Food and Agriculture Organization of the United Nations

FAO/APFIC Regional Consultative Workshop

BUILDING CLIMATE-RESILIENT FISHERIES AND AQUACULTURE IN THE ASIA-PACIFIC REGION

Bangkok, Thailand, 14–16 November 2017

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Abbreviations and acronyms

APFIC	Asia-Pacific Fishery Commission
ADB	Asian Development Bank
ATSEF	Arafura and Timor Seas Expert Forum
AusAID	Australian Agency for International Development
BFRI	Bangladesh Forest Research Institute
BFAR	Bureau of Fisheries and Aquatic Resources, Philippines
BOBLME	Bay of Bengal Large Marine Ecosystem
BOBP-IGO	Bay of Bengal Programme – Inter-Governmental Organisation
CBD	Convention on Biological Diversity
COP	Conference of the Parties
CSIRO	Commonwealth Scientific and Industrial Research Organisation
CT-ROMS	The Coral Triangle Regional Ocean Modeling System
CTI	Coral Triangle Initiative
CTI-CFF	Coral Triangle Initiative for Coral Reefs, Fisheries, and Food Security
DRM	Disaster Risk Management
EAFM	Ecosystem Approach to Fisheries Management
EAA	Ecosystem Approach to Aquaculture
EAAM	Ecosystem Approach to Aquaculture Management
EbA	Ecosystem-based adaptation
EEZ	exclusive economic zone
ENSO	El Niño-Southern Oscillation
FAD	fish aggregating device
FAO	Food and Agriculture Organization of the United Nations
FAO RAP	FAO Regional Office for Asia and the Pacific
FMA	fisheries management areas
GEF	Global Environment Facility
GHG	greenhouse gas
GTZ	German Technical Cooperation Agency
ICT	information and communication technology
IMTA	Integrated Multi-Trophic Aquaculture
INDC	Intended Nationally Determined Contribution
IPCC	Intergovernmental Panel on Climate Change
IUCN	International Union for Conservation of Nature
IUU	illegal, unreported and unregulated (fishing)
JICA	Japan International Cooperation Agency
LCO	local community organizations, Philippines
LDC	least developed country
LGU	local government unit, Philippines
LME	Large Marine Ecosystem
MMAF	Ministry of Marine Affairs and Fisheries, Indonesia
MPA	Marine Protected Area
NACA	Network of Aquaculture Centres in Asia-Pacific
NAMA	Nationally Appropriate Mitigation Action
NAPA	National Adaptation Programme of Action
NDC	Nationally Determined Contribution
NGO	non-governmental organization
NOAA	National Oceanic and Atmospheric Administration, United States
NORAD	Norwegian Agency for Development Cooperation
NOS	NOAA's National Ocean Service

PEMSEA	Partnerships in Environmental Management for the Seas of East Asia
PICTs	Pacific Island Countries and Territories
PIFSC	NOAA's Pacific Islands Fisheries Science Center
PDO	Pacific Decadal Oscillation
PSF	People's Survival Fund, Philippines
PSP	paralytic shellfish poisoning
QTP	Qinghai–Tibet Plateau
RA	Republic Act, Philippines
RAS	Recirculating Aquaculture System
SEAFDEC	Southeast Asian Fisheries Development Center
SPREP	Secretariat of the Pacific Region Environment Programme
UNCCD	United Nations Convention to Combat Desertification
UNFCCC	United Nations Framework Convention on Climate Change
UNICEF	United Nations Children's Fund
UNDP	United Nations Development Programme
USAID	United States Agency for International Development
WFC	World Council of Fisheries Societies

Executive Summary

The FAO/APFIC Regional Consultative Workshop, Building Climate-Resilient Fisheries and Aquaculture in the Asia-Pacific Region, was held on 14–16 November 2017 in Bangkok, Thailand. The workshop brought together policymakers, managers and practitioners who were engaged in addressing climate change in relation to fisheries and aquaculture in the Asia-Pacific region through the development and implementation of regional and national policies, programmes and projects.

The regional consultative workshop brought together 67 participants from Asia-Pacific Fishery Commission (APFIC) member countries, regional organizations and development partners with the following objectives:

- to increase the understanding of APFIC member countries and key regional players of the current status of climate change adaptation and mitigation efforts undertaken by the fisheries and aquaculture sectors in the Asia-Pacific region and of the potential for further efforts;
- to share knowledge among the countries and regional players of technological advances and good management practices for strengthening the resilience of fisheries and aquaculture; and
- on the basis of an in-depth analysis of key constraints and gaps, to make recommendations for a regional strategy and for priority actions at the regional and country levels to strengthen climate resilience and contribute to the mitigation of greenhouse gases (GHGs) produced by the fisheries and aquaculture subsectors in the Asia-Pacific region.

Key presentations by FAO set the scene for the workshop including an introduction to the United Nations Framework Convention on Climate Change (UNFCCC) Paris Accord and its implications for national actions, and regional overviews on the status of climate change adaptation and mitigation actions in the fisheries and aquaculture sectors. Presentations on the efforts and progress made by national governments and international and regional organizations in addressing the effects of climate change in the fisheries and aquaculture sectors were delivered and various issues and gaps, and the support needed to address climate change more effectively in the sectors were highlighted.

To reflect the diversity of issues faced in the region and the distinct needs of the aquaculture and fisheries sectors, participating countries were divided into fisheries and aquaculture groups and then into regional clusters to identify the threats/risks associated with climate variability and change and each sector's contribution to GHG emissions. The groups/clusters were also tasked with analyzing gaps and constraints and recommending strategies and actions at regional and national levels for addressing climate change impacts and climate variability to strengthen the climate resilience of the two sectors.

