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AQUATIC BIOSECURITY: A KEY FOR SUSTAINABLE AQUACULTURE DEVELOPMENT

SUMMARY

Biosecurity, as defined by FAO, is a strategic and integrated approach that encompasses both policy and regulatory frameworks aimed at analysing and managing risks relevant to human, animal and plant life and health, including associated environmental risks. It covers food safety, zoonoses, introduction of animal and plant diseases and pests, introduction and release of living modified organisms (LMOs) and their products (e.g. genetically modified organisms or GMOs), and the introduction of invasive alien species.

This paper presents an introductory discussion on major biosecurity concerns affecting modern aquaculture (e.g. transboundary aquatic animal diseases, food safety, public health risks on the use of veterinary medicinal products, bioinvasions, aquaculture issues pertaining to aquatic GMOs and some aspects of climate change). A brief background on the above risk sectors is provided and includes some specific examples. Since the biosecurity risks from some of these sectors are recognized and in many cases risk pathways are proven and clearly understood, a serious concern exists as to how these risks may be reduced or mitigated.

The use of risk analysis, adaptive management and the application of 'cautious interim measures' and the precautionary approach are proposed (or considered) as valuable decision-making tools which help identify, assess, manage, mitigate and communicate risks. However, they should be supported by improved planning and governance, improved institutional coordination, improved use of limited natural resources and measures to deal with the social and biological impacts of climate change.

A number of key biosecurity actions for reducing the risks from aquatic animal diseases, food safety risks from aquaculture, use of veterinary medicinal products, biological invasions, aquatic GMOs and potential climate change implications are presented here and the COFI Sub-Committee on Aquaculture is invited to provide guidance to meet these biosecurity challenges and advise upon appropriate biosecurity measures to protect the aquaculture sector.

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INTRODUCTION

1. The Food and Agriculture Organization of the United Nations (FAO) defines biosecurity as a strategic and integrated approach that encompasses both policy and regulatory frameworks aimed at analysing and managing risks relevant to human, animal and plant life and health, including associated environmental risks[1]. It covers food safety, zoonoses, introduction of animal and plant diseases and pests, introduction and release of living modified organisms (LMOs) and their products (e.g. genetically modified organisms or GMOs), and the introduction of invasive alien species.

2. Biosecurity is a holistic concept of direct relevance to the sustainability of agriculture, public health and protection of the environment including biological diversity. It is an essential element of sustainable agricultural development and food production. The overarching goal of biosecurity is to prevent, control and/or manage risks to life and health appropriate to the particular biosecurity sector.

3. The growing interest in biosecurity is driven by many factors. These include globalization (increase in volume and diversity) of trade in food, plant and animal products, changing food production practices and climate with new technologies, changing human and behavioural ecology, heightened awareness on biological diversity, greater demand for public health and environmental protection and other emerging issues such as soaring food prices, climate change and animal welfare. The current increased attention also recognizes the benefits of improving biosecurity through safeguarding plant and animal life and health, enhancing food safety, promoting environmental sustainability, protecting biodiversity and a long-term strategic response to soaring food prices.

4. In aquaculture, biosecurity is a collective term that refers to the concept of applying appropriate measures (e.g. proactive risk analysis) to reduce the probability of a biological organism or agent spreading to an individual, population or ecosystem, and to mitigate the adverse impact that may result from such[2]. It is concerned with issues related to managing aquatic animal health, conserving aquatic biodiversity and reducing public health risks associated with production and consumption of aquaculture products. This analysis incorporates the best information available on aspects of husbandry, epidemiology and good science.

5. In aquaculture, the drivers of risk analysis include resource protection, food security, trade, consumer preference for safe and good quality products, production profitability as well as other investment and development objectives. As an outcome, global agreements governing trade in agricultural and food products are increasing the responsibility of the competent authorities to improve their compliance standards associated with these agreements.

6. The main regulatory instrument governing biosecurity, the World Trade Organization's Agreement on Sanitary and Phytosanitary Measures (WTO's SPS Agreement), emphasizes the need to apply risk analysis as basis for taking any SPS measures. The three main international standard setting bodies are:

- the Codex Alimentarius Commission (CAC of FAO/WHO) concerned with food safety and quality;

[1] FAO. 2007. FAO Biosecurity Toolkit. Food and Agriculture Organization of the United Nations. Rome, FAO. 2007. 128p.

