3. A risk analysis process for aquaculture

This section presents an outline of a generic risk analysis process for aquaculture (brief summaries of the risk analysis processes specific to the seven risk categories can be found in Section 4, with detailed reviews given in Bondad-Reantaso, Arthur and Subasinghe, 2008). The general process, shown in Figure 2, consists of a preliminary step – scoping the risk analysis, and four major components: (i) hazard identification, (ii) risk assessment, (iii) risk management and (iv) risk communication. The following sections briefly discuss some of the important aspects of each of these activities.

3.1 DETERMINING THE SCOPE OF THE RISK ANALYSIS

3.1.1 Define the objectives of the risk analysis

At the outset of a risk analysis, it is imperative to understand what is to be achieved. The objective must be clearly stated and will generally define the scale and scope of the analysis along with the measurement endpoints and desired outcomes.

To accomplish this, a risk analyst needs to answer a number of questions about the purpose and nature of the risk analysis that will ultimately set the objectives and boundaries (the "scope") of the analysis. The precise questions will vary depending on the risk category. As an example, some useful questions that help define the scope of an ecological or environmental risk analysis are given in Box 1.

The analyst must also delineate the endpoint(s) of the risk analysis, which will provide guidance as to what hazards the assessment is trying to prevent, what outcomes it is trying to achieve and/or what values it is trying to protect. The endpoints will also be formed by examining exposure to the hazard and can be explored by asking appropriate questions.

3.1.2 Agree upon a risk analysis methodology and approach

With each of the seven risk categories, numerous risk analysis methodologies exist (qualitative, semi-quantitative or quantitative) to meet a variety of objectives. In many cases, risk analysis need not be complicated; however, choosing the methodology most appropriate to the problem that is being addressed will make the decision-making process easier. Considerations for selecting a risk analysis method include the quality and availability of data, the uncertainty surrounding the data, the available budget (including human resources) and the time available to undertake the assessment. It is also important to determine the linguistic level of approach, e.g. is it for seasoned risk analysis specialists, well-educated non-risk specialists or less well educated stakeholders? If a detailed analysis is required and

BOX 1

Some useful questions that help define the scope of an ecological or environmental risk analysis

Questions that help define the purpose and nature of the risk analysis and provide information that will guide it include:

- What is the scale of the risk assessment?
- What are the critical ecological endpoints and ecosystem receptor characteristics?
- How likely is recovery and how long will it take?
- What is the nature of the problem?
- What is the current knowledge of the problem?
- What data and data analyses are available and appropriate?
- What are the potential constraints?

Questions that establish the ecosystem boundaries include:

- What are the geographic boundaries?
- How do the geographic boundaries relate to the functional characteristics of the ecosystem?
- What are the key abiotic factors influencing the ecosystem?
- Where and how are functional characteristics driving the ecosystem?
- What are the structural characteristics of the ecosystem?
- What habitat types are present?
- How do these characteristics influence the susceptibility of the ecosystem to the stressor(s)?
- Are there unique features that are particularly valued?
- What is the landscape context within which the ecosystem occurs?
- What are the type and extent of available ecological effects information?
- Given the nature of the stressor, which effects are expected to be elicited by the stressor?
- Under what circumstances will effects occur?

Questions related to the stressor and its source include:

- What is the source of the hazard? (Is it anthropocentric, natural, point source or diffuse nonpoint?)
- What type of stressor is it? (Is it chemical, physical or biological?)
- What is the intensity of the stressor?
- With what frequency does a stressor event occur?
- What is the stressor event's duration? (How long does the stressor persist in the environment?)
- What is the timing of exposure? (When does it occur in relation to critical organism life cycles or ecosystem events?)
- What is the spatial scale of exposure? (Is the extent or influence of the stressor local, regional, global, habitat-specific or ecosystem-wide?)
- What is the distribution? (How does the stressor move through the environment?)
- What is the mode of action? (How does the stressor act on organisms or ecosystem functions?)

there is ample budget and no time constraints, then a fully quantitative analysis may be desired. However if a rapid decision must be made in the face of poor data availability or a limited budget, then a qualitative assessment may be more feasible.