National and regional efforts for climate resilience in fisheries and aquaculture

In recent years, countries in the APFIC region have made wide-ranging efforts with respect to climate change adaptation and mitigation. All APFIC member countries have ratified the UNFCCC and signed the Paris Agreement. Some of the least developed countries in the region (including Bangladesh, Cambodia, Lao People's Democratic Republic, Myanmar, Nepal and Timor-Leste) have developed a National Adaptation Programme of Action (NAPA) on Climate Change. When compared to the situation at the time of the initial APFIC/FAO consultative workshop Implications of Climate Change on Fisheries and Aquaculture: Challenges for Adaptation and Mitigation in the Asia-Pacific region held in Nepal from 24 to 26 May 2011,[1] countries have progressed significantly in their climate-related planning in the fisheries and aquaculture sectors, especially with respect to the degree that this has been integrated into broader climate change related planning at the agriculture sector level and beyond. Indeed member countries have integrated the fisheries and aquaculture sectors into the national climate change planning process to a significant extent.

[1] See FAO-RAP Publication 2011/17, 52 pp. Available at http://www.fao.org/3/a-ba0084e.pdf

The range of efforts presented across the APFIC countries, supported by regional and global partners, in fisheries and aquaculture includes:

Capture Fisheries	Aquaculture
Financing of climate adaptation and mitigation	Financing climate adaptation and mitigation
Adoption of climate smart/resistant/resilient fisheries	Adoption of climate-adaptive technologies or practices
Collaboration among different sectors and agencies	Adoption of framework for action
Capacity building	Awareness and capacity building
Research, monitoring and evaluation	R&D for development of climate change-resilient technologies or practices
Involvement of communities	Mechanisms to support farmers
Safeguarding vulnerable fishers and populations	Mechanisms to support vulnerable groups
Adoption of mitigation measures (fuel consumption efficiency and fuel-saving practices, reforestation)	Research on carbon sequestration and aquaculture as carbon sinks (e.g. culture of mollusks and seaweeds) or culture of low carbon footprint species
Ecosystem Approach to Fisheries Management (EAFM)	
Conservation of fisheries resources	
Enhancement of fisheries productivity	
Climate adaptation in sustainable development to ensure food security	

However, there remain significant gaps and constraints in the understanding of the sectoral effects of climate change and related vulnerabilities because of the lack of basic data on vulnerabilities and risk assessments, as well as a lack of data on projected impacts at local levels. Although the situation is improving, there remains limited awareness at the community level and a lack of knowledge on specific options (technological, management, risk management, livelihoods diversification, etc.) to reduce vulnerability/risk at the fisher/farmer levels.

Early-warning systems specific to the fisheries and aquaculture sectors and integration of the sectors into disaster risk management (DRM) frameworks also remain weak. In addition, cross-sectoral climate change strategies and plans, although incorporating fisheries and aquaculture more frequently than in the past, are still generally lacking specific strategies and actions for the sectors. Climate change issues often remain a low priority at the national political level, leading to a lack of national support or policy to address climate change challenges. Moreover, there often remains a lack of clear management approaches to the fisheries and aquaculture sectors, as well as roadmaps, plans, and policies to mitigate the emission of GHGs from the sectors.

Outcome of the regional consultation

In addition to providing a platform for sharing climate change adaptation and GHG mitigation efforts across the region, the regional consultation recommended national and regional strategies and actions for country governments, regional organizations, academic institutions and the private sector to further support climate change adaptation and GHG mitigation in the fisheries and aquaculture sectors. Recommendations included the need for:

- more policy frameworks and funding support targeting climate change adaptation, mitigation and disaster risk management in the fisheries and aquaculture sectors;
- country coordination and regional collaboration to develop a shared strategy and to share knowledge, research and experiences in strengthening climate resilience and reducing GHGs from the fisheries and aquaculture sectors;

- more research, development cooperation, training, technology and information exchange both at national and regional levels;
- strengthened management of the fisheries and aquaculture sectors to improve adaptability and the mitigation of GHGs emissions from the sectors;
- incorporation of social/human well-being into climate change vulnerability assessments and adaptation plans in the fisheries and aquaculture sectors;
- increased awareness of climate change adaptation, mitigation and disaster risk management among fisheries and aquaculture stakeholders;
- increased recognition of and support to GHG mitigation efforts (tools, practices, and market incentives) within the fisheries and aquaculture sectors; and
- support to building capacity among fisheries and aquaculture stakeholders so that they can undertake risk and vulnerability assessments and climate change adaptation planning.

Introduction

Fisheries and aquaculture contribute significantly to the economic growth of countries in the Asia-Pacific region. The sectors also contribute to food and nutrition security and to the livelihoods of an estimated 170 million directly and indirectly engaged in the value chains in fisheries and aquaculture production. Capture fisheries production has stagnated in the last two decades, but aquaculture production has continued to increase, and by 2014 exceeded production from capture fisheries in the Asia-Pacific region. Nevertheless, countries in the region are identified as among the most vulnerable to climate change impacts that will significantly affect the fisheries and aquaculture production chains. The region, which is home to more than 90 percent of the global population, also has the greatest exposure to risks related to extreme climatic events including tropical cyclones, storm surges and the resulting coastal flooding, as well as extended droughts. Hence, sustainable fisheries and aquaculture development in the region is of vital importance and continues to be a significant development challenge.

