories	Example of issues
Resources	access
	amenity value
	cultural values
	competition for use
Capacity	labour/skills (of people)
	services (institutional – government, private)
	infrastructure
	adaptation
Welfare	policy/regulations/permits (and changes within)
	equity
	essential resources
Cross-cutting issues	governance
	political framework
	legal framework
	globalization

BOX 5
Free listing of social hazards

- bad, poor or weak governance
- lack of knowledge/education/information
- terrorism
- poor policies, governance
- political/social instability
- widespread unemployment
- people quality
- lack of good education
- lack of labour adaptability
- lack of skilled labour
- lack of general education/training
- poor lifestyle/community living
- lack of national plans
- excessive regulation
- no clear property rights
- market functions
- lack of government support
- lack of political democracy
- globalization
- non-sustainable national policies
- negative views of aquaculture by consumers
- increasing population competing for resources
- lack of investment in human capital
- over-regulation
- competition for land, water and space
- infrastructure/industrial development
- dislocation of some sectors in the community
- civil unrest
- lack of formal contractual agreements/business ethics
- physical hazards
- biological hazards

TABLE 17
Economic hazards in aquaculture

Economic hazards	Examples
Production threats	Cost of production • cost of labour • cost of inputs (supplies): decreasing sales prices (prices of outputs); increasing production costs (prices of inputs); escalating interest rates; creditor instability
	Volume/yield • availability of inputs/services (seedstock low quality or limited availability; broodstock low quality or limited availability; lack/loss of skilled labour; limited availability of feed especially in extensive systems) • equipment/asset failure • siting • bioproduction (decreasing growth rates; disease spread) • detrimental environment weather
Market threats	Access • increasing food standards • credence, i.e. voluntary standards
	Price • competitors (decreasing market demand) • taxes • subsidies • substitutes

In deliberating on the category of financial risks, the Working Group noted that there are no financial hazards, but there are financial risks. Examples of economic hazards include market function, resource use, globalization, production infrastructure, taxation policy, market access, subsidies, interest rates, exchange rates and non-tariff barriers. The Working Group identified two major categories of economic hazards as shown in Table 17.

CONCLUSIONS AND RECOMMENDATIONS

Risk analysis methods as applied in the seven aquaculture sectors considered during the Expert Workshop have many commonalities but also many differences. An overriding feature of risk analysis as applied to all sectors is a firm foundation in drawing upon the results of scientific studies, the use of logic (deductive reasoning) in the risk assessment process and the application of "common sense" in assessing risk and applying risk management measures (e.g. separating the "probable" from the "possible"). General principles that apply to risk analysis for aquaculture include application of a precautionary approach when dealing with uncertainty, transparency of process, consistency in methodology, the use of common sense in assessing and managing risks, the use of stakeholder consultation (particularly when the risk analysis is undertaken by government), application of a high level of stringency (e.g. through the use of independent expert review), use of minimal risk management interventions needed to achieve an acceptable level or risk, the concept of unacceptable risk (and thus recognition that some "risky" actions cannot be managed and therefore should not be permitted under any circumstances), and the concept of equivalence (i.e. that alternate risk management measures achieving the required level of protection are equally acceptable).

The potential risks from aquaculture development to society and from the existing physical, social, and economic environment to aquaculture development and their impacts depend upon the species, culture system and operations management practices, and other non-technical factors such as human and institutional capacity. For some sectors, the likelihood of hazards becoming undesirable consequences is often difficult to quantify given present knowledge and the lack of appropriate tools. The wide range of hazards related to aquaculture requires a wide range of tools for risk assessment and skills among the people concerned. The effective use of risk analysis in aquaculture also requires effective communication among government and industry stakeholders and explanation of how risk analysis can be effectively applied to help resolve the issues and avoid possible conflicts.

Most risk analysis sectors make use of qualitative, semi-quantitative and quantitative methods (the exception being financial risk analysis, which uses only quantitative methods), depending on the complexity required for decision making. All methods are equally valid, however, qualitative risk assessment offers the advantages of rapidity and lower cost, and is applicable in most situations. Risk assessment also typically involves the use of project formulation, scenario (or probability) tree, diagrams, decision trees, pathways analysis and sensitivity analysis, an approach that allows investigation of the impacts of proposed risk management measures on the total risk estimate.

Individual risk sectors have widely differing approaches to the practical application of risk analysis. These include differences in philosophy, methodology and terminology that are well established for individual sectors. Sectors dealing with biological and physical hazards (e.g. pathogen risk analysis, genetic risk analysis, food safety risk analysis, ecological risk analysis and environmental risk analysis) have more similarities in approach with each other than they do to risk analysis as applied to social and financial risks. Never the less, they have significant differences in framework and terminology. An example is the use of the precautionary approach, which in ecological risk assessments of non-native species is employed by assuming that the species is "guilty until proven innocent" (assumption of harm), while in contrast, in pathogen risk analysis the species being imported is assumed to be "innocent" of potential to transmit serious disease until proven "guilty".

The process used to determine "acceptable risk" also varies among sectors. In some sectors this is clearly established by international standards enforced through government regulation (e.g. a Food Safety Objective for food products) or through a statement of national Appropriate Level of Protection, as is often the case in pathogen risk analysis. In other sectors (e.g. genetic, ecological, social and economic risk analysis) acceptable risk is often not fixed in advance and must be determined on a case by case basis by executive decision or general consensus (e.g. via agreement resulting from stakeholder consultation).

The application of a single risk analysis framework (e.g. that for pathogen risk analysis) across all sectors is neither possible nor desirable. It is more important that governments and the private sector give full consideration to possible risks in all these areas when considering proposals for aquaculture development (e.g. within the Environmental Impact Assessment (EIA) process). However, in general, this will involve a more in-depth and rigorous risk analysis process than that currently demanded by EIA protocols and existing international guidelines (e.g. ICES and EIFAC protocols).

Establishing appropriate national expertise and capacity to undertake risk analysis has become essential to meeting international trading standards and in allowing developing countries to obtain access to international markets. The Expert Workshop concluded that developing countries face many challenges in implementing risk analysis for the aquaculture sector.

New approaches are required to address the needs of developing countries. There are many opportunities for developing countries to obtain assistance in building expertise and capacity. These include bilateral programmes and assistance provided by WTO, FAO, OIE and national donor agencies, and regional agreements and programmes conducted by FAO, ASEAN and NACA, among others. The use of regional approaches that combine national expertise with the risk analysis expertise available in neighbouring countries may be the most cost-effective way for many countries to conduct risk analyses involving common and shared aquatic species. This approach will also involve sharing of databases and other sources of information. Particularly for introductions of exotic species into shared waterways, the sharing of risk analysis approaches and associated costs will be a practical action.

It is becoming increasingly recognized by government, private sector and the general public that "risky" practices in aquaculture development have led to major biological, social and economic impacts that have had long lasting negative impacts at the local, national and international levels. Risks in aquaculture need to carefully assessed and overly risky practices must be mitigated or prohibited in order for aquaculture to develop in a sustainable manner.

Application of the risk analysis process at the farm level is a challenging issue. In general terms, the risk analysis principles can be applied, risks can be identified and their likelihood assessed using, for example, epidemiological tools (for pathogen risks); however, the application of release assessment and exposure assessment may be slightly difficult. Risk management at the farm level can be developed around identified risks and can make use of better management practices (BMPs). BMPs, cluster management and the use of aquaclubs (or farmer societies) are promising approaches that will enable farmers to work together to identify and manage their own risks.

Specific recommendations arising from the seven risk sector papers presented during the Expert Workshop include:

For pathogen risk analysis

- Regional efforts should be made by developing countries to establish hatcheries and stocks with known health history, e.g. specific pathogen free (SPF) stocks, for the most frequently traded species (e.g. tilapia, marine shrimp, giant freshwater prawn, oysters).
- Greater attention should be given to generating information and knowledge essential to pathogen risk analysis.
- Appropriate research capacity and the ability to conduct targeted studies needed to address critical information gaps identified during sensitivity testing must be further developed.
- Studies in essential research areas such as the biological pathways for the introduction, establishment and spread of individual pathogens and information on trade are needed.
- For newly emerging diseases as well as some diseases in poorly studied aquatic animal species, basic studies on pathology and methods for rapid and accurate diagnosis are needed to facilitate accurate risk assessment and risk management.
- Increased surveillance of wild fish is needed to detect significant disease problems at an early stage.
- Improved disease reporting and well-designed contingency plans are also necessary.