Qualitative or even semi-quantitative risk analysis can often provide the level of information sufficient for use by a decision-maker in a rapid fashion; however, these analyses often require a number of assumptions to be made due to poor data quality or cost-saving measures that may result in increased uncertainty (see Section 3.3.4). As a consequence, qualitative and semi-quantitative risk analyses may occasionally be considered too subjective and lacking in scientific rigor. Alternately, fully quantitative risk analyses can be costly and time-intensive; however, they are often perceived as being more objective and scientifically defensible.

3.1.3 Identify the stakeholders

Identification of responsible agencies is fundamental to understanding the resourcing (both human and financial) and decision-making responsibility. If there is more than one responsible agency, a clear and concise statement of roles and responsibilities should be developed in advance to guarantee success. The early identification of non-statutory stakeholders will aid in the development of risk communication strategies, as well as in the gathering and exchange of information throughout the analysis.

3.2 HAZARD IDENTIFICATION

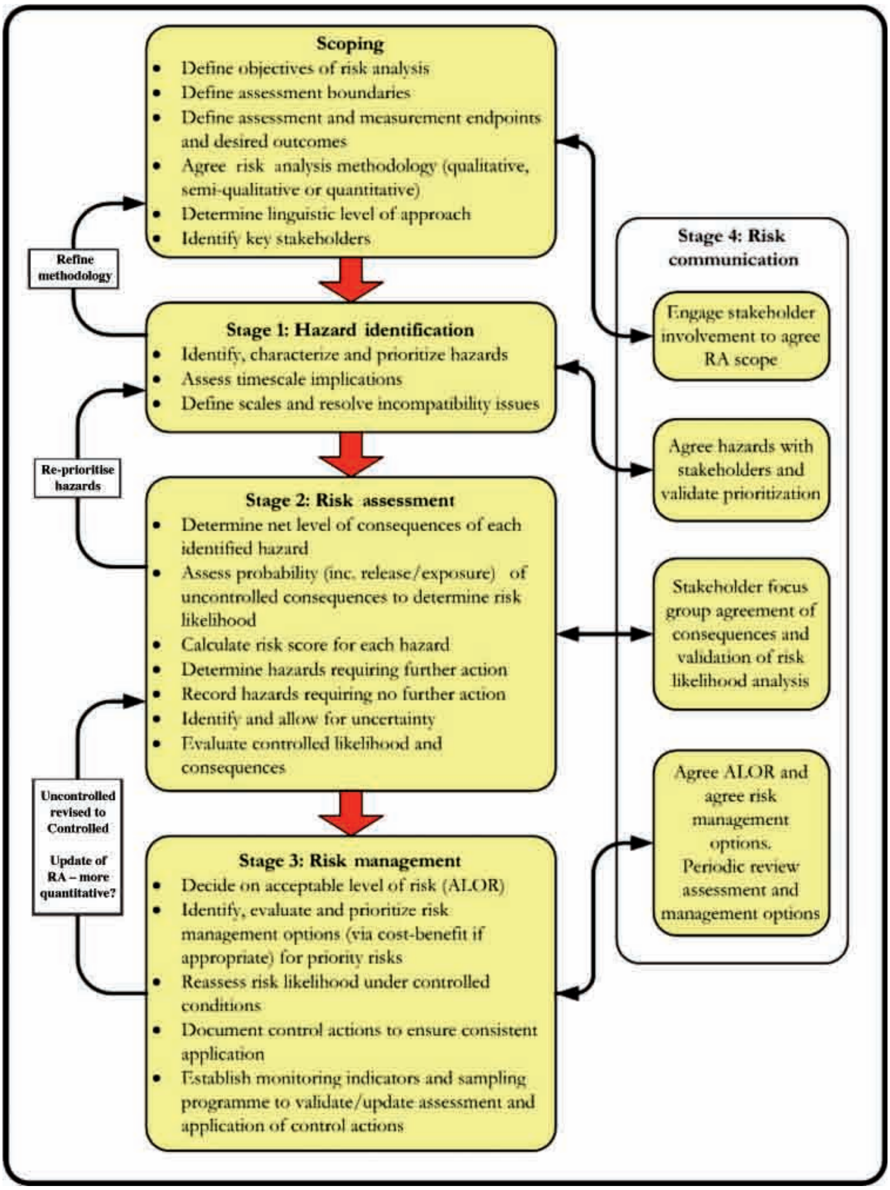
3.2.1 Identify, characterize and prioritize hazards