[2] Subasinghe, R.P. and Bondad-Reantaso, M.G**.** 2006. Biosecurity in Aquaculture: International Agreements and Instruments, their Compliance, Prospects and Challenges for Developing Countries, pp. 9–16. *In* A. David Scarfe, Cheng-Sheng Lee and Patricia O'Bryen (eds). Aquaculture Biosecurity: Prevention, Control and Eradication of Aquatic Animal Disease. Blackwell Publishing. 182p.

- the World Organisation for Animal Health, formerly known as the Office international des épizooties, (OIE) concerned with animal (including aquatic animal) life and health; and
- the International Plant Protection Convention (IPPC) concerned with plant life and health.

7. With regard to international trade in aquatic animals, different obligatory international treaties/agreements and other voluntary guidelines are involved. Examples of binding international agreements are that of the aforementioned WTO's SPS Agreement[3], the Convention on Biological Diversity[4], the Convention on International Trade of Endangered Species and European Union related legislation and directives. Examples of voluntary agreements/guidelines include that of the International Council for the Exploration of the Sea[5], the codes of practice of the EUROPEAN INLAND FISHERIES ADVISORY COMMISSION[6] and a number of FAO guidelines. In many instances, voluntary international guidelines are incorporated into national legislations and thus become mandatory at the national level.

8. Among the voluntary guidelines, FAO, for example, published a number of technical guidelines[7] to guide FAO member countries in the responsible conduct of aquaculture, health management for responsible movement of live aquatic animals and genetic resource management. These technical guidelines are within the premise of the FAO Code of Conduct for Responsible Fisheries (CCRF).

9. Under the FAO guidelines on health management for responsible movement of live aquatic animals, the essential elements are: policy, legislation and enforcement; risk analysis; pathogen list; information system; health certification and quarantine; surveillance and reporting; zoning; emergency preparedness; institutional structure; human resource development and regional and international cooperation.

10. A number of countries are now in the process of implementing and/or developing national aquatic animal health strategies or their equivalent and there are also ongoing initiatives to develop regional programmes to enhance aquatic animal health management and aquatic biosecurity capacity[8].

11. The FAO guidelines on genetic resource management provide guidance on aspects pertaining to broodstock management, genetic improvement methodologies, dissemination of

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[3] WTO. 1994. Agreement on the Application of Sanitary and Phytosanitary Measures. p. 69–84. *In* The results of the Uruguay Round of multilateral trade negotiations: the legal texts, General Agreement on Tariff and Trade (GATT), World Trade Organization, Geneva.

[4] CBD.1992. Convention on Biological Diversity. (available at www.cbd.int/)

[5] ICES. 2005. ICES Code of practice for the introductions and transfers of marine organisms2005. Copenhagen, International Council for the Exploration of the Sea. 30p.

[6] Turner, G. (ed.). 1988. Codes of Practice and Manual of Procedures for Consideration of Introductions and Transfers of Marine and Freshwater Organisms. EIFAC Occasional Paper No. 23. European Inland Fisheries Advisory Commission. Food and Agriculture Organization of the United Nations, Rome, Italy.

[7] FAO. 2008. Aquaculture development. 5. Genetic resource management. FAO Technical Guidelines for Responsible Fisheries. No. 5, Suppl. 3. Rome, FAO. 125p.; FAO. 2007. Aquaculture development. 2. Health management for responsible movement of live aquatic animals. FAO Technical Guidelines for Responsible Fisheries. No. 5, Suppl. 2. Rome FAO. 31p.; FAO/NACA. 2000. The Asia regional technical guidelines on health management for responsible movement of live aquatic animals and the Beijing consensus and implementation strategy. FAO Fisheries Technical Paper No. 402, 53p.; FAO. 1995. Code of conduct for responsible fisheries. Food and Agriculture Organization of the United Nations, 41p.

[8] FAO./Regional Commission for Fisheries. Report of the Regional Technical Workshop on Aquatic Animal Health. Jeddah, Kingdom of Saudi Arabia, 6–10 April 2008. FAO Fisheries and Aquaculture Report. No. 876. Rome. FAO. 119p; FAO. 2009. Report of the FAO Workshop on the Development of an Aquatic Biosecurity Framework for Southern Africa. Lilongwe, Malawi, 22–24 April 2008. FAO Fisheries and Aquaculture Report. No. 906. Rome. FAO. 55p.; Bondad-Reantaso, M.G., Arthur, J.R. and Subasinghe, R.P. (eds). 2009. Strengthening aquaculture health management in Bosnia and Herzegovina. FAO Fisheries and Aquaculture Technical Paper. No. 524. Rome, FAO. 83p.

genetically improved strains and material transfer agreements, risk assessment and monitoring in genetic improvement programmes, and conservation of wild fish genetic resources and aquaculture, etc.