In May 2011, member countries of the Asia-Pacific Fishery Commission (APFIC) and regional organizations, together with the Food and Agriculture Organization of the United Nations, Regional Office for Asia and the Pacific, convened a technical workshop, "Implications of climate change on fisheries and aquaculture: challenges for adaptation and mitigation in the Asia-Pacific region," in Kathmandu, Nepal. The workshop acted as a platform for partners and member countries to share experiences and lessons related to the impacts of climate change on fisheries and aquaculture. It also served as a platform for formulating recommendations for how member countries and partner organizations can better prepare for climate-related changes in order to strengthen the fisheries and aquaculture sectors in the Asia-Pacific region. Since then, there have been many important developments relevant to these sectors at the global, regional and national levels. Progress has been made in terms of improving our understanding of climate risk, vulnerability and resilience. Policies have been developed, and on-the-ground actions have been implemented to meet mitigation and adaptation targets in many countries.

Following the 2011 workshop in Kathmandu and responding to the recommendation made by the Seventy-sixth Executive Committee of APFIC that a platform be provided for key stakeholders to share lessons and good practices with respect to addressing the implications of climate change for fisheries and aquaculture in the region, the "FAO/APFIC regional consultative workshop: building climate-resilient fisheries and aquaculture in the Asia-Pacific region" was held from 14 to 16 November 2017 in Bangkok, Thailand.

The meeting provided observations on the current status of climate change impacts as well as predictions of future impacts. The specific objective of this workshop was to support the APFIC member countries in addressing climate change to strengthen the resilience of fisheries and aquaculture through:

- providing a platform for stakeholders to inform others about progress with respect to planning and implementation of climate change actions;
- sharing technological advances and good managerial practices in strengthening the climate resilience of the fisheries and aquaculture sectors in the region and actions to mitigate the emission of GHGs associated with the two sectors;
- reviewing the progress that has been made in capture fisheries and aquaculture in the region in the context of climate change adaptation and mitigation, and identifying capacity gaps and other constraints of the APFIC member countries in coping with climate change challenges and strengthening climate resilience; and
- identifying strategy recommendations for APFIC and its member countries for building resilience and supporting the potential for mitigating the emission of GHGs associated with the fisheries and aquaculture sectors in the Asia-Pacific region.

Workshop participation

The workshop brought together policymakers, managers and practitioners engaged in the development and implementation of national and regional policies, programmes and projects addressing climate change in the fisheries and aquaculture sectors in the Asia-Pacific region. There were 67 participants: 35 participants representing 16 countries; 14 participants from international and regional organizations; 6 participants from the private sector; and 12 participants from FAO projects and the FAO Regional Office for Asia and the Pacific.

Workshop format

Plenary sessions

The first plenary session provided a regional overview to set the scene for the workshop and consisted of key presentations by FAO officers and consultants on the following topics:

- Introduction to the Paris Accord on Climate Change and its implications for national actions—challenges and opportunities.
- Regional overview on the status of climate change adaptation and mitigation in fisheries.
- Regional overview on the status of climate change adaptation and mitigation in aquaculture.

The second plenary session was devoted to regional organizations' reports on their programmes related to climate adaptation and mitigation in fisheries and aquaculture in the Asia-Pacific region. The third plenary session was on the presentation of the outputs of the working group discussions.

Parallel sessions

After the first plenary session on the regional overview, there were two simultaneous sessions, one on aquaculture and another on fisheries, in which participating countries delivered presentations to provide overviews and updates on national efforts and progress, issues, gaps, and support needed to address climate change in the two sectors.

Breakout working group sessions

Following the second plenary session, participants were divided into fisheries and aquaculture working groups. Each group was further sub-divided into two groups. The first group consisted of representatives from the Bay of Bengal countries and the second was comprised of representatives from the other APFIC member countries. Each working group was tasked to discuss the following:

- threats/risks identification, contribution of the sectors to GHG emissions, and analysis of gaps and constraints; and
- recommended strategies and actions at regional and national levels for addressing climate change impacts and climate variability to build the climate resilience of the fisheries and aquaculture sectors.

The outputs of the working group discussions were presented during the third plenary session.

Expected workshop outcomes

The workshop was intended to provide the following outcomes:

1) increased understanding of APFIC member countries and key regional players of the current status of climate change adaptation and mitigation efforts for the fisheries and aquaculture sectors in the Asia-Pacific region and of the potential for further efforts;

2) broad sharing among the countries and regional players about technological advances and good management practices for strengthening the resilience of the fisheries and aquaculture sectors; and
3) recommendations made for a regional strategy and for priority actions at the regional and country levels to strengthen the climate resilience and contribute to the mitigation of GHG emissions of the fisheries and aquaculture sectors in the Asia-Pacific region. These should be based on an in-depth analysis of key constraints and gaps.

Opening session

Dr Chumnarn Pongsri, Deputy Director General, Department of Fisheries (DOF), Thailand expressed his appreciation to FAO/Regional Office for Asia and the Pacific (RAP) and partners for organizing the Consultative Workshop and welcomed the participants. He noted that climate change has received global attention, and that this has helped raise awareness, foster preparedness and stimulate efforts to address many of the likely negative effects of climate change, especially in the agriculture sector involving food production and food security of the world's population. He briefly introduced several efforts of the Thai government to address climate change impacts at the national level. He highlighted that the Ministry of Agriculture and Cooperatives of Thailand established an Agriculture Strategic Plan on Climate Change, 2017–2021 under the Climate Change Master Plan, 2015–2050 and the Department of Fisheries of Thailand is developing action plans to address climate change in fisheries. He informed many climate-relevant projects have been implemented in Thailand. He was confident that the Consultative Workshop would benefit all countries in the region through knowledge exchange and through the development of mechanisms in the aquaculture and fisheries sectors to address climate change issues and strengthen food security.