In simple terms, a hazard is something (an action, an organism, a physical condition, a piece of legislation, etc.) that may cause harm and therefore potentially create risk. A hazard may act synergistically to increase risk or may cause cascade events that lead to hazard migration (i.e. the action of one hazard creates additional hazards that result in increased likelihood and consequence). For example, caged finfish culture in shallow water increases the nutrient input to the system, frequently leading to eutrophication and accumulation of feces and excess feed on the substrate. This accumulation of organic material will lead to anoxia (reduced oxygen levels) in the sediments and have consequential impacts on infaunal organisms.

Hazard identification may proceed in a variety of ways, including via a Delphi process using expert opinion or by a more formalized assessment such as fault tree analysis (Hayes, 1997). For pathogen risk analysis, Arthur *et al.* (2004a) outline a multistage hazard identification process based on collation of prior knowledge (exhaustive literature review) and expert assessment to reduce the number of potential hazards. This process is useful for situations where significant prior knowledge exists, such as for pathogen risks, food safety and public health risks, financial risks and to a lesser extent, social risks.

In contrast, fault-tree analysis has been used to identify the chain of events leading to a hazardous occurrence in ecological, genetic and environmental risk analyses. Fault trees provide a rigorous mechanism to identify logical relationships and situations leading to hazardous situations. Hayes and Hewitt (1998, 2000, 2001) provide an explicit example of fault tree analysis in the context of marine biosecurity where the fault-tree analysis identified taxonomic hazards in donor ports and a number of subtle (and less tractable) hazards within the ballast water introduction cycle.

FIGURE 2
Overview of the risk analysis methodology



With regard to aquaculture, hazards can either affect the success of aquaculture operations, or the aquaculture activities themselves can be hazards (Table 3). These can vary across all core values (environmental, economic, socio-political and cultural) and can be represented within multiple risk categories.

3.2.2 Assess timescales

Hazards vary in their spatial extent and in the timing of presence. Some hazards are always present (e.g. tidal flow), whereas others may only occur at specific times (e.g. storm events). As a consequence, hazards may create windows of opportunity for impacts to occur. The temporal component of a hazard will vary depending on the stressor itself, the length of time that a stressor event occurs (short, medium or long term) and the length of time the hazard persists in the environment. For example, a disease outbreak may involve a vagile species that can persist for a long period of time, thus posing a greater risk than a disease that is caused by a

TABLE 3
Examples of hazards to and from aquaculture associated with the seven risk categories

Risk category	Hazard to aquaculture	Hazard from aquaculture
Pathogen risks	Disease outbreak causing loss of stock OIE-listed disease Food safety and public health concern Loss of consumer confidence	Disease outbreak in wild populations OIE -listed disease Food safety and public health concern
Food safety and public health risks	Bacteria Viruses Parasites Residual therapeutants Biotoxins (HABs)	Transfer of pathogen from aquaculture facility to wild Residual therapeutants
Ecological (pests and invasives) risks	Pest outbreak causing fouling Pest outbreak competing for space Pest outbreak predating on adult or juvenile stock	Escape of adult or juvenile stock into wild Release of non-target hitch-hiker into wild Release of species as /or associated with feed stock (e.g. microalgae, pathogens)
Genetic risks	Not applicable	Genetic introgression Loss of local adaptation Loss of locally adapted populations
Environmental risks	storm activity (including flooding) Predation Competition for food	Organic loading Inorganic loading Residual heavy metals Residual therapeutants Physical interaction with marine life Physical impact on marine habitat
Financial risks	Changing production costs Reduced production Equipment failure Poor quality broodstock Market demand fluctuations Increased regulatory costs	Volatility in the aquaculture industry affecting economy Global market instability Changes in transport costs due to "carbon-miles"
Social risks	Industrial action Skill shortage Civil unrest Excessive regulation	Poor workplace conditions Use of technology that replaces labour Pollution from farm Poor quality product Loss of resource access due to farm site

