



Submission from the International Center for Tropical Agriculture (CIAT) on behalf of the CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS), to UNFCCC SBSTA 42 on issues related to agriculture in response to SBSTA decision FCC/SBSTA/2014/L.14.

These are views on the assessment of risk and vulnerability of agricultural systems to different climate change scenarios at regional, national and local levels, including but not limited to pests and diseases FCC/SBSTA/2014/L.14 paragraph 3 (b).

Climate Change and Aquatic Animal Disease

Summary for Policy makers

More than 4.5 billion people get at least 15% of their average per capita intake of animal protein from fish. Fish is therefore a key element in food security and human nutrition. Analysis of future fish supply-demand scenarios suggests that farming of fish and other aquatic products will need to double production by 2030 to meet growing demand. About half of the demand for these foods is now met by aquaculture and Asia accounts for the bulk (90%) of the global aquaculture production of 66 million tones. However, aquaculture operations in the tropics experience higher cumulative mortalities and faster progression of diseases and this could be exacerbated by climate change leading to selection of virulent pathogens that have the potential to spread. This can result in introduction and spread of more virulent pathogens to natural fisheries and aquaculture landscapes, threatening a significant part of the global supply of nutritious animal foods. Understanding the interaction between climate sensitive aquaculture landscapes along with their aquatic hosts and climate sensitive aquatic animal diseases, mapping of potential risks, identification of suitable adaptation/mitigation intervention strategies should be the focus of future research and development, if we are to meet the future seafood demand for 9 billion people by 2050. There is paucity of information as to how aquatic animal disease outbreak dynamics are mediated by climate driven changes and what impact this will have on the future of aquaculture growth in the world, especially in Asia and Africa. We propose the following policy and research related recommendations for consideration:

- **Evaluate usefulness of aquaculture as a climate smart adaptation and mitigation strategy:** It is believed that aquaculture, in view of its resilience and adaptability and diversity of species cultured will be able to respond appropriately to climate change impacts and emerge as an alternative source of livelihoods for many. There is an urgent need at the policy level to evaluate usefulness of aquaculture as a climate-smart adaptation and mitigation strategy in climate sensitive geographies, so that its potential can be achieved in suitable geographies.
- **Build capacity for science based import risk analysis and development of biosecurity governance mechanisms:** It is expected that there will be increasing pressure to change

culture species to deal with disease impacts due to climate change. This will lead to increased industry demand for trans-boundary translocation of new fish and shellfish species. Building capacity for science based import risk analysis and development of biosecurity governance mechanisms in exporting and importing countries to manage risks of disease spread to receiving environments should be given high priority.

- **Provide enabling policy and investment support** to implement aquatic animal disease management and biosecurity, to prevent future disease losses associated with climate change in lower latitude aquaculture.
- **Manage risk by investing in food production systems with lower risk of losses:** For the purpose of planning and investment, there is a need to look beyond aquaculture, and assess to what extent investments into increased animal food production through aquaculture represents a higher or lower risk of losses to climate change than livestock, and even other food production sectors, in climate sensitive geographies.
- **Prioritise research to identify suitable adaptation/mitigation strategies:** Research and development should be aimed at understanding interactions between climate sensitive aquaculture landscapes along with their aquatic hosts and climate sensitive aquatic animal diseases, mapping of potential risks, identification of suitable adaptation/mitigation intervention strategies, if we are to meet the future seafood demand for 9 billion people by 2050.
- **Invest in breeding programs for salinity and thermo tolerant breeds** to address issues of seawater intrusion leading to salinity increases and rise in temperature.
- **Develop and implement better management practices (BMPs)** to address aquatic animal health risks specific for farming systems that are impacted by climate change. This will enable these farming systems to make suitable adjustments and become resilient.