For food safety and public health risk analysis

- The ability to undertake food safety risk analysis is essential to protect public health and promote international trade in food products, including products of aquaculture. For this sector, expertise in different fields such as food production (aquaculture), microbiology, epidemiology, food-processing technology and statistics is needed.
- Access to appropriate human and financial resources can be one of the major constraints for developing countries and thus needs to be addressed.

For genetic risk analysis

- Opportunities for informative case studies have been lost because of a lack of baseline data or because population monitoring was not begun until after a genetic harm was realized. Baseline data and case studies are thus needed to support genetic risk assessment.

- As background information useful as case study material is scattered across the scientific and grey literature and is not as well developed for aquaculture as for fisheries management, there is a need to identify and synthesize this literature.
- An understanding of some key issues (e.g. likelihood of outbreeding depression and fitness of transgenic fishes) is still emerging and thus further studies are needed.
- Studies to address the lack of knowledge of long-term impacts of genetic changes, the levels of variation needed to maintain viable populations over the long term and the relative risks posed by different classes of genetically modified aquaculture stocks are needed.
- Development of quantitative genetic risk analysis is very incomplete, especially with regard to estimating the likelihood of harm becoming realized given exposure to a hazardous agent.
- All these observations suggest the need for more genetic risk analysis studies, especially for nonsalmonid systems.
- For better management of genetic risks, more effort should be directed to developing and demonstrating cost-effective confinement systems for small aquaculture operations.
- To improve oversight of aquaculture by governments and non-governmental organizations, risk analysts need to apply the theory of genetic risk analysis, while drawing upon definitive case studies for guidance.
- As experience is gained, an adaptive approach to management of aquaculture systems is needed, not only for genetic risks, but also more generally for other types of risks.
- Effective communication of the principles and application of genetic risk analysis to organizations in both developed and developing countries is needed.
- There is a need for capacity-building in oversight bodies, especially in the public sector.

For ecological (pests and marine invasives) risk analysis

for pest risks

- Because anthropogenically driven deterioration of environmental conditions in aquatic systems can make conditions less congenial to native species and consequently favour exotic, robust species, risk assessors should take both ongoing and projected environmental changes and the ecological risk of introducing exotic species into account.
- The implementation of proper risk assessment schemes for screening the potential invasiveness of aquatic organisms before introduction will reduce the risk of importing invasive species and thereby minimize ecological and economic impacts. Qualitative assessment methods that are easy to use and do not require large amounts of resources or expertise can be readily adopted in Asia, which is the global centre of aquaculture production.
- The assessment method can be further developed and enhanced with advanced quantitative methods, if more relevant biological information on the taxonomic group of concern is available.
- As data and information availability has a huge influence on the quality and confidence of the risk assessment, more effort and funding must be dedicated to basic research on the life histories, population dynamics and ecology of cultured organisms.
- Better regional and international biological invasion information systems need to be established.
- Concerted efforts should be made to educate consumers and the private sector about the ecological risks and economic impacts of introducing invasive organisms,

and to establish mandatory application of legally binding species-specific risk assessments and risk management that will reduce the risks of biological invasion through aquaculture activities.
- More basic biological and ecological studies on new farming species (such as sea cucucmbers, sea urchins and sea squirts) in related to the predicted invasive sequence are needed.
- More efforts should be put into the development of economic instruments to give incentives to the aquaculture industry to follow relevant codes of practice and risk assessment protocols.

for marine invasive risks
- Target species Organism Impact Assessments are extremely useful in identifying management options; however, the ability to predict which species will invade or the potential impact of a species once it is introduced remains poor.
- Non-native food stocks such as live, fresh or fresh-frozen material may be the "silent sleeper" of aquaculture-associated invasions and can also represent a poorly managed pathway for pathogen invasion that can affect both cultured and wild stocks; thus risk analysis can be usefully applied to assessing the risks posed by these food stocks.

For environmental risk analysis
- As there are presently limited experiences and case studies associated with the more complex ecological risk analyses as applied to aquaculture, promotion of case studies and sharing of experiences are needed.
- The information on risk analysis that could be applied to aquaculture is scattered across the literature, from peer reviewed articles to the grey literature. A practical manual would be useful to assist risk analysis practitioners in the sector and to raise awareness on useful applications.
- The understanding of some key issues (e.g. risks associated with aquaculture and ecosystem functions, use of trash fish) is still limited. As far as possible, simple tools should be developed for the different hazards associated with aquaculture.
- A major challenge is to apply practical risk analysis methods to the small-scale aquaculture sector. The need to develop and demonstrate cost-effective risk management systems for small aquaculture operations is apparent.
- Capacity-building in all aspects of environmental risk analysis for aquaculture is needed.
- Risk analysis has a potentially important role in policy setting, but to be successful the institutional roles and responsibilities need to be carefully considered.

For financial risk analysis
- Aquaculture ventures are inherently risky and thus the need to conduct financial risk analyses to reduce the potential for financial loss is clear. Although a variety of rigorous methods for financial risk analysis are available, these need to be more widely put in practice.
- Education, software accessibility, training and assistance are needed in order for financial risk analysis to be widely adopted in aquaculture.
- Even if the financial risk problem is decomposed, sufficient data may not be available to estimate uncertainty and characterize the financial risk. Farm-level cost and production data and industry statistics are often difficult to obtain. In particular, aquaculture production data are not regularly collected in surveys conducted by agricultural ministries or are limited to highly aggregated values. Consequently, risk analysts are obliged to seek secondary or anecdotal information

to approximate the release, exposure and consequences associated with a hazard. There is therefore a need to improve collection and accessibility of financial data.

- It is vital that financial risk analysis methods be integrated in the early phases of hazard identification and risk assessment of traditional risk assessment methodologies in order to truly manage financial risk in aquaculture.

For social risk analysis

- If an industry, farm or sector as a whole adheres to socially responsible practices, it should face very little challenge, and none that is serious. The need therefore is to enable the farmers, processors, traders, input suppliers and others in the chain to adopt the codes of practice, adhere to better management practices and comply with regulations.
- To prevent free-riding, rent-seeking, corruption and other opportunistic behaviours that invite challenges to the sector, there is a need to improve governance mechanisms, particularly the effectiveness of various mechanisms of governance (mandatory, market-based and voluntary) instruments.
- There is a need to improve the ability of farmers to comply with an increasing number and stringency of requirements without jeopardizing their profitability; the challenge is for farmers to see as sensible to business to adopt and comply with all these requirements.
- There is a need to seek ways to make it attractive for insurers to insure aquaculture operations (particularly the numerous small farms).
- There is a need to develop a hybrid insurance approach that combines the market-oriented and social (public) insurance schemes.
- There is a need to establish a better system for micro-financing.
- There is a need to organize farmers, promote adoption of better practices and strengthen national farmer servicing systems that cater to small farmers.
- There is a need to assure the aquaculture sector that a social risk-free environment predicated on socially responsible behaviour will translate into sustained growth and development.