pathogen that is fragile outside of its host and will perish after mere minutes of exposure to the aquatic environment. Persistence in the environment may also be increased by the presence of an encystment life history stage of a hazardous species. Some harmful algal blooms are good examples of species that can persist for decades based on a dimorphic life history phase that involves cysts.

3.3 RISK ASSESSMENT

3.3.1 Determine the likelihood of the hazard being realized

Likelihood is typically described as the probability of an event (impact, incursion, release, exposure, etc.) occurring, ranging from rare events to likely or frequent events. There is no universal set of categorical likelihood descriptors, both the number of descriptors used and their definitions (descriptions) varying between and within risk categories. An example of a set qualitative likelihood descriptors used in a risk assessment is presented in Table 4. Qualitative and/or quantitative data can be used to assess likelihood.

3.3.2 Determine the consequences of the hazard being realized

Consequence is the outcome, generally negative, of an event (hazard) occurring. For each hazard there is at least one consequence that occurs (there may be more than one consequence from an event), which may range from positive to negative. Consequence may be expressed qualitatively or quantitatively. Consequences must identify the intensity or degree of impact, the geographical extent of impact and the permanence or duration of impact.

Consequences fall into four broad categories:

- Environmental impacts – Examples include loss of biodiversity, loss of habitats, disease in target and non-target species, and alterations to trophic interactions.
- Social and political impacts – Examples include altered employment rates, altered tourism, significant change to artisanal resources, international economic sanctions and loss of international trade.
- Cultural impacts – Examples include alteration to aesthetics, connection to the aquatic environment and religious beliefs.
- Economic impacts – Examples include loss of domestic and international trade, loss of current and potential resource(s), loss of consumer confidence, loss of production (e.g. poor food quality, disease, predation, escapes) and loss of business viability.

TABLE 4
An example of a set of categorical likelihood descriptor

Descriptor	Description
Rare	Event will only occur in exceptional circumstances
Very Low	Event could occur but is not expected
Low	Event could occur
Moderate	Event will probably occur in most circumstances
High	Event is expected to occur in most circumstances

Often there are limited data relating to the consequences of an event being realized. In such circumstances, the risk analyst can either:

- *State that the risk assessment cannot be completed due to data deficiencies.* If consequences are defined as data deficient, then the risk assessment process cannot proceed and risk management must decide whether to classify data-deficient records as high risk (conservative approach) or low risk (non-conservative approach). A risk averse decision-maker would classify all data deficient decisions as high risk and might employ a precautionary approach until essential data can be obtained; *or*
- *Undertake a Delphi process to fill data gaps.* The Delphi process fills data gaps by asking experts their opinion and beliefs about a hazard. Expert opinion must be drawn from all four consequence categories to ensure that each category (environmental, social and political, cultural and economic impacts) is thoroughly considered in the light of potential data. The Delphi process creates a statistical population of beliefs that can then be evaluated using classic statistics and can acknowledge uncertainty. A simplified example of a consequence matrix for an ecological risk analysis that was established via expert opinion is provided in Table 5. Within this table, note that threshold values (represented by percent values) are used to delineate levels within the matrix. These threshold values were also determined via the Delphi process.