Ms Xiangjun Yao, Regional Programme Leader, FAO Regional Office for Asia and the Pacific, welcomed the participants. She emphasized the significant contribution of fisheries and aquaculture (the "blue" sectors) to food and nutrition security and to the livelihoods of the people around the world, especially in the Asia-Pacific region, which is home to approximately 87 percent of people whose livelihoods are dependent on these sectors. She briefly summarized the status of fully or over-exploited capture fisheries, the rise of the aquaculture subsector, and the observed impacts of climate change and its associated risks and hazards. FAO and its partners are working together to reduce the vulnerability of dependent communities, supporting countries in their implementation of the FAO Code of Conduct for Responsible Fisheries, the Ecosystem Approach to Fisheries and Aquaculture, and the recently adopted Voluntary Guidelines for Securing Small-Scale Fisheries in the Context of Food Security and Poverty Eradication.

Mr Weimin Miao, FAO Aquaculture Officer, introduced the workshop, its objectives and format. He provided background summaries of the importance of fisheries and aquaculture in Asia-Pacific and discussed the implications of climate change and climate variability for these sectors in the region. The Asia-Pacific region accounts for 55 percent of global capture fisheries production and contributes over 90 percent of the global aquaculture production. Asia is home for some 50 million fishers and fish farmers, representing 85 percent to 90 percent of the world total, and many others are engaged in fisheries-related goods and services. At the same time, the Asia-Pacific region is the region most vulnerable to the impacts of climate change. Capture fisheries and aquaculture are among the most vulnerable sectors, and fishers and aquaculture farmers are the populations most vulnerable to the impacts of climate change and climate variability. Aquaculture and capture fisheries, particularly intensive aquaculture, are significant contributors to GHG emissions. He concluded that effective adaptation and mitigation are vitally important to the resilience and sustainability of fisheries and aquaculture in the region.

Mr Miao compared the objectives of the 2011 FAO/APFIC Regional Consultation on Climate Change with those of the current 2017 Regional Consultation. In his view, in light of witnessing real impacts of climate change and variability on capture fisheries and aquaculture, the changing socio-economic environment, and ongoing efforts and progress, the 2017 Consultation of necessity had different objectives as shown in Table 1.

Table 1. Regional consultation objectives in 2011 and 2017

Objectives of 2011 FAO/APFIC Regional Consultation on Climate Change	Objectives of 2017 FAO/APFIC Regional Consultative Workshop
• Share most up to date information on climate changes scenarios and the specific fisheries/ aquaculture related change patterns and their implications/potential impacts on fisheries and aquaculture sectors in Asia-Pacific region. • Build consensus on threats of climate changes to fisheries and aquaculture and need for timely actions to address the problem. • Review current planning and action in support of adaptation and mitigation of climate impacts in the areas of fisheries and aquaculture. • Identify issues and problems to address climate change impacts on fisheries and aquaculture. • Develop recommendations for national and regional actions to address climate adaptation and mitigation for the fisheries and aquaculture sectors in the region.	• Provide a platform for stakeholders to inform on progress with respect to planning and implementation of climate change actions. • Share technological advances and good managerial practices in strengthening the climate resilience of fisheries and aquaculture sectors in the region. • Identify specific capacity gaps and other constraints of the APFIC member countries in effectively coping with climate change challenges to fisheries and aquaculture and strengthening climate resilience of fisheries and aquaculture subsector in the region. • Recommend strategy and immediate actions at regional and country levels for APFIC and its member countries to build resilience of fisheries and aquaculture through adaptation and mitigation in Asia-Pacific region. • Asia-Pacific regional initiative for blue growth and Asia-Pacific regional initiative on climate change.

Key plenary presentations

Paris Agreement, fisheries and aquaculture

Beau Damen from FAO gave a presentation on "Agriculture, Paris and the NDC's: advancing climate action for agriculture." The Paris Agreement, which entered into force on 4 November 2016 and has been ratified by 194 Parties to the United Nations Framework Convention on Climate Change (UNFCCC), will act to limit the increase in global average temperature to below 2ºC. This is a long-term commitment to balance emission sources and sinks from 2020 to 2025 and later. Implementation is to be through Nationally Determined Contributions (NDCs), which are also known as Intended Nationally Determined Contributions (INDCs). Although the format and specific content of the initial NDCs submitted by countries was left largely to countries to decide, these documents generally included priority areas for adaptation and climate resilience; policies or mechanisms to meet target mitigation and adaptation contributions; and implementation requirements covering financial assistance, technology transfer and capacity-building. Existing planning processes for tackling climate change—including National Adaptation Programme of Action (NAPA), National Adaptation Plans (NAPs) and Nationally Appropriate Mitigation Actions (NAMAs)—will be key pillars of NDC preparation and implementation.

A review of the initial NDC submissions from Asia and the Pacific and priority actions by sector reveals that agriculture comprising crops, livestock, forestry, fisheries and aquaculture are key concerns for countries in the region. As many as 256 actions can be identified from INDCs submitted by parties in the region with 12 in the fisheries and aquaculture sectors (Figure 1). Eight countries in the region were responsible for the 12 priority actions and the majority of the actions focused specifically on adaptation in the fisheries and aquaculture sectors (Figure 2). Actions included employing stress-tolerant fish varieties, enhancing resilience to marine disasters, strengthening insurance schemes for fisher folk, and promoting adaptive aquaculture practices.