ANNEXES

Annex 1
EXPERTS AND EXPERT PROFILES

Name and contact details	Expertise/specialization
Peter Appleford Executive Director Fisheries Victoria Department of Primary Industries GPO Box 4440, Melbourne, Victoria, Australia 3001 Tel. No.: (61-3) 9658 4360 Fax No.: (61-3) 9658 4203 E-mail: peter.appleford@dpi.vic.gov.au	Extensive experience in fisheries and aquaculture regulation, management, research and education. Fisheries Victoria administers the *Fisheries Act 1995* (the Act) which provides for the management, development and use of Victoria's fisheries and aquatic biological resources in an efficient, effective and ecologically sustainable manner. This includes a requirement to protect and conserve fisheries resources, habitats and ecosystems, including the maintenance of ecology and genetic diversity. The Act also provides for industry development with a commitment to promote sustainable commercial fishing and viable aquaculture industries. More specifically, Fisheries Victoria leads State Government policy implementation to expand marine aquaculture, including the provision of more that 1 700 hectares of Crown land (offshore and land-based coastal) for the purpose of marine aquaculture development. In addition the DPI undertakes applied research, stakeholder consultation, policy development, the development of Biosecurity Codes, development of best practice aquaculture management plans, and the development of disease response structures and protocols for aquaculture. DPI's management response to a recent outbreak of abalone viral ganglioneuritis provides a case study of international significance particularly in the absence of definitive scientific information about the infectious organism and significant socio-economic loss to key industry stakeholders.
Richard Arthur FAO Consultant Box 1216, Barriere British Columbia, Canada V0E 1E0 Tel. No.: (1-250) 672 0221 E-mail: jrarthur@telus.net	Private consultant in international aquatic animal health issues based in western Canada. Career includes periods in Asia with IDRC as Fish Health Network Coordinator and as Fisheries Program Officer (Asia and Pacific), and in Canada, as a research scientist in aquatic parasitology with the Canadian DFO. Over the past 20 years, international experience has been primarily in Asia, but also in projects in Africa, Latin America, Eastern Europe and the South Pacific. During the past five years contracted as an expert in pathogen risk analysis for regional projects and short-term training courses funded by FAO, NACA, APEC and others. In 2004, led a team of five scientists who conducted pathogen and pest risk analyses for live crustaceans on behalf of the Secretariat of the Pacific Community. Lead author on a manual on risk analysis for the safe movement of aquatic animals and recently drafted the Technical Guidelines on *Health Management for the Movement of Live Aquatic Animals*, in support of FAO's CCRF. In 2007, completed an assignment as international consultant in aquatic animal health management for the World Fish Center as part of an Asian Development Bank funded project to create a pro-poor national strategy for aquaculture development for the Philippines. Currently contributing risk analysis expertise to an FAO-funded project to develop a national aquatic animal health strategy for Bosnia and Herzegovina.

Puttharat Baoprasertkul
Fisheries Biologist
Inland Aquatic Animal Health Research Institute
Department of Fisheries
Kasetsart University Campus, Ladyao, Jatujak
Bangkok 10900, Thailand
Tel. No.: (66-2) 579 4122
Fax No.: (66-2) 561 3993

Fishery Biologist at Thailand's Department of Fisheries. Experience in genetic manipulation techniques (gynogenesis and sex reversal), molecular genetics and immunogenetics, particularly genes related to innate immune defenses and their expressions. Currently involved in biosecurity project and selective breeding program for giant freshwater prawn, and genetic diversity of aquatic plants.

Pe**dro Bueno**
Adviser
Network of Aquaculture Centres in Asia-Pacific (NACA)
Suraswadi Bldg, Department of Fisheries
Kasetsart University Campus
Ladyao, Jatujak
Bangkok 10900, Thailand
Tel. No.: (66-2) 561 1728 to 9
Fax No.: (66-2) 561 1727
E-mail: pedro.bueno@enaca.org

Currently Adviser to NACA, previously Director General and before that Information Specialist of NACA and the Regional Seafarming Development Project. Taught Development Communications courses in the University of the Philippines and was assistant scientist conducting training and research on farming systems at the International Rice Research Institute. Did research on diffusion of innovations, worked on rural development projects specializing on the use of various communications media to inform target audiences of the advantages and risks of adopting innovations in agriculture as well as aquaculture. Helped conceptualize and establish a network of rural educational radio stations in the Philippines based in agricultural universities. Undertook special training in agricultural project development, evaluation and management. Worked in various rural development, information and extension, and institutional development projects for UNESCO, UNDP, FAO, World Bank and UNOPS.

Ingrid Burgetz
Senior Advisor Aquatic Biotechnology
Fisheries and Oceans Canada
12W114-200 Kent Street
Ottawa, Ontario K1A 0E6, Canada
Tel. No.: (1-613) 990 5260
Fax No.: (1-613) 993 7665
E-mail: burgetzi@dfo-mpo.gc.ca

National Analyst for Aquatic Biotechnology for Fisheries and Oceans Canada (DFO). Manages the federal Fisheries and Oceans Aquatic Biotechnology and Genomics Research and Development Program. This includes research focusing on regulatory research related to aquatic animals with novel traits, environmental risk assessment methodology research, investigation of the interaction between genotype and environment, and ecosystem effects of aquatic animals with novel traits, including transgenic aquatic animals. Involved, in conjunction with scientific specialists and regulators, in the identification of key gaps in scientific knowledge related to regulatory research and aquatic products of biotechnology. Prior to moving to DFO in 2006, Ingrid was a senior analyst of technology developments related to the regulatory system responsible for environmental risk assessment of novel plants, vaccines and microbial fertilizer supplements.

Marnie Campbell
Senior Lecturer, Australian Maritime College
National Centre for Marine and Coastal Conservation
Private Mailbag 10, Rosebud
Victoria 3939, Australia
Tel .No.: (61-3) 6335 4571
Fax No.: (61-3) 6335 4590
E-mail: m.campbell@amc.edu.au

An expert in marine biosecurity and ecosystem restoration, with more than 85 publications on various aspects of marine ecology, risk analysis, effects of fishing on the marine environment, ecosystem restoration and biosecurity management. Has given invited keynote and plenary presentations and been an invited panel member at more than 12 international fora. Marnie has worked in more than 14 countries as a biosecurity researcher with agencies such as CSIRO-CRIMP, the IMO GloBallast Programme, Biosecurity New Zealand and with the Australian Maritime College. Currently a senior lecturer and course coordinator for the National Centre for Marine and Coastal Conservation, Australian Maritime College. Co-founding member of the International Marine Biosecurity Education and Research Consortium, which provides biosecurity education and training opportunities across the Pacific Basin and Indian Ocean. Research interests have focused on elucidating human-mediated impacts on biodiversity in the marine environment and developing remediation and management options. Her career has maintained a balance between active science research and the interface with management/policy.

Jim Chu
Head of Licensing and Enforcement
Agriculture, Fisheries and Conservation Department
China, Hong Kong Special Administrative Region
8/F, Cheung Sha Wan Government Offices
303 Cheung Sha Wan Road, Kowloon, Hong Kong
Tel. No.: (852) 2150 7107
Fax No.: (852) 2314 2866
E-mail: jim_cw_chu@afcd.gov.hk

Fisheries Officer of Agriculture, Fisheries and Conservation Department, China, Hong Kong SAR. Head of Fisheries Licensing and Enforcement. Expertise in marine finfish culture. Has been working on developing Good Aquaculture Practices and fish farm accreditation system. Currently involved in formulation of food safety management framework in China, Hong Kong SAR.

Jason Clay
VP, Markets & Managing Director, Agriculture
World Wildlife Fund
Washington DC, United States of America 20016
Tel .No.: (1-202) 778 9619
Fax No.: (1-202) 822 3474
E-mail: jason.clay@wwfus.org

An anthropologist by training, has taught at Harvard, worked in the US Department of Agriculture, and spent more than 20 years working with human rights and environmental NGOs. Has undertaken extensive research on the social and environmental impacts of shrimp aquaculture, and in 1999 created the Shrimp Aquaculture and the Environment Consortium that includes the WWF, World Bank, FAO and NACA, to identify and analyze better management practices that address the environmental and social impacts of shrimp aquaculture. Studied anthropology and Latin American studies at Harvard University, economics and geography at the London School of Economics, and anthropology and international agriculture at Cornell University where he received his Ph.D. in 1979. Author or co-author of 12 books (the most recent being *Global Agriculture and the Environment*, Island Press 11/03), and more than 300 articles. Has given numerous invited lectures and consulted with many international and national organizations and foundations, including the World Bank, the Asia Development Bank, USAID, UN FAO, UNCTAD, UNEP, UNDP, Ford Foundation, Rockefeller Foundation, Packard Foundation, MacArthur Foundation, Pew Charitable Trusts, and hundreds of international environmental, human rights and community-based NGOs.