TABLE 5

Example consequence matrix: economy as defined by primary and secondary industry, tourism, education and intrinsic value

Descriptor	Economic impacts
Insignificant	Reduction in national income from introduced species impact shows no discernible change
	No discernable change in strength of economic activities
	If the introduced species was removed, recovery is expected in days
Minor	Reduction in national income from introduced species impact is <1%
	Reduction of strength in individual economic activities is <1%
	Economic activity is reduced to 99% of its original area (spatial context) within a defined area
	If the introduced species was removed, recovery is expected in days to months; no loss of any economic industry
Moderate	Reduction in national income from introduced species impact is 1–5%
	Reduction of strength in individual economic activities is 1–5%
	Economic activity is reduced to less than 95% of its original area (spatial context) within a defined area
	If the introduced species was removed, recovery is expected in less than a year with the loss of at least one economic activity
Major	Reduction in national income from introduced species impact is 5–10%
	Reduction of strength in individual economic activities is 5–10%
	Economic activity is reduced to less than 90% of its original area (spatial context) within a defined area
	If the introduced species was removed, recovery is expected in less than a decade with the loss of at least one economic activity
Catastrophic	Reduction in national income from introduced species impact is >10%
	Reduction of strength in individual economic activities is >10%
	Economic activity is reduced to less than 90% of its original area (spatial context) within a defined area
	If the introduced species was removed, recovery is not expected with the loss of multiple economic activities

Source: modified from Campbell, 2005.

TABLE 6
A typical risk matrix, where risk is denoted by: N = negligible, L = low, M = moderate, H = high, E = extreme

	Consequence				
Likelihood	**Insignificant**	**Minor**	**Moderate**	**Major**	**Catastrophic**
Rare	N	L	L	M	M
Very low	N	L	M	H	H
Low	N	L	H	H	E
Moderate	N	M	H	E	E
High	N	M	E	E	E

3.3.3 Calculate the risk of consequence realization

For each hazard that was identified, a measure of risk must be derived by multiplying likelihood by consequence. A risk matrix (Table 6) is used to derive this measure of risk. Again, the exact nature of the matrix may vary depending on the risk category and the individual risk analysis.

3.3.4 Identify uncertainty

As previously discussed, uncertainty can occur for a number of different reasons. Byrd and Cothern (2005) suggest nine different categories of uncertainty:

1) *Subjective judgment* – This is typical of the Delphi approach, where data are absent, partly absent or conflicting, and hence a poll of expert opinion is used to ascertain the missing information. Because it is based on opinion, the result is subject to error or uncertainty.
2) *Linguistic imprecision* – Words can have different meanings in different situations, or multiple meanings. Thus, when defining uncertainty in qualitative terms people can easily misunderstand what was meant. For example, the word "old" may have a different meaning to different people based on their perceptions (to a five-year-old child, 30 may seem very old, but to a 70-year-old pensioner, 30 may seem young). To avoid this, terms should be fully and accurately defined or quantitative measures of uncertainty should be used, where possible.
3) *Statistical variation* – Standard deviation is a common method to express statistical variation. If experimental data exist, then statistical variation can be expressed.
4) *Sampling* – Sampling bias may result in an incorrectly represented trend in results, which in turn may lead to an identified level of uncertainty. Sampling for impact needs to consider resource constraints but more importantly, the statistical robustness of the sampling programme to ensure that an accurate answer can be reached.
5) *Inherent randomness* – The world is an extremely dynamic and inherently variable place that humans have a limited capacity to measure. This limitation due to the randomness results in uncertainty.
6) *Mathematical modeling* – Model uncertainty occurs because it is difficult to fit mathematical models or equations to environmental data. Models are imperfect because of the inherent randomness in the environment and our lack of ability to accurately measure the cause of many events.

7) *Causality* – Relationships (correlations) between cause and effects are often captured via epidemiological data. Yet a correlation does not demonstrate causality. To scientifically demonstrate cause is difficult and when combined with the dynamic nature of the world, it often precludes us from knowing the exact cause of an event.
8) *Lack of data or information* – For most risk analyses, data are lacking. If data are missing, this must be stated up-front. If missing data are compensated for by extrapolating existing data or by using a Delphic approach, then this must also be stated up-front, as these become assumptions of the risk assessment that can affect the risk manager's decisions.
9) *Problem formulation* – It is important to solve the correct problem. A risk can be misunderstood and consequently, the wrong problem can be "solved".