Background

More than 4.5 billion people get at least 15% of their average per capita intake of animal protein from fish (Bene et al., 2015). Activities in fish (fisheries and aquaculture) value chains globally contributes substantially to income and therefore indirectly to food security of more than 10% of the World population in developing and emergent economies (Bene et al., 2015). Fish is therefore a key element in food security and human nutrition. About half of the demand for these foods is now met by aquaculture; the world's fastest growing food production sector, growing at an average annual rate of nearly 10% since 1970 and reaching 66 million tons in 2013. Asia accounts for the bulk (90%) of the global aquaculture production. Analysis of future fish supply-demand scenarios suggests that farming of fish and other aquatic products will need to double production by 2030 to meet growing demand (World Bank 2014).

Aquaculture represents a significant opportunity to improve the supply of nutritious animal source foods in the diets of poor consumers, without creating further negative impacts on ecological systems and environmental services. However, this opportunity needs to consider the possible impact of future climate change on aquaculture including aquatic animal diseases and put in place systems and strategies to mitigate climate change impacts on aquaculture. The overarching question is: how climate change will impact aquaculture and aquatic animal diseases in future. We examine the distribution of aquaculture in different climatic regions and aquatic environments, distribution of major aquatic animal pathogens in these climatic regions and provide some insights into possible long term implications climate change can have on aquatic animal pathogens and resulting diseases in aquaculture.

Climate change and aquaculture

Currently aquaculture contributes close to 50% of global food fish consumption. Considering the future human population growth and stagnating capture fisheries, future sea food needs has to be met largely by aquaculture. The impact of climate change is not going to be uniform across the globe. It is essential to understand the distribution and practice of aquaculture across different latitudes in the three distinct climatic regions (topical, sub-tropical and temperate) of the globe in order to be able to build future scenarios of likely impacts of climate change on aquaculture. While doing this it is also necessary to consider the three distinct environments (freshwater, marine and brackish water) where the likely impacts of climate change may have different repercussions on the aquatic animals and their disease causing pathogens.

Aquaculture is predominantly present in tropical and sub-tropical climatic regions and geographically Asia dominates in accounting for more than 80% of global aquaculture. Elements of climate change that are likely to impact aquaculture, based on IPCC (2007) forecasts include global warming, sea level rise, changes in ocean productivity and circulation pattern, water stress, changes in monsoon patterns and occurrence of extreme weather events (De Silva and Soto, 2009). These elements of climate change are likely to manifest differently in different climate zones and aquatic environments. Depending on the climatic zone the impacts on aquaculture could be both positive and negative. Adaptive strategies needed to prevent and counteract the impacts of climate change should therefore start in Asia. In general, deltaic

regions in the tropics are purported to be areas that are likely to be heavily impacted by climate change, primarily through sea level rise and the consequent sea water intrusion. Also, such areas in the tropics are hubs of aquaculture and fisheries activities with large populations. Chinese and Indian carps, catfishes, tilapia, brackishwater shrimp and freshwater prawn are the major aquatic animals farmed in Asia.

All aquaculture animal species farmed for human consumption are poikilothermic, therefore, any increase and/or decrease in temperature of their aquatic habitat will have significant influence on their body metabolism and amongst others this could also include influences on susceptibility/resistance to diseases. It is argued that aquaculture, in view of its resilience and adaptability and diversity of species cultured will be able to respond appropriately to climate change impacts and emerge as an alternative livelihood (De Silva and Soto, 2009). Should aquaculture evolve as a climate smart adaptation and mitigation strategy, among other things, it is essential to examine how aquatic animal pathogens will respond to climate change and in the changed scenario how aquatic animal pathogens will interact with their farmed hosts.