In the lead up to the commencement period for the Paris Agreement in 2020, countries will be working to prepare detailed national NDC implementation strategies for the agriculture sectors. This process will provide an opportunity for enhanced coordination of regional positions on climate change and agriculture issues. From the perspective of the fisheries and aquaculture sectors, additional work could be undertaken to work with national UNFCCC focal points and other agriculture sector stakeholders to ensure that these

Figure 1. Number of INDC actions identified for agriculture and land-use sectors in Asia-Pacific region by sector

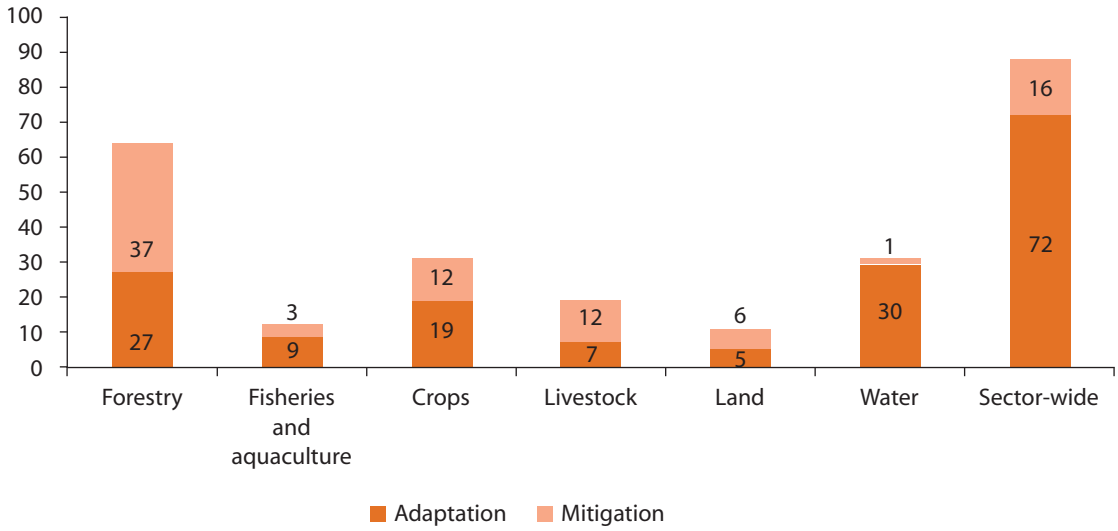
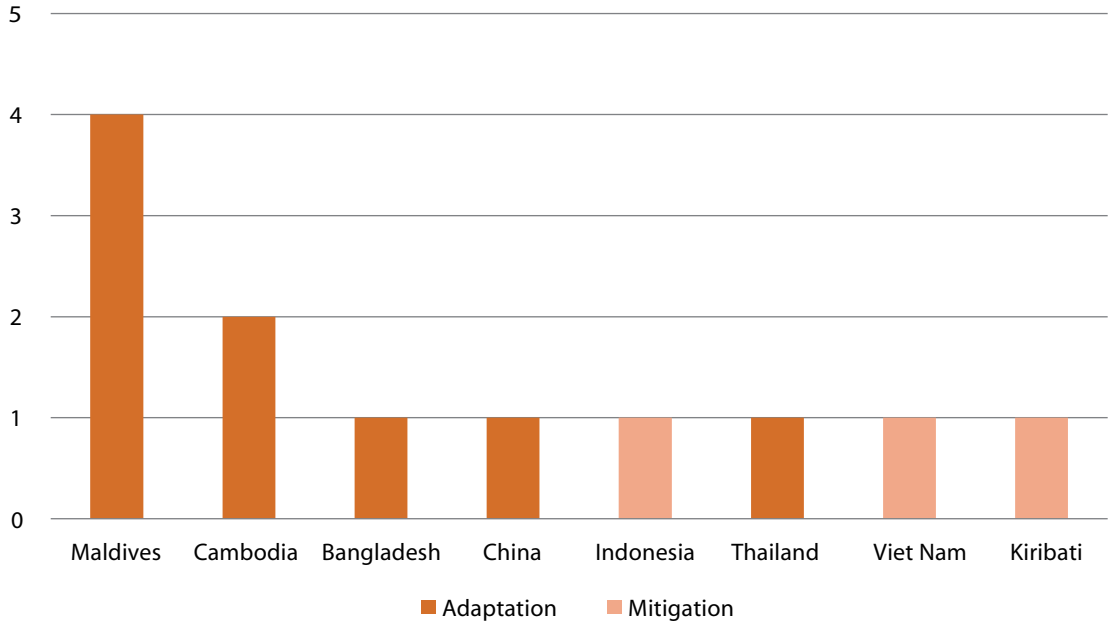


Figure 2. Number of INDC actions by country and activity focus in the fisheries and aquaculture sectors



sectors are better reflected in the NDCs. In developing implementation strategies, key challenges will relate to improving transparency in implementation and in the achievement of NDC outcomes, scaling-up successful projects to the national level, and securing financial support for the process. Under the UNFCCC, there are resources being made available through mechanisms such as the Global Environment Facility and the Green Climate Fund. These mechanisms may provide opportunities to leverage multilateral finance to design and deliver programmes that target sector specific issues and deliver climate change benefits for the fisheries and aquaculture sectors.