For the risk assessment to proceed, the types of uncertainty associated with the assessment should be identified and stated up-front, thus allowing stakeholders to understand the assumptions that are made within the evaluation. By stating these assumptions up-front, risk managers can then allow for the uncertainty in their decision-making.

3.4 RISK MANAGEMENT

3.4.1 Determine the Acceptable Level of Risk

Acceptable level of risk (ALOR) is based on social and political perspectives. Risk perception can be shaped by culture (Byrd and Cothern, 2005; Slimak and Deitz, 2006), context, control (if you can control the risk is the threat lower?) and benefit (a willingness to accept risk if the benefit is sufficiently high). It will also depend on the stakeholder's needs, issues and knowledge. For example, poorly informed stakeholders might perceive a greater or lesser risk than what actually exists. Also, stakeholders may examine risk from different perspectives (e.g. pathogens, environmental issues, introduced species, etc.) and will be informed based on different statutory obligations.

In some risk categories having well-defined frameworks (i.e. pathogen risk analysis, food safety and public health risk analysis), determining the appropriate level of protection (ALOP), and consequently, the ALOR, is explicitly not a part of the risk analysis process. For these sectors, ALOR is typically a national standard that is explicitly or implicitly set by political decision, legislation and/or past practice that are outside the framework of an individual risk analysis (for example, for import risk analysis, the ALOP is typically a political decision that is made at the national level and is applicable across the plant, terrestrial animal and aquatic animal biosecurity subsectors). In other cases (such as genetic, social and financial risk analyses), a predetermined ALOR does not exist, and what constitutes "unacceptable risk" must be determined on a case by case basis by expert opinion and stakeholder consultation. In these cases, the risk assessment process needs to integrate the divergent views, subjective rationalities and preferences of experts and stakeholders to establish an effective ALOR. This can be done via a Delphic approach, which allows discussion and the opportunity to compromise and/or seek consensus. Through this process, ambiguities or conflicts can be resolved.

In either case, once the ALOR has been established and the estimated risk for the hazard being assessed has been determined, the risk analyst compares the two values to determine if the risk is "acceptable" or "unacceptable" (significant). If the risk is acceptable, then the risk assessment for the particular hazard is completed, and the risk analyst can either approve the proposed action (if there is only a single hazard being assessed) or move on to assessing the next hazard posed by the action being proposed. If the risk posed by the hazard is found to be unacceptable, then risk management options can be considered.

3.4.2 Identify, evaluate and prioritize risk management options

Where a risk assessment has determined that a hazard poses a significant risk, the risk analyst may attempt to identify possible management options (i.e. mitigation options) and assess their effectiveness in lowering the risk posed by the hazard by reducing either the likelihood or consequences of its realization. Trade-offs between different mitigation options must be assessed, hence application of cost-benefit analyses may be essential to some risk categories (e.g. financial risk analysis) to prioritize the risks.

Risk management typically follows a four-step process:

- Determine the options for mitigation;
- Re-calculate the level of risk under each option;
- Compare the new risk estimate with the ALOR to see if the risk mitigation option is likely to be effective in reducing risk to an acceptable level; and
- Evaluate other synergistic and interacting information. This typically involves cost-benefit, risk-risk, and risk-benefit analyses; assessing technical feasibility; determining social acceptability, legal conformance and regulatory objectives, and political perceptions; and assessing enforceability.

At the end of the risk management process, decisions can be made that modify risk. This is referred to as risk treatment and includes:

- *Risk avoidance* – A risk manager decides not to become involved in a risk situation or takes action to withdraw from a risk situation (Aven, 2003). An example, may be to halt importation of the Pacific white shrimp (*Litopenaeus vannamei*) into regions where it is not native if native shrimp populations may be seriously affected.
- *Risk optimization* – This is accomplished by undertaking a process that minimizes the negative and maximizes the positive consequences and their respective probabilities. For example, the importation of Pacific white shrimp may lead to economic growth and greatly improve the livelihoods of farmers directly involved in this activity (positive consequences). This aspect is played up, while the loss of natural biodiversity and the potential spread of pathogens (negative consequences) may be played-down.[3]

[3] Note, however, that in pathogen risk analysis, consideration of the potential benefits resulting from the cross border movement of an aquatic animal commodity is specifically excluded.