Jesper Clausen
APO Aquaculture
FAO Regional Office For Asia And The Pacific
Maliwan Mansion, 39 Phra Atit Road
Bangkok 10200, Thailand
Tel. No.: (66-2) 697 4242
Fax No.: (66-2) 697 4445
E-mail: jesper.clausen@fao.org

Worked with aquaculture in the Asian-Pacific region for 6 years and currently based at FAO Regional Office for Asia and the Pacific in Bangkok working with aquaculture and food safety. Before working for FAO, worked for NACA both in Thailand and in Vietnam, mainly on the Consortium on Shrimp Farming and the Environment, and for University of Copenhagen, Faculty of Life Science as project manager on the project Fishborne Zoonotic Parasites in Vietnam (FIBOZOPA). Main areas of experience and expertise are aquaculture and the environment, food safety aspects of aquaculture production and pre-harvest better management practices.

F. Brian Davy
International Institute for Sustainable Development
250 Albert St Suite 553
Ottawa, Ontario Canada K1P 6M1
Tel. No.: (1-613) 288 2025
Fax No.: 1-613) 238 8515
E-mail: bdavy@iisd.ca

Academic training mainly in biology (Texas A&M and Cornell Universities) with over 35 years of experience in aquaculture/natural resources management in Asia and globally. Work experience has been primarily with IDRC (International Development Research Centre of Canada) both based in Singapore and Canada and with Tokyo University of Fisheries/National Aquaculture Center in Japan. Founding member of the Asian Fisheries Society and currently a Senior Fellow with IISD based in Canada.

Sena De Silva
Director General
Network of Aquaculture Centres in Asia-Pacific (NACA)
Suraswadi Bldg, Department of Fisheries
Kasetsart University Campus
Ladyao, Jatujak,
Bangkok 10900, Thailand
Tel. No.: (66-2) 561 1728 to 9
Fax No.: (66-2) 561 1727
E-mail: sena.desilva@enaca.org

Director-General of NACA and Adjunct Professor, Deakin University, Victoria, Australia. Over 35 years of experience in the academia, and aquaculture and inland fisheries management research and development Held academic positions in universities in Sri Lanka, Stirling, Scotland, National University of Singapore and Deakin University, Australia. Was responsible for developing and delivering post-graduate courses in aquaculture in the "distance mode". Internationally reputed researcher in finfish nutrition and reservoir fisheries, and expertise in fish introduction and biodiversity in relation to aquaculture. Author of three advanced texts and over 200 research publications in international journals. Serves on the editorial board of the journals Aquaculture International, Aquaculture Research, Fisheries Management and Ecology. Recipient of many awards, including the NAGA Award (ICLARM) in 1993, Deakin University Vice Chancellor's award for "Best Researcher", Asian Fisheries Society Gold Medal in 2004 and Honorary Life Member of the World Aquaculture Society (2005). Was a founder member of the Asian Fisheries Society and served in the Council for nine years.

Nihad Fejzic
Deputy Director
State Veterinary Office of Bosnia and Herzegovina
Radiceva 8/II,
71 000 Sarajevo, Bosnia and Herzegovina
Tel. No.: (387) 33 258 840
Fax. No.: (387) 33 265 620
E-mail: nihad.fejzic@vet.gov.ba

Deputy-Director of the State Veterinary Office (SVO) of Bosnia and Herzegovina (BiH), responsible for managing SVO, drafting of national animal health regulations, border veterinary inspections, coordination of network of diagnostic laboratories, training and education activities; National Project Coordinator of FAO/TCP/3101 Strengthening Capacity on Aquaculture Health Management. Current interests include disease control, introduction of live fish and fishery products, aquaculture health management.

Eric Hallerman
Dept of Fisheries and Wildlife Sciences
Virginia Tech University
Blacksburg, VA, United States of America 24061-0321
Tel. No.: (1-540) 231 3257
Fax No.: (1-540) 231 7580
E-mail: ehallerm@vt.edu

Professor and Head of the Department of Fisheries and Wildlife Sciences at Virginia Polytechnic Institute and State University. Research interests include population genetics of fish and wildlife species, genetic improvement of aquaculture stocks, and aquaculture biotechnology and related policy. Current projects include: environmental risk assessment for growth hormone transgenic Atlantic salmon, population genetic characterization of Virginia brook trout populations, and genetic stock structure of horseshoe crab populations. Author, coauthor or editor of three books, including one in press on risk assessment for transgenic fishes, and over 100 peer-reviewed papers in scientific journals, and is on the editorial advisory board of *Aquaculture*. Teaches Genetics for Aquaculturists, Conservation Genetics, and Advanced Conservation Genetics, and other courses as needed. Mentored eight M.S. and three Ph.D. students to completion, with two M.S. and three Ph.D. Students in progress. Shared his expertise with the National Research Council, the U.S. Department of Agriculture, the Food and Drug Administration, the Food and Agriculture Organization of the United Nations, and several private-sector firms.

Matthias Halwart
Fishery Resources Officer (Aquaculture Service)
Food and Agriculture Organization of the United Nations
Viale delle Terme di Caracalla
00153 Rome, Italy
Tel. No.: (39-06) 570 55080)
Fax No.: (39-06) 570 53020
E-mail: matthias.halwart@fao.org

Fishery Resources Officer of the FAO Aquaculture Management and Conservation Service with main responsibility for aquaculture production and portfolio of activities ranging from technical project to normative policy-oriented studies and reviews covering topical areas of integrated agriculture-aquaculture and integrated irrigation aquaculture, cage aquaculture, aquatic biodiversity and organic aquaculture in Africa, Asia and Pacific, Latin America and the Caribbean and Europe. Besides project backstopping work, mainly in Asia and Africa, current major normative tasks include contributing to the Special Programme for Aquaculture Development in Africa (SPADA) and the NACA-like network for Africa as well as interdepartmental work in interdisciplinary groups on biological diversity, organic agriculture and integrated farming systems. An important component of the work programme is the lead responsibility for the organization, conduct of and follow-up to workshops and symposia related to the above technical areas – the most recent one being the proceedings of regional reviews and global synthesis on cage culture.

Clayton Harrington
Policy Officer – Aquaculture
Fisheries and Aquaculture
Department of Agriculture Fisheries and Forestry
GPO Box 858,
Canberra ACT 2601, Australia
Tel. No.: (61-2) 6272 3722
Fax No.: (61-2) 6272 4875
E-mail: clayton.harrington@daff.gov.au

Policy Officer at DAFF Australia. Involved in policy analysis, development and implementation of aquaculture policy in order to promote sustainable aquaculture in Australia and Asia-Pacific. Key projects include implementation of the Australian prawn farmers marketing and promotional levy; development of Australian ornamental fish strategy and research projects; Australia's National Pollutant Inventory in relation to aquaculture; European Union Prawn Working Group, maintaining market access for Australian prawns.

Chad Hewitt
Professor, Australian Maritime College
Macquarie Bank Foundation Chair
National Centre for Marine and Coastal Conservation
Private Mailbag 10
Rosebud, Victoria 3939, Australia
Tel. No.: (61-3) 6335 4576
Fax No.: (61-3) 6335 4590
E-mail: c.hewitt@ncmcc.edu.au

Expert in marine bioinvasions science and management with over 100 publications in various aspects of marine ecology, risk determination and management of non-native species and vectors. Research interests focus on biological invasions at all stages of the process, including vector analyses and limitations to successful transport, inoculation and establishment success and impact analyses. Worked as a researcher in marine bioinvasions in the United States (University of Oregon, Oak Ridge National Labs and University of Tennessee) and Australia (CSIRO Centre for Research on Introduced Marine Pests –CRIMP) and as a senior official, Chief Technical Officer Marine Biosecurity, for the New Zealand government. Currently the Director of the National Centre for Marine and Coastal Conservation at the Australian Maritime College and has recently established the International Marine Biosecurity Education and Research Consortium with funding from the Australian Government. This Consortium provides Marine Biosecurity education and training opportunities in support of APEC across the Pacific Basin. Has worked at the interface between science and science application to policy and management providing a unique perspective on education and training needs.