12. This paper presents an introductory discussion on major biosecurity concerns affecting modern aquaculture (e.g. transboundary aquatic animal diseases, food safety issues, public health risks on the use of veterinary medicinal products, bioinvasions, aquaculture issues pertaining to aquatic genetically modified organisms and some aspects of climate change) and suggested actions required to improve biosecurity that will support sustainable aquaculture.

MAJOR BIOSECURITY RISKS IN AQUACULTURE

Transboundary aquatic animal diseases (TAADs)

13. Transboundary aquatic animal diseases (TAADs) are aquatic animal diseases or pathogens that are highly contagious, have the potential for very rapid spread irrespective of national borders and can cause serious socio-economic consequences. Domestic and international trade are important pathways for the introduction of TAADs; increase in trade, if done in a haphazard manner, increases the potential of facilitating new mechanisms by which pathogens and diseases may be introduced and spread to new areas together with host movement.

14. Risks related to the international movement of live aquatic animals and their products may range, for example, from the emergence of new pathogens, limitations in control options for aquatic animal diseases, occurrence of multi-factorial disease syndromes, frequent sub-clinical infections in aquatic animals, undomesticated status of aquatic animals due to lack or little information available on biological requirements and health status, accidental release of pathogens during or after international transport of packaged materials and others. Three specific examples, provided below, demonstrate different goals for aquatic animal movements involving different pathways – and thus, presenting different levels of risks of pathogen transfers[9].

15. Example 1. Epizootic ulcerative syndrome (EUS): International spread and its emergence in southern Africa 10 years after the last major outbreak in Asia. EUS, an OIE-listed disease[10], is caused by a fungus and has been reported only in Asia and North America prior to 2006. The disease has now been confirmed for the first time in the southern African region in 2007[11]. EUS affects many kinds of finfish, those living both in the rivers and in the estuaries; it causes high losses through fish mortalities, market rejection, public health concerns and reduced aquatic productivity. It affects more than 50 species of finfish and has now reached three continents (Asia, North America and Africa) with a potential negative threat to environment and biodiversity. When EUS occurs in natural water bodies, there is very little possibility for eradication. Movement of infected fish between areas is already a proven pathway for the spread of EUS. Movement of ships and boats, fish migrations and ocean currents are potential pathways for the spread of the fungus. Some EUS outbreaks occur where there are heavy rainfalls and floods; drop in temperature, low alkalinity and salinity, and acidified run-off water from acid sulphate soils.

16. Example 2. Global spread of white spot syndrome virus (WSSV) of shrimp. WSSV, an OIE-listed pathogen[12], causes significant disease, reaching up to 100 percent mortality. One of the most highly translocated and introduced pathogens (through global movement of the infected host) affecting global aquaculture, WSSV has wide geographic (almost all major shrimp producing regions of the world) and host range, with an extensive range of carriers and vectors

[9] Bondad-Reantaso, M.G., Lem, A. and Subasinghe, R.P. 2009. International trade in aquatic animals and aquatic animal health. What lessons have we learned so far in managing the risks? Fish Pathology 44(3): 107–114.
[10] HTTP://WWW.OIE.INT/ENG/NORMES/FCODE/EN_CHAPITRE_1.10.2.HTM
[11] FAO. 2009. Report of the International Emergency Disease Investigation Task Force on a Serious Finfish Disease in Southern Africa, 18–26 May 2007. Rome, FAO. 2009. 70p.
[12] HTTP://WWW.OIE.INT/ENG/NORMES/FCODE/EN_CHAPITRE_1.9.5.HTM

(including both marine and freshwater shrimp species and other decapods, such as crabs and marine and freshwater crayfish; wild broodstock and fry, as well as numerous other crustaceans and even aquatic insect larvae). WSSV can enter the shrimp and pond through different routes (e.g. infected shrimp seed, water, carrier animals and transfer of infected animals and farm equipment from one farm to another). There is no possibility for treatment. Transmission studies have also demonstrated that non-penaeid carriers of WSSV transmit the virus to shrimp. WSSV can also be transmitted via frozen shrimp products. Some of the factors that can trigger outbreaks of white spot disease (WSD) in shrimp with subclinical infections include rapid changes in water temperature, hardness and salinity or reduced oxygen levels for extended periods.