- *Risk transfer* – This involves the sharing of the benefit of gain or burden of impact from a risk with another party. Typically, this occurs via insurance or other agreements. For example, a government may agree to provide "insurance" against the potential for transfer of pathogens associated with the importation of Pacific white shrimp. This insurance would cover farmers of other shrimp species that would be adversely affected by a pathogen imported with Pacific white shrimp.
- *Risk retention* – This involves the acceptance of the benefit of gain and/or burden of loss from a risk. It also includes the acceptance of risks that have not been identified but does not include treatments that include risk transfer.

3.4.3 Reassess risk likelihood under controlled conditions

Once a risk management strategy or control option has been identified, it is necessary to reassess the likelihood and consequences arising from a hazard under the new management regime. It is imperative to determine whether the risk reduction achieved under the management option achieves the ALOR in a cost-efficient fashion, and whether it is an effective strategy. Efficiency includes an assessment of whether the management option requires a long-term management action and who will be responsible for the action. Effectiveness may include an assessment of the level of risk reduction that is achieved relative to costs and whether the risk will return if management is reduced or removed. These considerations must be taken into account when considering long-term decisions.

3.4.4 Document management actions

Once a risk manager has identified risk mitigation actions, it is important that these are implemented. The management action, how it was implemented and the realized outcomes need to be recorded accurately and assessed against expected outcomes. By doing so, the performance of the management action can be monitored and improved if it fails to meet expected goals. Documenting the performance of actions allows iterative improvements to be made and provides future risk managers with consistent data on attempted mitigation measures that can be used to establish principles for subsequent decision-making. If the outcomes of risk management actions are not recorded and communicated, then it is impossible to know if an action is worthy for future attempts.

3.4.5 Establish monitoring indicators and a sampling programme

Risk management actions should be monitored in both space and time to ensure that the expected outcomes are being met or if alterations to the actions need to occur. Typically, management actions are monitored using indicators and a robust sampling programme. These need to be established prior to, during and after the control actions have been established. For example, when using a biological control agent to control a weed (such as alligator weed infestations in waterways), the population of the weed and the biological control are monitored over time and along the infestation and control regions to provide a statistically robust picture of how the biological control is impacting upon the weed. If the biological control is having no effect, then another control action can be attempted. Without monitoring the action, the risk manager may be under the false impression that a control effort was successful in mitigating a risk when in actuality the control action had had no effect.

While monitoring programmes are intrinsic to evaluating management outcomes, they are typically at significant risk of delivery failure due to issues such as continued long-term funding, availability of appropriately trained personnel, continued access to monitoring sites and the political will to continue a long-term programme. Prior to establishing long-term monitoring programmes, the risk manager needs to ensure that the duration of the programme is sufficient to achieve the desired outcomes and to secure political and financial support for this period.

3.5 RISK COMMUNICATION

3.5.1 Engaging stakeholders and building consensus

Risk communication is the process of explaining risk and communicating the process and outcomes of the risk analysis. Its aim is to inform people that are "outside" of the formal risk analysis process, so that they can understand the risk assessment that is being conducted and equally important, provide information to the process. Stakeholders can provide vital information, including relevant aid in determining hazards and in outlining standard operating procedures (SOPs) that may create hazards or more importantly, provide risk management options. Risk communication also aims to aid people in accepting risk management decisions while also providing risk managers with an insight into stakeholder concerns. Risk communicators must engage both the general community and the stakeholders to understand how the public views risk (risk perception).

As an operating principle, risk communicators must engage truthfully and openly with stakeholders, accepting information and advice as it is offered. Risk communication most frequently fails when the stakeholders feel that they have been ignored or that their opinions are discounted. By maintaining an open policy of communication, many of these stakeholder concerns will be avoided.