Regional overview of the efforts addressing climate change in the fisheries sector in the APFIC region

Supin Wongbusarakum, International Fisheries Consultant to FAO, presented overviews of climate change and its impacts in the Asia-Pacific region. In particular, she discussed the impacts on the fisheries sectors, the implications of climate impacts for local communities and at national and regional levels, and she talked about both adaptation and mitigation efforts.

The project global mean air temperature is predicted to increase by 0.3ºC to 0.7ºC by 2035, 0.5ºC to 1ºC by 2050 and by 0.5ºC to 4ºC by 2090. In contrast, the ocean has warmed by 0.11ºC per decade between 1971 and 2010. The warming of the ocean is reshaping the fisheries with marine species moving away from the equator to cooler waters, with warm water species replacing temperate species, and with the continued warming in the tropics further reducing catch potential. Coral bleaching associated with El Niño events has also decimated reefs in many areas in Asia. "The number of years between recurrent severe bleaching events has diminished fivefold in the past four decades, from once every 25 to 30 years in the early 1980s to once every 5.9 years in 2016". This has seriously decreased the abundance of reef-associated and dependent fish species. At the same time, coral reefs and calcified marine life are at risk from increasing ocean acidification, which has further impacts on marine ecosystems, the productivity of coral reef fisheries and, ultimately, food security. Sea level rise is observed and further rises are predicted. By the end of this century, sea level rise will occur in more than 95 percent of the ocean area. About 70 percent of coastlines worldwide are projected to experience sea level change within ±20 percent of the global mean, which is expected to be higher than today in the range of 40–75 cm.

Although there are insufficient observational records to draw conclusions about trends in precipitation and monsoons, future increases in precipitation extremes related to the monsoons are very likely in East Asia, South Asia and Southeast Asia. Impacts of flooding can be significant. Eastern and northern hemisphere monsoons will produce more precipitation than those in the west and south. Monsoon areas will expand in Central Asia and East Asia, and in the tropical Pacific and the Southern Indian Ocean.

Climate change risks for fisheries are increasing, with species richness and fisheries decreasing at tropical latitudes. Climate change impacts have been observed and are predicted with respect to fish production zones in the Asia-Pacific as detailed below.

Impacts on inland fishes and ecosystems

A small number of records and peer-reviewed publications document changes on inland fishes and ecosystems as follows:

- Temperature change in lake thermal structure affects productivity.
- Evapotranspiration reduces fish habitat size.
- Temperature changes affect spawning and migration.
- Precipitation increases river runoff, which in turn causes eutrophication and potential fish kill.
- Sea level rise causes salinity intrusion in freshwater systems (e.g. Mekong Delta).

Impacts on coastal/nearshore fishes and ecosystems

- Primary (phytoplankton) production is highly variable, no long-term observed changes.
- Coral bleaching is widely observed, leading to degraded habitat and decreases in fish abundance.
- Harmful algal blooms are projected to expand in Northeast Asia and Southeast Asia.
- Small pelagic fishes have latitudinal shifts in spawning grounds (e.g. sardines and scads in India, and increasing catches of scads in deeper, cooler waters.

Impacts on pelagic fishes and tropical ocean systems

- Primary production projected to decline.
- Shift in spatial distribution of tuna species is primarily a result of changes in water temperatures, impacting suitable spawning areas.
- Pacific longline catches of yellowfins and skipjacks follow the western Pacific Warm Pool movement from west to east for skipjack and yellowfin.
- Projected increases in higher latitudes for wahoo and mahi-mahi.

Fisheries are of paramount importance to the Asia-Pacific region. Asia is home to 84 percent of the global population engaged in the fisheries and aquaculture sectors. Of the 18 million people engaged in fish farming, 94 percent are in Asia. There are many implications of climate change impacts for fishing communities and the general public (Table 2) and there are important national implications too (Table 3).

Table 2. Implications of climate change impacts for fishing communities and the general public

Areas of impacts	Specific examples
Livelihood	• More efforts for the same amount of catch • Change in net income because of increased fishing costs • Different types of harvesting strategies, gear types and methods required • Impacts on all stakeholders along value and supply chains
Cultural and non-tangible implications	• Change of diet/seafood • Change in cultural traditions that are linked to certain species • Social relationship, including collective action • Sense of identity as fishers and sense of place
Gender vulnerability	Stronger impacts on women, resource poor and marginalized populations
Health and safety	• Coastal risks (sea level rise, salt water intrusion, storm, erosion) • Work at sea • Food security and health hazards
Nutrition and food security	• Increased stress because of reliance of fish for protein • All food security aspects are impacted (availability, stability, access, utilization) whereas population continues to grow

Table 3. Implications of climate impacts at national level

Areas of impacts	Specific examples
Economy and trade	• Changes in the price and value of catches, earnings to fishing companies, national labour markets, industry re-organization, and re-orientation to changes in export earnings or deficits • Domestic fleets vulnerable to fluctuations of tuna fisheries in their exclusive economic zones
Fisheries governance	• Problem with conventional of single species management and maximizing production • Need for precautionary approach, integrating climate lens and resilience building • Implication of impacts on regional level
Transboundary issues	• Tuna stocks change among and within their exclusive economic zones and there will be both "winners and losers" • Competition within fisheries subsector and with other sectors • IUU fishing will increase • Need for collaboration among different countries to address transboundary issues

Initiatives towards climate-resilient aquaculture in the Asia-Pacific region

Evelyn Grace de Jesus-Ayson, International Aquaculture Consultant to FAO, presented an overview on the status of climate change adaptation and mitigations in aquaculture in the Asia-Pacific in view of the impacts of climate change-related events.