17. Example 3. Koi herpes virus (KHV) in Indonesia: national spread of the virus from ornamental fish to cultured and wild stocks. KHV, another OIE-listed pathogen[13], is a good example of a disease which originated from an imported ornamental fish and which quickly spread to cultured and eventually wild fish stocks. Trade in ornamental fish and other ornamental aquatic species is a major pathway for the introduction of fish disease. There is therefore a great concern about the largely loosely regulated movement of ornamental fish species and aquatic organisms spreading diseases or become pests that negatively impact aquatic systems.

Biosecurity and food safety in aquaculture

18. From the food safety perspective, biosecurity is important for the control of zoonotic pathogens[14]. Fishborne trematodes affect over 30 million people in Asia with a conservative estimate of 10 million people infected with liver fluke, *Opisthorchis viverrini* in Thailand and Laos alone[15]. The parasite enters the aquaculture environment through fecal contamination of waters and even in areas where human infections are very rare. The parasite's life cycle can be maintained in fish eating animals such as cats, dogs and pigs. This is borne out by an outbreak that occurred in Italy in 2007 and subsequent studies showed that 80 percent of fish in Lake Bolsena were infected with *Opistorchis felinius*[16]. In some parts of China, infection in domestic animals like cats and dogs with *Clonorchis sinensis* could be 60–100 percent[17]. Thus a strategy like mass treatment of infected individuals alone is inadequate to control this public health risk and use of biosecurity principles to minimise entry of the parasite into aquaculture systems would be imperative.

19. Though fish and fishery products account for less than 5 percent of foodborne salmonellosis[18], *Salmonella* contamination of products of aquaculture is still a major problem as indicated by a large number of import refusals in some major markets due to this pathogen. While human sewage is an important source of *Salmonella*, the source can be minimized by following WHO Guidelines for safe use of wastewater and grey water in aquaculture[19]. However, domestic and wild animals, for e.g. birds, frogs, rodents and reptiles, may bring in *Salmonella* into aquaculture systems[20] and biosecurity is important for minimizing this.

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[13] HTTP://WWW.OIE.INT/ENG/NORMES/FCODE/EN_CHAPITRE_1.10.6.HTM

[14] A zoonosis is any infectious disease that can be transmitted from non-human animals, both wild and domestic to humans.

[15] Andrews, R.H., Sithithaworn, P. and Petney, T.N. 2008. *Opisthorchis viverrini*, an underestimated parasite in world health. Trends in Parasitology, 24:497–501.

[16] Armignacco, O., Caterini, L., Marucci, G., Ferri, F., Bernardini, G., Raponi, G.N., Ludovici, A., Bossu, T., Morales, M.A.G. and Pozio, E. 2008. Human illness caused by Opisthorchis felinius flukes, Italy. Emergine Infectious Diseases 14:1902–1905.

[17] Lun, Z., Gasser, R.B., Lai, D., Li, A., Zhu, X., Yu, X. and Fang, Y. 2005 Clonorchiasis, a key foodborne zoonosis in China. Lancet Infectious Diseases 5:31–41.

[18] Greig, J.D. and Ravel, A. 2009. Analysis of foodborne outbreak data reported internationally for source attribution. International Journal of Food Microbiology 130:77–87.

[19] WHO. 2006. WHO Guidelines for Safe use of waste water, excreta and greywater Vol III Waste water and Excreta use in aquaculture. 162p.

[20] FAO. 2010. Report of Expert Workshop on Application of biosecurity measures to control *Salmonella* contamination in sustainable aquaculture. (draft report).

Public health risks on the use of veterinary medicinal products

20. Veterinary medicinal products are substances or combination of substances presented for treating or preventing disease in animals or which may be administered to animals with a view to making medical diagnosis or restoring, correcting or modifying physiological functions in animals[21]. They include antimicrobial agents[22], chemotherapeutants[23], disinfectants[24] and vaccines[25].

21. Veterinary medicinal products are used in aquaculture during production and processing, to prevent and treat pathogens and diseases and to achieve production efficiency. For example, gains in aquaculture production capacity would not have been possible without the use of antimicrobial agents. They have progressively been taken up by the industry with improved learning and better understanding of health management and biosecurity application to aquaculture. The significant benefits on their use in a wide range of applications (e.g. treatment of ongoing/emerging/re-emerging diseases, new species culture development, alternative to other failed preventative strategy, development of culture technology and animal welfare) are recognized.