Tim Huntington
Poseidon Aquatic Resources Management Ltd
Windrush, Warborne Lane, Portmore
Nt Lymington, Hampshire S041 5RJ
United Kingdom
Tel. No.: (44) 1590 610 168/636 576
Fax No.: (44) 1590 610 168
E-mail: tim@consult-poseidon.com

Director of Poseidon Aquatic Resource Management Ltd, a Europe and Australia-based fisheries and aquaculture consultancy. Specializes in developing policy, strategy and management solutions for environmentally sustainable aquaculture and capture fisheries. Has led a number of relevant studies for the FAO, World Bank, ADB and European Commission, including guidelines for aquaculture development in sensitive coastal areas (EC, 2005), evaluation of the impact of the use of feed fish in European aquaculture (FAO, 2006), assessment of environmental variables for inclusion in the Common Fisheries Policy (EC, 2003), environmental impacts of coastal aquaculture in Bangladesh (World Bank, 2001–2003), coastal zone management for aquaculture development in Belize (UNDP/GEF,1996) and a Strategy for Human Capacity Building in Fisheries (FAO, 2003–2004). He also regularly works as a fishery assessor to the Marine Stewardship Council 'Principles and Criteria for Responsible Fishing' standard.

Lotus E. Kam
Post-Doctoral Researcher
University of Hawaii
3050 Maile Way, Gilmore 111
Honolulu, Hawaii United States of America 96822
Tel. No.: (1-808) 754 1161
Fax No.: (1-504) 285 1865
E-mail: lotus.kam@gmail.com

Post-doctoral researcher in Biosystems Engineering at the University of Hawaii. PhD in Communication and Information Sciences, dissertation work established a framework to develop a Bayesian decision network model of biosecurity import risk for Hawaii shrimp aquaculture. Previous research and publications include market studies, economic analyses, and enterprise financial and production models in aquaculture. Research employs a variety of decision-theoretic, simulation, operations research, and quantitative methods for conducting feasibility, cost-benefit and risk analyses, and the development of computer applications for managerial decision support. Her Master of Business Administration with emphasis in Management Information Systems enables her to provide a distinctive strategic business approach to using innovative technologies and results-driven performance metrics that inform policy and business decisions affecting aquaculture development.

Iddya Karunasagar
Senior Fishery Industry Officer
(Quality Assurance)
Fish Utilization and Marketing Service
Food and Agriculture Organization of the United Nations
Viale delle Terme di Caracalla
00153 Rome, Italy
Tel. No.: (39 06) 57054873
Fax No.: (39-06) 57055188
E-mail: iddya.karunasagar@fao.org

Has been working in the area of pathogens associated with aquatic animals for over 25 years and published over 150 papers in international journals. Has wide experience with both fish/shrimp pathogens causing disease in aquatic animals and human pathogens associated with aquatic animals, which affect the safety of fish to the consumer. Has been working very closely with FAO/WHO Microbiological Risk Assessment for Foods and was a member of Drafting Group for Risk Assessment of *Vibrio* spp. in seafood. He participated as an FAO Consultant on TCP "Strengthening National Capability in Fish Trade Including Risk Assessment and Traceability" in six countries in Asia. In recognition of his contribution for generating scientific data required for risk assessment, he was awarded the biannual "Research Contributor of the Biennium" Award by the International Association of Fish Inspectors at Sydney, Australia in 2005. In India, Dr. Karunasagar was conferred the position of "National Professor" by the Indian Council of Agricultural Research and received the prestigious "Rafi Ahmad Kidwai Award"from the Ministry of Agriculture. In May 2007, Dr. Karunasagar joined FAO as Senior Fishery Industry Officer (Quality Assurance) based in Rome.

Yin Kedong
Associate Professor, Griffith University
Australian Rivers Institute
Environment 2 Building (N13)
170 Kessels Road
Nathan, QLD 4111, Australia
Tel. No.: (61-7) 3735 4256
Fax No.: (61-7) 3735 7615
E-mail: k.yin@griffith.edu.au

Associate Professor at the Australian Rivers Institute, a multi-disciplinary environmental oceanographer with an impressive academic record in marine ecology. Possesses an impressive comprehension of the dynamics of a coastal marine system and is an expert in interpreting the complex spatial and temporal variability of physical processes, nutrients and plankton in the water column. Over the years, has been working on dynamics of nutrients and plankton in a natural marine ecosystem. His study also focuses on eutrophication processes by examining how biological components respond to an input of nutrients, including anthropogenic nutrients. Research in the Pearl River estuary revealed that phosphorus is the most limiting nutrient to phytoplankton biomass production in the estuarine-influenced waters south of Hong Kong. He was chief environmental oceanographer for a large consulting project: Environment and Engineering Feasibility Study under the Hong Kong's Harbor Area Treatment Scheme. His scientific findings have made a significant contribution to the formation of the sewage treatment strategy in terms of the removal of inorganic nutrients. In this project, he has gained a great deal of knowledge on environmental risk analysis and risk communication. He is experienced in conducting large estuarine projects, as he is chief scientist for several large projects.

Thitiporn Laoprasert
Fisheries Biologist
Inland Aquatic Animal Health Research Institute
Department of Fisheries
Kasetsart University Campus
Ladyao, Jatujak
Bangkok 10900, Thailand
Tel. No.: (66-2) 579 4122
Fax No.: (66-2) 561 3993
E-mail: tpetchinda@yahoo.com

Senior Fisheries Biologist, Aquatic Animal Health Research Institute, Thailand's Department of Fisheries (DOF). Early career on seed production of freshwater fishes and initiated pioneering work on monitoring of antibiotic residues in shrimp products. Since 1994 involved in fish disease work, completed MSc (Fish Pathology) from Stirling University. Has been doing research on fish disease particularly parasitic and fungal diseases, disease diagnosis, prevention and control for students, farmers, fisheries official staff and the private sector within the country and also for scientists and fish disease researchers from neighboring countries. Involved in setting up aquatic animal disease surveillance system, aquatic animal farm monitoring system, standardization and certification of live aquatic animal health for export, and setting up a quarantine system for aquatic animals imported to Thailand. Served as member of AAHRI newsletter and provided technical information and served as editorial team member of Thai Fisheries Gazette.

Kenneth M. Y. Leung
Department of Ecology and Biodiversity
The University of Hong Kong
Pokfulam, China, Hong Kong Special Administartive Region
Tel. No.: (852) 2299 0607
Fax No.: (852) 2517 6082
E-mail: kmyleung@hkucc.hku.hk

Assistant Professor of the Department of Ecology & Biodiversity, the University of Hong Kong (HKU). Obtained B.Sc. in Applied Environmental Sciences at the University of Portsmouth in England and M.Phil. in Mariculture and the Environment at the City University of Hong Kong. In 2000, accomplished his PhD in marine ecotoxicology at the University of Glasgow in Scotland. Subsequently, took up a position as a Croucher Foundation Postdoctoral Research Fellow at Royal Holloway, University of London where he and his colleagues developed some practical, probabilistic approaches for assessing ecological risks of industrial chemicals in aquatic ecosystems. Research interests include aquatic toxicology, ecological risk assessments, derivation of water and sediment quality guidelines, biomonitoring and mariculture. Since 1999, published more than 40 SCI peer-reviewed articles in the field of ecotoxicology and ecological risk assessments. He is a founding member of the editorial board of the international journal *Integrated Environmental Assessment and Management,* which is published by the Society of Environmental Toxicology and Chemistry (SETAC). Serves as a regional representative for SETAC (Asia/Pacific) and Australasian Society for Ecotoxicology

Pingsun Leung
Professor, University of Hawaii at Manoa
MBBE/CTAHR
3050 Maile Way, Gilmore 111
Honolulu, Hawaii USA 96822
Tel. No.: (1-808) 956 8562
Fax No.: (1-808) 956 9219
E-mail: psleung@hawaii.edu

Professor at University of Hawaii in Manoa, Current research focus is in aquacultural and fisheries economics. Current teaching responsibility includes engineering economics, spreadsheet modeling, biosystems modeling, biosystems simulation and operations research for management. Serves as cooperating graduate faculty in the Department of Economics and the Department of Natural Resources and Environmental Management. Served as consultant to UN FAO, NACA, ADB, MRC, WFC and UNDP. Founding editor of Aquaculture Economics and Management and serves as a member of the editorial board of *Aquaculture*.