The total world fisheries production is projected to continue to increase with most of the increase coming from aquaculture. Most of the production will come from countries in Asia. The projections are based on specific assumptions regarding the future macro-economic environment, absence of major perturbations in the markets, absence of severe climate disturbances and major fish disease outbreaks and longer-term productivity trends. However, climate change impacts especially extreme weather events threaten the sustainability of capture fisheries and aquaculture development in both marine and freshwater

environments. Hence, at a global level, climate change impacts on aquaculture will likewise impact food and nutrition security, poverty alleviation and livelihood security, and economic development. The effects could be higher in the largely developing countries of the Asia-Pacific region which accounts for about 90 percent of the world's aquaculture production and where more than 80 percent of the fish farmers are small-scale farmers, are resource poor, and highly dependent on fish for food and nutrition security. Freshwater fish production is threatened by climate change impacts as well as water scarcity and the pollution of freshwater by fish farming, which can also be exacerbated by climate change.

Hazards to aquaculture associated with global climate change

Climate change impacts occur as a result of gradual atmospheric warming and pose three broad types of hazards to aquaculture systems: physical, chemical and biological, and most of the chemical and all of the biological hazards are offshoots of the physical hazards. The impacts of global climate change on aquaculture can also be categorized into short-term impacts and long-term impacts that arise from either extreme meteorological events or long-term global climate trends. The short-term impacts include production losses from loss or mortality of stocks and damage to infrastructure because of extreme weather events, and production losses resulting from outbreaks of diseases, parasitic infestation, or harmful algal blooms. Long-term impacts include scarcity of wild seed because of degradation of habitats and breeding or nursery areas; reproductive or recruitment failure because of increased water temperatures that are beyond the optimum range for development, growth and survival or ocean acidification that hinders normal development in shellfishes; limited access to water for farming; limited access to feed sources or supply of feed ingredients; and decreased productivity because of sub-optimal farming conditions.

Vulnerability to climate change

Vulnerability to climate change impacts is determined by the level of economic development and the strength of governance. Economic losses resulting from climate change impacts continue to increase across all regions and seriously threaten small-scale aquaculture farms that are often located in areas that are vulnerable to climate change impacts. Inherent features and attributes of the aquaculture subsector that influence its vulnerability to climate change impacts include:

- Culture environment: many aquaculture systems are in environments that are highly vulnerable to natural hazards, e.g. mariculture sites in coastal areas would be highly exposed to cyclones, storm surges, siltation brought about by flooding (if close enough to river systems), harmful algal blooms and oxygen depletion from the upwelling of anoxic water. Brackishwater culture sites are usually in low-lying areas that are vulnerable to high temperatures and wide temperature fluctuations, storm surges, flooding, erosion, siltation and saline intrusion and freshwater culture systems are vulnerable to drought and water scarcity, flooding and saltwater intrusion.
- Species and system: vulnerability of species and systems as well as institutional and structural adaptation strategies for farmers and at the local level depends on the location of the farms, farm density and production intensity. Generally, dependence on a single species makes the aquaculture subsector more vulnerable. Mollusks in coastal aquaculture are probably the most vulnerable to ocean acidification. Tilapias and carps are considered resilient, are highly adaptable to a wide range of environmental and ecological conditions, the broodstock and hatchery technologies are widely adopted and the culture systems are highly diversified. Several fast-growing strains of tilapias, including saline-tolerant ones, have been bred.
- Farmers: small-scale stakeholders have less adaptive capacity against the threats to climate change impacts compared to large-scale commercial players; hence the focus should be placed in building general adaptive capacity that support small-scale aquaculture producers and value chain actors.
- Industrial aquaculture: commercial and industrial scale aquaculture operations, including seed production facilities depend on a skilled workforce (about 30 percent of the variable cost is labour) and makes industrial-scale aquaculture sensitive to climate change-induced risks, whereas high-tech operations and good management of large farming companies generally offer good risk

prevention and mitigation capability against risks, but remain vulnerable to hazards such as cyclones, red tide and disease.

- Regions: The Intergovernmental Panel on Climate Change Fifth Assessment Report (IPCC AR5) projections point to the higher vulnerability of tropical ecosystems to climate change, including the communities that depend upon the resources for food and economic security. Bangladesh, Cambodia, China, India, the Philippines and Viet Nam were identified as the most vulnerable countries worldwide. A recent assessment identified Viet Nam, Bangladesh, China and Thailand among the most vulnerable considering all culture environments – freshwater, brackishwater and marine.

Mitigation and adaptation strategies

The need for adaptation in the fisheries and aquaculture sectors and the associated challenges are expected to increase with climate change. The IPCC AR5 identified approaches for managing the risks of climate change through adaptation that are built around a sustainable livelihoods framework, and an Ecosystems Approach to Aquaculture Management (EAAM), supported by risk assessment and management along the value chain and a feasibility assessment. The capacity of the main stakeholders to apply these concepts should be developed or strengthened.