22. However, there is also increasing recognition of its limitations. Use of these substances/agents lead to problems related to bacterial resistance, antimicrobial agent residues in products, potential transfer of resistance genes and possibility of these reaching human pathogens. In some cases, chemotherapy may complicate health management by triggering toxicity, and occasionally public health and environmental consequences. In addition, their efficacy under certain aquatic environments is questionable, both with regard to treatment goals and the potential cost of untargeted effects.

23. Equally important ongoing concerns include the perceived widespread use of antimicrobial agents in aquaculture, irresponsible use (e.g. use of banned products and misuse based on incorrect diagnosis), the lack of approved antimicrobial agents for certain aquaculture species and diseases and significant variations in regulatory frameworks and enforcement in different countries. These could have implications for the environment, human food safety, and the development of antimicrobial resistance; and further, these can have further impact on free trade. Concurrently, the concern is likely to be higher when regulatory processes for aquatic veterinary medicinal products are not well developed.

24. While the government has a key role in promoting the sustainability of aquaculture production and ensuring public health, the prudent use of veterinary medicinal products does not rest with the government alone, but is a responsibility for all. It is an important part of on-farm biosecurity; they reduce pathogen challenges, ensure that the natural defence mechanisms of the cultured stocks are maximized, that disease and mortality are minimized, and that the costs of containing, treating and/or eradicating diseases are reduced. The injudicious and/or incorrect use of veterinary medicinal products is an important biosecurity concern to successful and sustainable aquaculture.

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[21] EU Directive 2001/82/EC.

[22] ANTIMICROBIAL AGENT – any substance of natural, semi-synthetic, or synthetic origin that at *in vivo* concentrations kills or inhibits the growth of microorganisms by interacting with a specific target.

[23] Chemotherapeutants – chemicals used to treat infections or non-infectious disorders (modified from FAO, 2001).

[24] Disinfectants – Chemical compounds capable of destroying pathogenic microogranisms or inhibiting their growth or survival ability (modified from OIE, 2009a).

[25] Vaccines – Antigen preparation from whole or extracted parts of an infectious organism, which is used to enhance the specific immune response of a susceptible host (from FAO, 2001).

Biological invasions

25. One of the top five drivers of global biodiversity loss and the threat[26] which is increasing due to tourism and globalization, biological invasions or bioinvasions is a broad term that refers to both human-assisted introductions and natural range expansions[27].

26. Invasive aquatic species are organisms that have the ability to colonise/invade diverse habitats by multiple pathways. Some of the characteristics of invasive species include: high productivity; high tolerance/capacity to adapt to various environmental conditions; lack of efficient biological control agents in new habitats; wide host range and voracious appetite; and long survival rate.

27. Risks from aquaculture include the use of non-native species as target stocks; potential for introduction of hitchhiker (associate) species when importing new stocks; use of non-native, fresh or frozen feed stocks and movement of aquaculture equipments. In contrast, the risks to aquaculture from both freshwater and marine bioinvasions from other sources (including other aquaculture operators) include pathogens, parasites, biofouling and harmful algal blooms.

28. Global spread of many marine organisms by shipping has been one of the major biosecurity concerns during the last decade. The accidental widespread occurred, internationally, from the hulls of vessels of all sizes and large ships. Ballast water may transport all groups of marine organisms, whereas hull fouling is by encrusting organisms, such as macro-algae, bivalve molluscs, barnacles, bryozoans, sponges and tunicates. The apparent transport of toxic algae in ballast water has had a profound effect on aquaculture activities because of the necessity of farm closures during blooms. Encrusting organisms may also introduce novel pathogens; however, their biggest impact is fouling of ports, coasts and aquaculture facilities. The continual need to clear away such organisms can affect the economic survival of marine farms.

29. Invasive alien species are a multi-faceted problem in the importation and culture of aquatic species for commercial, recreational and hobby pursuits. Just as many intended introductions have had economically beneficial outcomes[28], a number of species introductions have contributed to ecosystem disruption from escapes and establishment of exotic species in the wild. In addition, environmental disturbances can also weaken aquatic ecosystems making them vulnerable to invasions[29]. Analysis of information from FishBase[30] identified 18 species with various levels of reported adverse ecological impacts, with more than half of these species being used in commercial aquaculture.

30. Managing and responding to global threats posed by invasive species is central to many aspects of biodiversity protection.