Graham Mair
Senior Lecturer
School of Biological Sciences
Flinders University
PO Box 2100
Adelaide SA 5001, Australia
Tel. No.: (61-8) 820 15968
Fax No.: (61-8) 820 13015
E-mail: graham.mair@flinders.edu.au

Senior lecturer in aquaculture at Flinders University in South Australia and has recently taken on a major role as program leader for the Value Chain Profitability research program within the newly approved Australian Seafood Cooperative Research Centre. President of the Asian Pacific Chapter of the World Aquaculture Society. Prior to moving to Australia in 2004, worked for >15 years in S.E. Asia on a range of aquaculture genetics research projects in the context of aquaculture as a component of sustainable livelihoods. Experience across the whole research continuum from technical development through to upscaling, commercialization, dissemination and uptake/ impact assessment and thus has an appreciation of the varying levels of environmental and social risks posed by genetic improvement. Recently involved in the production of a book entitled *Environmental Risk Assessment of Genetically Modified Organisms, Volume 3: Building Scientific Capacity for Transgenic Fish in Developing Countries* to be published by CABI later in 2007 and was the lead author on a chapter covering the reduction of risk through confinement. This book covers a wide range of risk assessment and risk management issues that have broader relevance to genetically improved fish in general.

Zorana Mehmedbasic
Associate
State Veterinary Office of Bosnia and Herzegovina
Radiceva 8/II, 71 000
Sarajevo, Bosnia and Herzegovina
Tel. No.: (387) 33 258 840
Fax No.: (387) 33 265 620
E-mail: zorana.mehmedbasic@vet.gov.ba

Associate Officer of BiH SVO; working on development of veterinary legislation and other veterinary tasks for which SVO BiH is authorized as central veterinary authority, including aquatic animal health regulations, epidemiology, diagnostic veterinary laboratories and FAO/TCP/3101. Current interests include animal health control, introduction of live fish and fishery products to BiH and aquaculture health management.

C.V. Mohan
Coordinator, Aquatic Animal Health
Network of Aquaculture Centres in Asia-Pacific (NACA)
Suraswadi Bldg, Department of Fisheries
Kasetsart University Campus
Ladyao, Jatujak, Bangkok 10900
Thailand
Tel. No.: (66-2) 561 1728 to 9
Fax No.: (66-2) 561 1727
E-mail: mohan@enaca.org

Coordinator of Animal Health Program of NACA. Specialized in the field of aquatic pathology. Since 1982, has been involved with aquatic animal health teaching and research at the College of Fisheries, Mangalore, India, and appointed Professor of Fish Pathology. Since March 2003, has been working in NACA as the Regional Aquatic Animal Health Specialist, managing the regional programme in 21 countries of the Asia-Pacific region. Expertise includes fish and shrimp diseases, epidemiology, surveillance and risk management. Over 20 years of teaching, research and development experience in aquatic animal health and has authored and coauthored over 60 papers in peer reviewed international journals.

Thuy Thi Thu Nguyen
Coordinator, Genetics & Biodiversity
Network of Aquaculture Centres in Asia-Pacific (NACA)
Suraswadi Bldg, Department of Fisheries
Kasetsart University Campus
Ladyao, Jatujak, Bangkok 10900
Thailand
Tel. No.: (66-2) 561 1728 to 9
Fax No.: (66-2) 561 1727
E-mail: thuy.nguyen@enaca.org

Coordinator of genetics and biodiversity programme of NACA. Expertise in molecular genetics and its application in phylogeny, broodstock management and conservation. Provides advice and training on the applications of molecular genetic techniques in relation to inland fisheries management and aquaculture development. Coordinates the Genes and Fish column in *Aquaculture Asia* magazine. Currently involved in the following projects: (a) development of broodstock and conservation plan for two indigenous fish species in Sarawak, Malaysia; (b) development of a conservation plan of the critically endangered Mekong giant catfish; and (c) taxonomy and genetic resources management of scallop species in Thailand.

Michael J. Phillips
Coordinator, R & D
Network of Aquaculture Centres in Asia-Pacific (NACA)
Suraswadi Bldg, Department of Fisheries
Kasetsart University Campus
Ladyao, Jatujak, Bangkok 10900
Thailand
Tel. No.: (66-2) 561 1728 to 9
Fax No.: (66-2) 561 1727
E-mail: Michael.phillips@enaca.org

Environment Specialist and Program Manager (Research and Development), of NACA. Expertise in shrimp farming and environmental impacts of aquaculture. Has been working on environmental issues in Asian aquaculture for over two decades. In recent times, has been involved in tsunami rehabilitation work for fish farmers in Aceh and also played a major role in developing the "International Principles for Responsible Shrimp Farming," which received the "Green Award" by the World Bank in 2006. Considerable experience working with farmers and was instrumental in initiating and directing one of the most successful projects, in collaboration with the Marine Exports Development Authority, India, in reviving the livelihoods of small-scale shrimp farmers following the disease epidemics in 1997/98. Involved in leading the work on certification and standardization in aquaculture, a burning problem for small-scale farmers globally.

Ben Ponia
Aquaculture Adviser
Secretariat of the Pacific Community
BP D5-9884 Noumea Cedex – New Caledonia
Tel. No.: (687) 262 000
Fax No.: (687) 263 818
E-mail: benp@spc.int

Aquaculture Adviser of the Secretariat of the Pacific Community (SPC), a Pacific intergovernmental organization based in Noumea, New Caledonia. Manages the aquaculture program, which serves a regional focal point for the sector and provides a broad range of assistance to its member governments. Worked extensively throughout SPC's 22 Pacific Island member countries and is a strong advocate for forging professional linkages outside of the region, particularly to Asia. Prior to joining SPC in 2001, was the Director of Research at the Cook Island Ministry of Marine Resources. Is university educated in New Zealand, Hawaii, and Australia with a special interest in black-pearl farming (oyster physiology and lagoon water quality).

Melba Bondad-Reantaso
Fishery Resources Officer (Aquaculture Service)
Food and Agriculture Organization of the United Nations
Viale delle Terme di Caracalla
00153 Rome, Italy
Tel. No.: (39-06) 570 54843
Fax No.: (39-06) 570 53020
E-mail: melba.reantaso@fao.org

Retired in 2000 as Senior Aquaculturist from the Philippine Bureau of Fisheries and Aquatic Resources, Monbusho scholar (1991–1995) and JSPS postdoctoral fellow (1998–1999). Joined FAO in 2004 as Fishery Resources Officer (Aquaculture), managed NACA's aquatic animal health regional programme (1999–2002); Research Pathologist at Maryland DNR's Cooperative Oxford Laboratory from 2002. Initiated pioneering work on pathogen risk analysis under APEC/NACA/FAO project, co-author of a manual and two commissioned studies on pathogen/ecological risk analysis for SPC; spearheaded the development of National Strategies on Aquatic Animal Health in Nepal, Myanmar, Philippines, Indonesia; led international emergency disease investigation task forces on suspected EUS outbreak (Botswana, 2007), koi herpes virus (Indonesia, 2002), and pearl oyster mortalities (Philippines, 1996). Currently Lead Technical Officer of the FAO-Norway funded project (B.1Objective) Risk Assessment and Management in Aquaculture and (D.1Objective) Support to National Biosecurity Initiatives/Policies to Countries facing High Risks of Diseases/Pests; and FAO TCP projects with biosecurity/risk analysis components (Belize, Latvia, Bosnia & Herzegovina). Presently involved in global assessment of freshwater seed resources in aquaculture, particularly small-scale aquaculture, GAL Source Book on Gender in Fisheries and Aquaculture, capacity building activities in aquaculture and aquatic animal health management and chief editorial responsibilities for *FAO Aquaculture Newsletter*.

Philip Adam Secretan
Managing Director - AUMS Ltd.
Aquaculture Underwriting
Management Services
112 Malling Street
Lewes, East Sussex, BN7 2RJ, UK
Tel. No.: (44-1) 273 488094
Fax No.: (44-1) 273 479645
E-mail: secretan@aums.com

Managing Director of AUMS Ltd. Aquaculture Underwriting Management Services, of UK. Convenor of the biennial series of Aquaculture Insurance & Risk Management conferences, the 10th, which was supported by FAO and held in Vigo, Spain, in April 2006. Has been closely involved in aquaculture insurance and risk management since 1974, when he was centrally involved in founding the insurance market for aquaculture stock mortality in Lloyd's of London and the international insurance market. Lectured widely on aquaculture insurance and risk management and has conducted numerous risk management surveys of individual operations and regional industries in many parts of the world involving many different species and growing systems.