Climate Change and Aquatic Animal Diseases

Disease is a greater concern for aquaculture than it is for the capture fisheries because diseases can proliferate when aquatic animals are reared in close proximity at high densities (Walker and Mohan, 2009). There is concern that climate change may further increase the risk to aquaculture posed by diseases through alterations in the distribution, prevalence and virulence of pathogens (bacteria, viruses, fungi and parasites), and changes in the susceptibility of the host species (Halvell et al., 1999). Ideally, the projected changes to disease risk for both fisheries and aquaculture should be considered in future scenarios in view of the impending climate change. However, this is not going to be easy because the likely responses of endemic, exotic and emerging aquatic pathogens are not known well enough. Here an attempt has been made to highlight the influence of climate change on aquatic disease causing pathogens, identify climate sensitive aquatic pathogens and outline the main climate change related factors that are likely to cause changes in the distribution, prevalence and virulence of aquatic pathogens in climate sensitive geographies to raise awareness of this potentially severe problem. Table 1 provides a list of key aquatic diseases in Asia and why they could be considered climate sensitive. This exercise can be expanded to cover all the important infectious (parasites, bacteria, fungi, viruses) and non-infectious diseases of cultured aquatic animals.

Table 1: Showing some of the key OIE listed, non-OIE listed and emerging aquatic diseases prevalent in the tropics and their relation to some of the key elements of climate change

Name of the Disease	Why climate change sensitive?
Infection with <i>Aphanomyces invadans</i> (Epizootic Ulcerative Syndrome-EUS)	Fish Fungal Disease Seasonal disease of wild and farmed freshwater and estuarine fish; grows best at 20-30°C; salinity over 2ppt can stop the spread, 97 species of fish confirmed to be susceptible; no data available on vectors; transmission horizontal; outbreaks normally associated with cooler months of the year and after rainfall;
Koi herpes virus disease (KHVD)	Fish Viral Disease Reported both in tropics and temperate regions; common carp and varieties of this species like koi are most susceptible; Disease pattern influenced by temperature; occurring between 16 and 25°C;
Viral Encephalopathy and Retinopathy (VER)	Fish Viral Disease Serious disease of several marine fishes; reported from more than 50 species mainly marine; water most important abiotic vector; reported in both tropics and temperate regions; outbreaks related to water temperature
White Spot Disease (WSD)	Shrimp Viral Disease Wide host range especially decapod crustaceans in marine, brackish and freshwater systems; horizontal and vertical transmission, outbreaks induced by rapid changes in salinity; temperature has profound influence on disease outbreaks with temperatures of 16-30°C conducive for outbreaks; stocking in cold season is one of the predisposing factors of WSD outbreaks
Infectious Myonecrosis	Shrimp Viral Disease Temperature and salinity effects are considered to be predisposing factors to disease outbreaks
White tail disease	Viral Disease of Freshwater Prawn Penaeid shrimp and aquatic insects are vectors; rapid change in salinity, temperature and pH are predisposing factors to disease outbreak
Shrimp AHPND	Emerging bacterial Disease of Shrimp Caused by pathogenic strain of <i>Vibrio parahaemolyticus</i> ; reported from Asia and Latin America; Nutrient loading and water quality as predisposing factors
Fish Ectoparasites like protozoans, flukes, crustaceans (Argulus, Lernaea)	Life cycle and larval development influenced by water temperature
Streptococcus infection in fishes	Diverse host range; Higher temperatures (>30oC) predisposes fishes like tilapia to outbreaks of Streptococcus infection

There are several factors that are likely to increase the risk of diseases emergence and spread in the future. With globalization and increasing volume of international trade in live aquatic animals and their products, new pathways have been created for spread of trans-boundary aquatic animal pathogens (Rodgers et al., 2011). Intensive aquaculture operations provide an ideal platform for emergence of serious aquatic pathogens (Walker and Mohan, 2009). Irrespective of disease risks involved, aquaculture and global trade will continue to intensify and expand. What will happen to the disease risks of cultured animals in future in the face of expected climate

change events is not clear. However, based on the principles of disease development process and role of stress in disease development, it is possible to make some predictions on the likely impact of climate change on diseases in aquaculture. The effects of global climate change on infectious diseases of aquatic animals are hypothetical until more is known about the degree of change in temperature and other environmental factors.