[26] Carlton, J.T. 2001. Introduced Species in U.S. Coastal Waters: Pew Oceans Commissions Report. Pew Oceans Commissions. Washington, D.C.; Vitousek, P.M., Mooney, H.A., Lubchenko, J. and Melillo, J.M. 1997. Human domination of Earth's ecosystems. Science 277:494-499.

[27] see Carlton, J.T. 2001 above. Note: Within the scope of this definition, the following are also terms are also used: alien species, aquatic nuisance species, exotic species, non-native species, foreign species, non-indigenous species, invasive species.

[28] see for example De Silva, S.S., Subasinghe, R.P., Bartley, D.M., and Lowther, A. 2004. Tilapias as alien aquatics in Asia and the Pacific: a review. FAO Fisheries Technical Paper. No. 453. Rome, FAO 65p.

[29] Lee, D.J. and Gordon, R.M. 2006. Economics of aquaculture and invasive aquatic species – an overview. Aquaculture Economics and Management 10:83–96.

[30] Casal, C. 2006. Global documentation of fish introductions: the growing risks and recommendations for actions. Biological Invasions 8:3–11.

Aquaculture issues pertaining to aquatic GMOs

31. Advances in molecular genetics and biotechnology[31] are significant scientific achievements during the last three decades. As long as necessary measures are taken to safeguard human health and the environment, they can offer potential for significant improvements in human well-being. Under Article 19.3, contracting parties of CBD agreed to consider the need for developing appropriate procedures to address the safe transfer, handling and use of any living modified organisms (LMOs)[32] resulting from application of biotechnology that may have adverse effects on the conservation and sustainable use of biodiversity. The Cartagena Protocol on Biosafety, a supplementary agreement to the CBD adopted in 2003, governs the movements of LMOs from one country to another.

32. Some of the potential benefits of genetic improvement through gene transfers include targeting aquaculture production traits such as, for example, growth rate, freeze resistance, disease resistance, reproductive sterility and others. Development of some growth hormone (GH)-transgenic lines is well advanced and efforts to commercialize them are ongoing. With the prospect of improved production efficiency, it can be expected that some aquaculturists would desire to produce GH-transgenic fish commercially[33].

33. Significant escape of fish through equipment failures, handling or transport operations, predator intrusion, and storm damage are some of the pathways which cause significant escape of fish in commercial aquaculture operations. Even as farm operators attempt to prevent escapes through various types of confinement systems, installation of predator deterrent devices and other mechanisms, escapes can still occur. Therefore important concerns include ecological or genetic interaction of escaped fish with local intraspecific and interspecific populations; competition for space and food resources and direct predation; potential breakdown of locally adapted traits through interbreeding and introgression, and may range up to replacement of native stocks by cultured stocks. Such concerns are posed by the prospect of producing transgenic fish in aquaculture, with additional unknowns posed by possible effects of the transgene.

34. While some risk management measures can be put in place to minimize the likelihood of harm for escaped transgenic fish (e.g. producing transgenic fish only under conditions of strict confinement), it will be essential to update the risk analysis process using an adaptive management approach[34]. This is because all potential harms and associated pathways cannot always be known and precisely predicted *a priori.*

35. During the fourth session of COFI/SCA (Chile, 2008), the working document on Governance in Aquaculture considered GMOs as a controversial issue with disagreements between proponents and opponents on benefits and risks and well as governance issues. It is

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[31] Biotechnology means “any technological application that uses biological systems, living organisms, or derivatives thereof, to make or modify products or processes for specific use" (Convention on Biological Diversity). 2. “Interpreted in a narrow sense, ... a range of different molecular technologies such as gene manipulation and gene transfer, DNA typing and cloning of plants and animals" (FAO's statement on biotechnology).

[32] A living modified organism (LMO) is defined in the Cartagena Protocol on Biosafety as any living organism that possesses a novel combination of genetic material obtained though the use of modern biotechnology (UNEP, 2009). LMOs are generally considered to be the same as genetically modified organisms (GMOs). While different classes of organisms have been included in the term GMO – including organisms modified by gene transfer, chromosome set manipulation, and interspecific hybridization. A transgenic fish or shellfish bears within its chromosomal DNA a gene construct – i.e., a transgene, a gene whose expression is under novel regulation – that was introduced by human intervention.

[33] Hallerman, E. 2009 Improving biosecurity: aquaculture issues pertaining to GMOs: a contribution to development of the larger Theme III.3 Paper concerning biosecurity (unpublished).