Susana V. Siar
Fishery Industry Officer
Fishing Technology Service
Food and Agricultural Organization of the United Nations
Viale delle Terme di Caracalla
00153 Rome, Italy
Tel. No.: (39-06) 570 56612
Fax No.: (39-06) 57055188
E-mail: Susana.Siar@fao.org

Fishery Industry Officer (Rural Development) at the Fishing Technology Service, FAO. From 1989 to mid-2004 she was connected with the Aquaculture Department of the Southeast Asian Fisheries Development Center (SEAFDEC) in Tigbauan, Iloilo, Philippines, where she was involved in community-based coastal resource management, socio-economic surveys of fishing communities, and in training related to aquaculture development. Shortly before she joined FAO, she was working for the WorldFish Center in Penang, Malaysia as a regional coordinator and was involved in project management and coordination with research partners under the projects on fisheries co-management (Asia and Africa) and the dissemination and adoption of aquaculture technology in the Philippines. Her present projects and involvement include: Technical Cooperation Project on Capacity Building in Support of Cleaner Fishing Harbours in India; case studies on the social, economic and environmental impacts of beach seining; review of the current state of world capture fisheries insurance; pilot projects on establishing and strengthening organizations of women fish processors; pilot project on organizing sea safety groups; and case studies on the use of socio-economic and demographic information in community-based fisheries management.

Temdoung Somsiri
Senior Fisheries Biologist
Inland Aquatic Animal Health Research Institute
Department of Fisheries
Kasetsart University Campus
Ladyao, Jatujak, Bangkok 10900
Thailand
Tel. No.: (66-2) 579 4122
Fax No.: (66-2) 561 3993
E-mail: tsi_f@yahoo.com

Currently head of the aquatic animal health research section of the Inland Aquatic Animal Health Research Institute, Department of Fisheries, Thailand. Expertise on fish and shellfish microbiology. Nearly 20 years experience, involved in disease diagnosis, disease control regime for both local consumption and exportation, involved with the governmental aquaculture policy and the registration of chemicals and micro-organisms used in aquaculture. Most recent research concerning Asiaresist project funded by the EU focused on three major subjects, including assessment of the extent of antibiotic resistance in aquaculture, assessment of the potential for antibiotic resistance transferring in aquaculture, and identification of critical control points to eliminate antibiotic resistance, especially chloramphenicol resistance in the Southeast Asian aquaculture environment. Outcomes of the project have been available among the partners and the information is freely accessible via the internet (www.medinfo.dist.unige.it/**asiaresist**/). Supervised MSc and Ph.D. students of Kasetsart University since 1995.

Putth Songsangjinda
Fisheries Biologist
Department of Fisheries
1/19 Moo 3, Kaorupchang, Muang District
Songkhla 90000 Thailand
Tel. No.: (66-74) 311 895
Fax No.: (66-74) 442 054
E-mail: putthsj@yahoo.com

Senior Fisheries Biologist, Thailand's Department of Fisheries. More than 20 years of research work in the field of aquaculture system management, particularly on environmental quality, aquaculture eutrophication, effluent treatment, recirculation system, material budget and modeling in marine shrimp production. Involved in the development of shrimp farm certification schemes of Thailand since 1999 and trained for the ISO and IEC guide for the quality system certifications, especially for the organic aquaculture production system. Invited as a lecturer in many topics related to the experience in development of shrimp farm certification scheme, mangrove friendly shrimp culture and shrimp farm management in many Asian countries by NACA, SEAFDEC and private companies.

Rohana P. Subasinghe
Senior Fishery Resources Officer (Aquaculture Service)
Food and Agriculture Organization of the United Nations
Viale delle Terme di Caracalla
00153 Rome, Italy
Tel. No.: (39-06) 570 56473
Fax No.: (39-06) 570 53020
E-mail: rohana.subasinghe@fao.org

Senior Fisheries Resources Officer (Aquaculture) of the Fisheries and Aquaculture Department of FAO. Specialized in aquaculture, disease control and health management (with particular reference to microbiology and immunology). Has worked in all parts of the world, with most experience in Asia. Was responsible for many projects on aquaculture and aquatic animal health at national, regional and international levels. A former teacher of the University of Colombo and the Universiti Putra Malaysia, Rohana earned his PhD from Stirling University. Has been responsible for initiating major policy changes in aquatic health management in relation to aquaculture in the region and globally. Currently serves as Technical Secretary to the Sub-Committee on Aquaculture of the Committee on Fisheries of the FAO.

Varin Tanasomwang
Director
Samutsakhon Coastal Fisheries Research & Development Center
127 Moo 8, Khok-Kham, Muang
Samut Sakhon Province 74000, Thailand
Tel. No.: (66-34) 426 220
Fax No.: (66-34) 857 138
E-mail: scadc@ji-net.com

Director of Samutsakhon Coastal Fisheries Research and Development Center, Coastal Fisheries Research and Development Bureau, Department of Fisheries. Earned a Bachelor Degree from Kasetsart University in 1977 in the field of aquaculture, Master Degree from Miyazaki University in 1986 and Doctoral Degree from Hiroshima University in 1989 in the field of Fish Pathology. Current work includes responsibility for all activities in the center, which includes administration, research and development, farm certification, inspection of drug residues in cultured shrimp and diagnosis of aquatic animal health; also involved in improvement of marine shrimp farm standard and preparing procedures of the certification body.

Suda Tandavanitj
Director, Inland Aquatic Animal Health Research Institute Department of Fisheries
Kasetsart University Campus
Ladyao, Jatujak,Bangkok 10900 Thailand
Tel. No.: (66-2) 579 4122
Fax No.: (66-2) 561 3993
E-mail: sudat@fisheries.go.th

Background is fishery biology. Worked as Head of the Antibiotic Residue Inspection Unit at Phuket Coastal Fisheries and Development Center from 1990–2003. During that period, involved in a number of researches on shrimp diseases, especially parasitic and viral diseases. Currently serving as Director of the Aquatic Animal Health Research Institute of Thailand's Department of Fisheries. Involved with the national aquatic animal disease control policy under the Animal Epidemic Act. Also appointed as a member of the National Fish Disease Committee as well as the Committee of the Antibiotic Control Plan.

Sanin Tankovic
Senior Associate, Veterinary Public Health
State Veterinary Office of Bosnia and Herzegovina
Radiceva 8/II, 71 000 Sarajevo, Bosnia and Herzegovina
Tel. No.: (387) 33 258 840
Fax No.: (387) 33 265 620
E-mail: sanin.tankovic@vet.gov.ba

Senior Associate for Veterinary Public Health of the SVO of BiH. Involved in drafting of national animal health regulations; national residue control plan, veterinary sanitary conditions during import of live fish and fishery products into BiH, and other tasks related to SVO as central veterinary authority; participating in FAO/TCP/3101; currently interested in introduction of live fish and fishery products into BiH and aquaculture health management.

Montira Thavornyutikarn
Senior Fisheries Biologist
Coastal Aquatic Animal Health Research Institute
130/2 Moo 8, Tambol awong
Muang District
Songkhla 90100, Thailand
Tel. No.: (66-74) 334 516 to 8
Fax No.: (66-74) 334 515
E-mail: montira_tha@yahoo.com

Fishery Biologist at the Coastal Aquatic Animal Health Research Institute, Thailand's Department of Fisheries. Specialized in shrimp diseases. Since 2004, responsible for aquatic animal disease control and health management. Involved in epidemiology, surveillance and risk management, standard farm practices such as good aquaculture practice/code of conduct. Research focussed on herbs using in aquaculture. Fields of interest include epidemiology, surveillance and biotechnology.