The role of environmental stress, in particular, temperature fluctuations, salinity changes, low pH and low dissolved oxygen to stress the host and suppress its immune system have been recognized long back. As a consequence, the incidence of disease outbreaks and rates of pathogen transmission often increase during changes in the environment. Particularly severe problems can occur when climate change linked environmental extremes not only stress the host, but also favor the pathogen. Increases in temperature and salinity due to climate change are of particular concern in this regard. The modes of transmission and virulence of pathogens can also be influenced by climate change. It can be strongly argued that aquaculture will witness alterations in the development, transmission and survival of pathogens and the susceptibility of their aquatic hosts. Environmental perturbations on account of climate change can significantly influence the disease process and might lead to increased disease outbreaks and spread of diseases to new geographical areas.

Aquaculture, Aquatic Animal Disease, Climate Change-Interactions

Precise impacts of climate driven change on aquaculture and aquatic animal diseases are uncertain and difficult to predict in view of complex interactions. Considering the interpretations of De Silva and Soto (2009) and Leung and Bates (2013), it is almost certain that economic hardships of climate change will be felt mostly by people living in lower latitudes (tropics and sub-tropics) where more aquaculture is concentrated and where disease incidence is more frequent. Compared to temperate regions, aquaculture in the tropics has the potential for greater economic loss due to climate change-mediated disease mortality. It is also expected that environmental deterioration is likely to be more severe in tropics and interactions with climate change outcomes is bound to increase the frequency and risk of disease in tropics. This coupled with the limited capacity of these countries to implement mitigation measures could make the matters worse for these communities.

In terms of adaptation, there is a need for developing very specific strategies to address geography specific problems (De Silva and Soto, 2009). For example, establishment of a breeding program for a salinity tolerant strain of striped catfish with an aim to address the issues of seawater intrusion leading to salinity increases so that the striped catfish farming communities in the lower reaches of the Mekong could continue their livelihoods. Similar possibilities could be extended to breed or select for thermo-tolerance for use in geographies that are expected to see increases in temperature. From an aquatic animal health management perspective, development of better management practices (BMPs) to address aquatic animal health risks specific for the farming systems that are subjected to climate change impacts will enable these farming systems to make suitable adjustments and become resilient. Adaptation strategies could include for example even moving cage units to cooler waters or lowering to deeper waters when warm weather events are forecast.

Compared to Asia, aquaculture is in its infancy in African continent, but has huge potential to expand and contribute to food and nutritional security of the region. Countries like Nigeria, Egypt and Namibia are making large investments in aquaculture. Water borne pathogens have the potential to spread at faster rates compared to terrestrial systems and ocean circulation patterns and international trade (especially trade in live aquatic animals) have the potential to transmit disease across wide geographies. Reports of two major disease; EUS since 2007 (Botswana, Namibia and Zambia) and WSD since 2011 (Mozambique) are clear examples of how diseases can jump national and international borders and bring about devastating impacts on communities. EUS occurs in natural freshwater systems and extreme weather events like flooding can distribute the disease over thousands of kilometers. Spread of EUS up and downstream of Zambezi river (4th longest river in Africa) is a strong possibility and this would put the livelihoods of several million people in 7 countries (Angola, Botswana, Malawi, Mozambique, Namibia, Zambia and Zimbabwe) at risk (FAO, 2009).

Conclusions

There is a risk that aquaculture operations in the tropics will experience higher cumulative mortalities and faster progression of diseases in the future, and this will most likely be exacerbated by climate change leading to varieties of virulent pathogens (Mennerat et al 2010) that have the potential to spread geographically. This can furthermore result in introduction and spread of more virulent pathogens to natural fisheries and aquaculture landscapes, threatening a significant part of the global supply of nutritious animal sources foods. How disease outbreak dynamics can be mediated by climate driven changes are of paramount importance.

Disease management and biosecurity implementation will be vital to prevent future disease losses that would be associated with aquaculture in lower latitudes. There is always a tendency to oversimplify the underlying mechanisms by which climate change influences disease emergence, transmission and spread. There are few studies that present evidence to validate the direct effect of climate change on aquatic animal disease. Some of the key research areas could be (1) climate projections for aquaculture hot spots in tropics (2) the effects of climate change on fish production and (3) the influence of climate change on fish diseases and subsequently on fish yields under future climates.