[34] Adaptive management (AM), also known as adaptive resource management (ARM), is a structured, iterative process of optimal decision making in the face of uncertainty aimed to reduce such uncertainties over time via system monitoring. In this way, decision making simultaneously maximizes one or more resource objectives and, either passively or actively, accrues information needed to improve future management. AM is often characterized as "learning by doing."

important to understand carefully the benefits, risks and risk management issues before uptake into commercial production can proceed.

CLIMATE CHANGE SCENARIOS THAT WILL AFFECT BIOSECURITY

36. Riparian and coastal systems in which many aquaculture operations occur will be vulnerable to climate change scenarios such as sea level rise, increased incidence of storm surges and land-based run-offs, as well as extreme weather events resulting in flooding and drought and perturbations such as rise in sea temperature. In the tropics, becoming hotter and water levels rising may mean movement of species from tropical into sub-tropical regions; increased evaporation will increase coastal salinities and inundation of coastal regions, thus posing particular difficulty to coastal shrimp farms. Such species movement has the potential to cause range extension of diseases, especially of relatively non-host specific pathogens.

37. While climate change remains highly unpredictable, the incidence of storm events resulting in loss of stocks and infrastructure is likely to increase, resulting in higher financial, genetic and social risks. Increased temperatures may lead to greater likelihood of pathogen, food safety and public health and ecological risks. Better analysis of risk and climate change in the aquaculture sector would provide a basis for advising governments and industry appropriate management strategies[35].

IMPROVING AQUATIC BIOSECURITY USING RISK ANALYSIS AS A DECISION-MAKING TOOL

38. Biosecurity safeguards animal health, enhances food safety, promotes environmental sustainability and protects biodiversity. It can also stimulate increased market supply and private investments, as it enables farmers to produce healthy products that are highly competitive in the market and also demonstrates that an exporting country is a responsible trading partner. Effective biosecurity plays an important role in every stage of the life cycle of an aquatic animal from hatching to harvesting and processing, and is thus essential to ensuring sustainable and healthy aquatic production.

39. Biosecurity is among the seven major areas under the medium-to-long-term assistance under the strategic framework for response of the Asian Development Bank to the crisis on soaring food prices. The current global crisis on food prices has now given pressure to both governments and the international community to ensure an adequate supply of food for a growing population. Biosecurity can enable developing countries to grow more food efficiently, increase their incomes and thus improve their resilience, reducing their vulnerability and enabling them to effectively respond to the impacts of higher food prices and other food production risks.

40. At the heart of modern approaches to biosecurity is the application of risk analysis. Risk analysis offers an effective management tool where pragmatic decisions can be made that provide a balance between competing environmental and socio-economic interests, despite limited availability of information. The use of risk analysis for decision-making can enhance the ability of decision-makers in the aquaculture sector to identify risks and mitigation or management strategies to meet such challenges, particularly at the level of national policy development.

41. An important process in the risk analysis process is pathway analysis. It follows a logical process by identifying possible routes (pathways) and the individual steps and critical events leading to an introduction. It estimates the probability of each step/event and gauges the

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[35] Arthur, J.R., Bondad-Reantaso, M.G., Campbell, M.L., Hewitt, C.L., Phillips, M.J. and Subasinghe, R.P. 2009. Understanding and applying risk analysis in aquaculture: a manual for decision-makers. FAO Fisheries and Aquaculture Technical Paper. No. 519/1. Rome. FAO. 113p.

effectiveness of risk mitigation. Information and databases are needed to understand and analyse the risks and pathways which may be transportation-related, trade-related, human-assisted related or through natural spread pathways. Effective risk communication is an essential element during the process.

42. Precautionary approach (PA), widely used in fisheries management and elsewhere when governments must take action based on incomplete information has an important application to biosecurity. Application of PA in aquaculture risk analysis would be that both importing and exporting countries act responsibly and conservatively to avoid the adverse impacts of an introduction. It can be applied throughout the risk analysis process when "cautious interim measures" are considered necessary, for example, to ban or restrict trade until a sound risk analysis can be completed; during the pathways analysis when key information gaps will be revealed and must be addressed by, e.g., targeted research; and during risk management, when risk mitigation measures are identified to reduce the risk to an acceptable level.

43. Risk analysis is an important decision-making tool. It is a concept and a process. It is important to understand and embrace the concept first and not be discouraged or intimidated by the anticipated complexity of the process. It is also only one of a large number of components of a biosecurity strategy. It cannot function effectively unless the other components have been developed and the means to implement them are in place. In applying risk analysis, there are a number of important considerations which need to be put in place. These include improving planning and governance, improving institutional coordination, addressing issues associated with globalization and trade, improving the use of limited natural resources and dealing with the social and biological impacts of climate change[36.]