3.5.2 Identifying stakeholders

Stakeholders are derived from a variety of sources, including sectoral interests (those directly associated with the industry being regulated) and external interests (those who have an interest in the outcomes of the risk assessment and who may be secondarily affected). It is the risk communicator who must decide which stakeholders need to be engaged in the risk analysis process and how and when they should be engaged in order to achieve the best outcome of the risk analysis process.

Stakeholders within the aquaculture sector being assessed (e.g. finfish farmers, oyster farmers, prawn farmers) will have a direct and immediate interest in any risk analysis being undertaken. They will have a significant interest in the intended outcomes, but are also likely to have information vital to conducting the risk assessment. Communicating the risk analysis approach, results and outcomes and the future consultation programme to stakeholders within the aquaculture sector (including communities, fishers, etc.) is imperative to achieve the ultimate goal of effective risk management.

Each risk analysis will have a unique set of external stakeholders, which can include, for example, other aquaculture sectors, concerned scientists, NGOs and government agencies. Similarly, public stakeholders, including adjacent landowners, recreational users, native or indigenous communities, and transboundary interests of adjacent countries will provide a broad external stakeholder base for consideration. These stakeholders may or may not have information of vital interest to the risk analysis, depending on the scope of the analysis. In some instances, such as transboundary interests, engagement is mandated under several international agreements. Regardless, it is imperative that communicating the risk analysis results, outcomes and future consultation programme to stakeholders both within and outside the aquaculture sector occur throughout the process.

3.5.3 Stakeholder contributions to the risk analysis process

Effective stakeholder consultation throughout the entire risk analysis process is essential to information gathering, consensus building, acceptance of the conclusions of the risk analysis by those who will be most affected, and successful implementation of risk management measures. For example, during hazard identification, the participation of stakeholders can lead to increased identification of potential hazards. By accessing stakeholder information, the risk analyst not only increases information flow but also improves communication with the stakeholder community. Once relevant hazards are identified, appropriate stakeholders must be engaged to validate and provide a reference for each specific hazard (or hazard grouping). Stakeholder composition may vary between hazards. For example, stakeholders that are interested in introduced marine species may not be interested in or knowledgeable about animal pathogens. Stakeholders that may be of importance at this stage include farmers, scientists, the interested public and product marketers.

Different stakeholders may be approached during the risk assessment process. This is particularly important when consequences across environmental, social and political, cultural and economic impacts are assessed. Stakeholders must have relevant background knowledge and experience to ensure that accurate data are collected; thus each of the consequence groups should be represented by stakeholders during the risk assessment process. Examples of relevant stakeholders include communities, fishers, agriculture farmers, government officials, economists, natural scientists, social scientists and cultural groups (e.g. indigenous groups).

During risk management, stakeholder communication is directed towards two groups: those who will be affected by the management actions (the public) and those who are legislating and regulating to help mitigate the risk (government officials). Regardless of the decision, some stakeholders are likely to be adversely affected by the outcomes of the risk analysis. As a consequence, the need to provide opportunities for public consultation on risk management outcomes is emphasized. For some sectors, stakeholders may also participate in setting the ALOR to be applied during the risk analysis process.

3.5.4 Dissemination of results and outcomes

The dissemination of the risk assessment results and risk management considerations and outcomes is essential to gain stakeholder understanding and support. Frequently a report is prepared to provide a formal outcome of the risk analysis process. A model template for a risk analysis report is presented in Box 2.

BOX 2

Model template for the contents of a risk analysis report

- Describe the preliminary risk analysis objectives and plans.
- Describe the scale and scope of the risk analysis (e.g. environmental setting of the planned aquaculture development).
- Describe the operational context of the project/system to be assessed.
- Review the risk analysis process and agreed endpoints with a statement of ALOP.
- Discuss the primary data sources or experts and methods used for data collection and analysis.
- Describe the identified hazards with risk profiles (likelihood and consequence assessments) for each hazard; include a summary of uncertainty in each risk profile.
- Identify risk management options for each risk profile and provide advice on the extent to which the risk is reduced by the management option.