NR Umesh
Project Supervisor, MPEDA/NACA
Plot No 8, SBI Officers' Colony
Rajendra Nagar, Kakinada 533003
East Godavari District, Andhra Pradesh, India
Tel. No.: (91-9440) 711 600
E-mail: nrumesh@yahoo.com

Fisheries postgraduate with more than 13 years of field experience in aquaculture projects in India (shrimp project for 5 yrs), Jordan (tilapia project for 6 yrs) and Ghana (IFC project in tilapia for 2 yrs). From 2006 working as Project Supervisor in the MPEDA-NACA village demonstration program, which is a collaborative project between MPEDA and NACA on shrimp disease control in India. Current job in the project is to organize small-scale farmers into self-help groups known as "Aquaclubs" for adoption of "BMPs" towards capacity building among the farmers; promoting better management practices to improve aquaculture productivity and profits in Aquaclubs/societies; capacity-building and empowerment of primary producers; facilitating improved service provision to farmers; connecting farmers to markets to receive a better price for quality product; technology transfer and diversification to other commercially important species; supporting improved food security and sustainable livelihoods in aquaculture communities. Current interests include formation of Aquaclub/Society as a promising model for farmers, especially small farmers to work together, solve their day to day farming problems and earn their livelihood by helping the industry to meet the customer demand.

Cheng Wo Wing
Head of Aquaculture Management
Agriculture, Fisheries and Conservation Department
China, Hong Kong Special Administrative Region
8/F, Cheung Sha Wan Government Offices
303 Cheung Sha Wan Road, Kowloon, Hong Kong SAR
Tel. No.: (852) 2873 8337
Fax No.: (852) 2870 0324
E-mail: ww_cheng@afcd.gov.hk

Fisheries Officer (Aquaculture Management) at Agriculture, Fisheries and Conservation Department (AFCD) in HKSARG. Current responsibility includes accredited fish farm scheme, baseline survey on local fish farms, oyster monitoring programme and food safety for seafood. Prior to joining AFCD in 1997, worked for 5 years in Ocean Park Corporation on a range of projects including Shark Aquarium, Ocean Theatre and Atoll Reef. Experience includes wetland management, marine conservation, environmental impact assessments and thus has an appreciation of environmental protection and sustainable development of aquaculture. Hasdedicated services in NGOs, including WWF, Friends of the Earth and Green Power. Obtained M. Phil. from the Chinese University of Hong Kong (1981) and Ph.D. from l'Univerite de Bretagne Occidentale, France (1985). Expertise includes fish and shrimp culture, oceanarium management and environmental impact assessment.

Malinee Witchawut
Fisheries Biologist
Marine Shrimp Culture Research Institute
Department of Fisheries
Kasetsart University Campus
Ladyao, Jatujak, Bangkok 10900
Thailand
Tel. No.: (66-2) 561 3997
Fax No.: (66-2) 561 3997
E-mail: mwitchawut@hotmail.com

Senior Fisheries Biologist at the Marine Shrimp Culture Research Institute, Thailand's Department of Fisheries. The institute has primary responsibility to carry out investigations for further advancement of technology in the fields of shrimp genetic selection and breeding technology, shrimp culture technology, coastal environment protection, shrimp farm management and shrimp farm standard practices. Involved in Food Safety Project (particularly for marine shrimp farms and products), in policies and planning on import and export of marine shrimp products and live aquatic animals, improvement of marine shrimp farm standards (procedure and regulation) and products quality control.

Annex 2
EXPERT WORKSHOP PROGRAMME

Date, Day and Time	Activities
Thursday, 7 June	Arrival of participants to Bangkok
Day 1: Friday, 8 June	
08:00-11:00	Travel from Bangkok to Rayong by car
11:00-14:00	Check-in and lunch
14:00-14:15	Opening remarks Dr Rohana Subasinghe (FAO) Dr Sena de Silva (NACA)
14:15-14:30	Presentation 1: Project purpose, participation, process, products Dr Melba Reantaso (FAO)
14:30-14:45	Self-introduction of workshop participants
14:45-15:15	Presentation 2: General principles of the risk analysis process and its application to aquaculture Dr J. Richard Arthur (FAO Consultant)
15:15-15:45	Coffee break
15:45-16:10	Presentation 3: Food safety and public health risk associated with products of aquaculture Dr Iddya Karunasagar (FAO)
16:10-16:35	Presentation 4: Pathogen risk analysis for aquaculture production Dr Melba Reantaso (FAO)
16:35-17:00	Presentation 5: Application of risk analysis to genetic issues in aquaculture (25 min) Dr Eric Hallerman (Virginia Polytechnic Institute and State University)
17:00-17:30	Discussion (30 min)
17:30-17:40	Day 1 and 2 announcements
19:00-	Welcome dinner
Day 2: Saturday, 9 June	
08:30-08:55	Presentation 6: Ecological (pest) risk assessment and management Dr Kenneth Leung and Dr David Dudgeon (University of Hong Kong)
08:55-09:20	Presentation 7: Environmental Risk Analysis Dr Michael Phillips (NACA) and Dr Rohana Subasinghe (FAO)
09:20-09:45	Presentation 8: GESAMP WG 31 Environmental risk assessment and communication in coastal aquaculture (work in progress) Dr Rohana Subasinghe (FAO)

09:45-10:10	Presentation 9: Marine invasive species risk analysis Dr Marnie Campbell and Dr Chad Hewitt (National Center for Marine and Coastal Conservation, Australian Maritime College)
10:10-10.40	Coffee break
10:40-11:05	Presentation 10: Guidelines for the ecological risk assessment of marine fish aquaculture Mr Colin Nash (NOAA) – to be presented by Mr Phillip AD Secretan
11:05-11:30	Presentation 11: Financial risks analysis in aquaculture Dr Lotus Kam and Dr Pingsun Leung (University of Hawaii)
11:30-11:55	Presentation 12: Social risks in aquaculture Mr Pedro Bueno (NACA)
11:55-12:20	Presentation 13: Insurance industry risk analysis process Mr Phillip AD Secretan (AUMS Limited)
12:20-12:45	Presentation 14: Better management practices in shrimp aquaculture: experiences in India Mr. Umesh NR (MPEDA/NACA)
13:10-14:30	Lunch break
14:30-15:30	Presentation of guidelines for the working groups and discussion
15:30-18:00	Parallel working group discussions Working Group 1 Working Group 2 Working Group 3
15:30-16:00	Coffee break
18:00	End of day
Day 3: Sunday, 10 June	
08:30-08:40	Day 3 Announcements
08:40-18:00	Continue parallel working group discussions Working Group 1 Working Group 2 Working Group 3
10:00-10:30	Coffee break
10:30-11:30	Reporting of working group progress
13:00-14:30	Lunch break
14:30-15:30	Parallel working group discussions Working Group 4 Working Group 5
15:30-16:00	Coffee Break
16:00-18:00	Parallel working group discussions Working Group 4 Working Group 5
18:00	End of day

Day 4: Monday, 11 June	
	Day 4 Announcements
09:00-10:30	Presentation 15: Working Group 1 and discussion (30 min)
10:30-11:00	Presentation 16: Working Group 2 and discussion (30 min)
09:30-10:00	Presentation 17: Working Group 3 and discussion (30 min)
11:00-11:30	Coffee Break
11:30-12:00	Presentation 18: Working Group 4 and discussion (30 min)
12:00-12:30	Presentation 19: Working Group 5 and discussion (30 min)
12:30-14:00	Lunch break
14:00-14:30	Final conclusions and way forward Dr Rohana Subasinghe (FAO)
14:30-15:00	Closing ceremony
15:00-15:30	Coffee break
15:30-	Participants depart for Bangkok
Tuesday, 12 June	
	Participants depart from Bangkok to home country

Annex 3
EXPERT WORKSHOP GROUP PHOTO

Forty-two aquaculture experts (policy-makers, risk analysis practitioners and technical experts in various aspects, e.g. diseases, food safety, genetics, environment, socio-economics, aquaculture insurance) representing various international, regional and national organizations and institutions in Asia, the Pacific, Oceania, Europe and North America, participated in the FAO/NACA Expert Workshop on Understanding and Applying Risk Analysis in Aquaculture held in Rayong, Thailand, from 7 to 11 June 2007.