CONCLUSIONS

44. The importance of aquaculture is undoubtedly recognized. Aquaculture offers a solution to many of the food security issues facing the growing human population. It bridges the gap between stagnating yields from many capture fisheries and an increasing demand for fish and fishery products. It also offers opportunities to alleviate property, increase employment and community development and reduce overexploitation of natural aquatic resources, thus creating social and generational equity, particularly in developing countries. However, the sector is also in direct conflict with other users of the aquatic habitat and the adjacent coastal and riparian areas, including economic, environmental and social interests. Therefore, an effective and integrated way to manage the various business, environmental and social risks will be a necessity for the sustainable growth of the sector. These include both risks to the environment and society from aquaculture and to aquaculture from the environmental, social, and economic settings in which it operates[37.]

45. The rapid expansion of the aquaculture sector under various national and regional jurisdictions has resulted in a diversity of regulatory frameworks. A number of international agreements, organizations and programmes are part of a loose international framework for biosecurity which reflects the historically sectoral approach to regulation in this area. Prevention and appropriate pre-border and border controls are still the key to managing risks from diseases, invasive species and pests. Eradicating and/or managing diseases and pests is not only extremely

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[36] Arthur, J.R., Bondad-Reantaso, M.G., Campbell, M.L., Hewitt, C.L., Phillips, M.J. and Subasinghe, R.P. 2009. Understanding and applying risk analysis in aquaculture: a manual for decision-makers. FAO Fisheries and Aquaculture Technical Paper. No. 519/1. Rome. FAO. 113p.

[37] Arthur, J.R., Bondad-Reantaso, M.G., Hewitt, C., Campbell, M.L, Hewitt, C.L., Phillips, M.J. and Subasinghe, R.P. 2009. Understanding and applying risk analysis in aquaculture: a manual for decision-makers. FAO Fisheries and Aquaculture Technical Paper. No. 519/1. Rome FAO. 113p.

difficult, costly and in other situations, not possible once they become established in the environment. Further development of aquaculture therefore brings new challenges to biosecurity.

46. Suggested key actions for reducing the risks from aquatic animal diseases, public health concerns from use of veterinary medicinal products, biological invasions, aquaculture issues with aquatic GMOs, through effective biosecurity, include the following:

- identify competent authority/ies and oversight bodies and interagency coordinating responsibilities;
- make biosecurity as an explicit element of national aquaculture development plans/programmes;
- establish effective regulatory processes and appropriate infrastructure to enforce them;
- enhance compliance to regional and international treaties and instruments through effective implementation of national strategies and national policy and regulatory frameworks;
- build capacity in risk analysis and adaptive management at all levels, from farm production level to oversight bodies, both public and private sectors;
- encourage the application of risk analysis as an essential decision-making tool to support timely assessment of threats and uncertainties from new or expanding species and technologies;
- implement surveillance and reporting programmes and provide effective diagnostic services to detect and identify the emergence and spread of diseases and pests;
- build emergency preparedness capacity through rapid and timely response to reduce potential catastrophic consequences of disease/pest incursion;
- empower and educate farmers with information and tools such as situation-specific better management practices, cluster organization and management, simple and practical farm level biosecurity plan;
- revitalize effective extension and diagnostic services at primary production levels, ensuring operational capability of oversight bodies to effectively respond to biosecurity emergencies;
- prudent and responsible use of antimicrobial therapy, effective enforcement of current regulations and improved access to disease diagnostic services and extension support to farmers;
- generate research and information and databases (local and global) that will support biosecurity assessments and early warning;
- enhance aquatic animal welfare as a prerequisite to aquatic animal health; and
- build working partnerships between sectors (including industry cooperation) and enhance regional and international cooperation.

ACTIONS REQUIRED FROM THE SUB-COMMITTEE

47. The Sub-Committee is invited to:

- revise, as appropriate, the information put forward in this paper and share national experiences in improving aquatic biosecurity;
- discuss the key actions to be taken by the public and private sectors, the FAO Department of Fisheries and Aquaculture Department and relevant stakeholders and recommend urgent decisions for improving biosecurity to support sustainable aquaculture; and

- provide guidance to meet biosecurity challenges of the future and deliver the level of biosecurity measures appropriate to protect the aquaculture sector.