Understanding interaction between climate sensitive aquaculture landscapes along with their aquatic hosts and climate sensitive aquatic animal diseases, mapping of potential risks, identification of suitable adaptation/mitigation intervention strategies should be the focus of future research and development, if we are to meet the future seafood demand for 9 billion people by 2050.

Predictive modelling will help to identify the most vulnerable aquaculture sectors (based on geography and species adaptive range) and disease risks to these sectors. However, the complexity of these biological systems and the imperfect nature of the data available to support modelling work, means that industry and public sector biosecurity systems, emergency disease

response systems (including disease monitoring and reporting systems) and animal health management systems must be well resourced, flexible and responsive. Importantly, resource managers and regulators must recognize and manage risks associated with increased incidence of extreme weather events. One serious consequence of extreme weather events, such as flooding and storms, is an increased risk of aquatic animals escaping from holding systems into natural environments. The potential for increased fish escapes to pose a disease risk to wild fish and shellfish populations need to be recognized, studied and managed — once established in natural waters, aquatic animal diseases are near impossible to eradicate

Taking a broader view it will also be important to research beyond aquaculture, and assess to what extent investments into increased animal food production through aquaculture represents a higher or lower risk of losses to climate change than livestock, and even other food production sectors.

Authorship and Acknowledgement

This submission was prepared by Chadag Mohan, World Fish Center, Penang, Malaysia, with support from the CGIAR research program on Climate Change, Agriculture and Food Security (CCAFS).

References

- Christophe Béné , Manuel Barange, Rohana Subasinghe , Per Pinstrup-Andersen, Gorka Merino, Gro-Ingunn Hemre & Meryl Williams (2015). Feeding 9 billion by 2050 – Putting fish back on the menu. Food Sec
- De Silva S.S., Soto D. (2009). Climate change and aquaculture: potential impacts, adaptation and mitigation. *FAO Fisheries Technical Paper*, 530: 137-215.
- Harvell, C.D., Kim, K., Burkholder, J.M., Colwell, R.R., Epstein, P.R., Grimes, J., Hofmann, E.E., Lipp, E., Osterhaus, A.D.M.E., Overstreet, R., Porter, J.W., Smith, G.W., & Vasta, G.R. (1999). Emerging marine diseases - climate links and anthropogenic factors. *Science*, 285: 1505–1510.
- 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.
- IPCC. (2007). Climate Change 2007: Synthesis Report. Contribution of Working Groups I, II and III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, Pachauri, R.K. and Reisinger, A. (Eds.)]. IPCC, Geneva, Switzerland. pp 104. (Also available at www.ipcc.ch/pdf/assessment-report/ar4/syr/ar4-syr-topic/pdf.)
- Leung T.L.F and Bates, A.E (2013). More rapid and severe disease outbreaks for aquaculture at the tropics: implications for food security. *Journal of applied Ecology*, 50: 215-222.
- Mennерat, A., Nilsen, F., Ebert, D. & Skorping, A. (2010) Intensive farming: evolutionary implications for parasites and pathogens. *Evolutionary Biology*, 37, 59–67.
- OIE (2014). Aquatic animal health code (17th Edition).
- Rodgers, C.J., Mohan, C.V. and Peeler, E.J. (2011). The spread of pathogens through trade in aquatic animals and their products. *OIE Scientific and Technical Review*, 30(1): 241-256
- Walker P. J & Mohan C.V. (2009). Viral disease emergence in shrimp aquaculture: origins, impact and the effectiveness of health management. *Reviews in Aquaculture*, 1: 125-154
- World Bank. (2014). Fish to 2030 Prospects for Fisheries and Aquaculture. World Bank Report, No. 83177-GLB. Washington, DC: World Bank