The selection or design of adaptation measures should engage the participation of the main stakeholders, that is, the measures selected should be compatible with their livelihood objectives, strategies and assets. The resources and actions needed to strengthen capacities for access and use of assets are widely agreed on and clear and options are not rigidly imposed, so it is reasonable to expect that participation in their implementation is sustained. EAAM integrates the economic, environmental, social and political components of the adaptation measures. It fosters synergy in the governance of the aquaculture subsector and in the other sectors, helps avoid the maladaptation that results from competition over resources and lack of cross-sectoral governance, and provides the opportunity to incorporate policy that reduces the adverse impacts of aquaculture. Value chain-oriented risk assessment and management result in a holistic rather than a piecemeal adaptation measure. As such, it could easily be integrated into a sustainable aquaculture development plan. Feasibility assessments supported by cost-benefit analyses provide the basis for transparent decision-making, showing who bears the cost and who reaps the benefits, and how benefits could be shared equitably. Overall, these tools and strategic approaches would foster coherent and mutually-strengthening adaptation measures among various economic sectors and most probably promote a resilient and highly adaptive social system.

Adaptation and mitigation responses are underpinned by common enabling factors including effective institutions and governance, innovation and investments in environmentally-sound technologies and infrastructure, sustainable livelihoods, as well as behavioural and lifestyle choices. The four widely discussed impacts are: effluent discharge from farms that pollute local freshwater resources, marine environments and other fish farms; the escape of farmed fish that can have detrimental effects on wild fish populations through competition and interbreeding; the spread of parasites and diseases between wild and farmed fish; and the conversion of mangroves into fish farms. Another issue is the use of fish to feed fish, either as ingredient of manufactured feed or as direct food. Nevertheless, aquaculture is an adaptation for the capture fisheries subsector. Aquaculture can be an alternative livelihood for fishers so small-scale aquaculture should be strengthened. Almost all Pacific Island Countries and Territories (PICTs) look to expand freshwater aquaculture (some opt for mariculture) to improve food security in the light of the expected impacts of climate change on capture fisheries. Aquaculture development should be promoted for income and food security for rural families, in areas where it will not compromise other ecosystem functions, such as mangroves. Another recommendation is the use of fast-growing species (fish) to shorten the production cycle and allow early harvest. The increasing adoption of polyculture practices opens opportunities for additional food production and income generation for farmers. Farming a wider variety of species could provide more adaptation options to compensate for the uncertain intensity and timing of climate change effects. Diversifying livelihood enterprises (farm and non-farm) increases coping ability and adaptive capacity to unforeseen and long-term changes.

National plans, strategies and policies for climate resilience in fisheries sector

Countries in the APFIC region have made wide-ranging climate change adaptation and mitigation efforts. All APFIC countries have ratified the United Nations Framework Convention on Climate Change (UNFCCC) and signed the Paris Agreement. Some of the region's least developed countries (including Bangladesh, Cambodia, Lao People's Democratic Republic, Myanmar, Nepal, and Timor-Leste) have developed a National Adaptation Programme of Action (NAPA) on climate change.

Financing climate adaptation and mitigation

All countries work toward securing funds from both national and international sources to support their climate adaptation and mitigation activities. Cambodia, Bangladesh, Sri Lanka and other countries allocate funding from within the country whereas others seek international funding, including from the Global Climate Fund, the Global Environment Facility (GEF), World Bank, Network of Aquaculture Centres in Asia-Pacific (NACA), United States Agency for International Development (USAID), and Japan International Cooperation Agency (JICA).

Climate smart/resistant/resilient fisheries

The APFIC countries are addressing climate change in fisheries production and management planning. Related efforts include climate-smart fisheries for sustainable food security, climate-smart management practices, innovative adaptation technologies, and climate change resistant fisheries products. Some of the specific efforts being made by various countries are:

- Bangladesh has climate change resilient fisheries in its development plan.
- The FishAdapt project in Myanmar strengthens the adaptive capacity and resilience of fisheries and aquaculture dependent livelihoods.
- In line with the Coral Triangle Initiative strategies, Timor-Leste is strengthening the climate-change resilience of coastal communities and improving food security.
- The Philippines has developed recommendations for enhancing the resiliency of fisheries infrastructures.
- Sri Lanka has pilot projects working toward climate resilience and seeks ways to ensure that its national development trajectory can be supported and become more climate change resilient.
- Indonesia has developed guidelines on the adaptation of tuna fisheries to climate changes.
- Malaysia and Indonesia have insurance for fishers.
- Several countries, including Cambodia, Malaysia, Nepal, and the Philippines are working to establish community-targeted early-warning and notification systems regarding climate changes.

Ecosystem Approach to Fisheries Management (EAFM)

Climate-resilient fisheries require a holistic fisheries governance framework to address changing climate. The principles of EAFM emphasize stakeholder engagement, multi-sectoral planning, adaptive management, and a precautionary approach. Planning and decision-making without waiting for complete scientific information has become necessary, and more acceptable, as a means of addressing climate impacts in a proactive manner. Many countries in the Asia-Pacific region have already implemented parts of the EAFM and are building on what they have started. A number of countries have adopted EAFM or are promoting it as a national approach to managing fisheries. These include Indonesia, Lao People's Democratic Republic, Malaysia, Myanmar, Nepal, Philippines,Thailand and Timor-Leste. FAO and other international agencies, including USAID and the United States National Oceanic and Atmospheric Administration, have collaborated with country partners in the AFPIC region to build capacity in EAFM and to help develop and implement EAFM plans.

Collaboration among different sectors and agencies

Efforts have been made to integrate climate change policy with other inter-related national policies and across different sectors, including fisheries and aquaculture. These efforts are taking place at both regional (e.g. Lower Mekong Region) and national levels in Pakistan, Sri Lanka, Viet Nam, and others.

Conservation of fisheries resources

Multiple efforts have been made by countries in the Asia-Pacific region to conserve, restore, and enhance biodiversity and the health of ecosystems and their services in order to realize sustainable social and economic development and improve carbon sequestration. Fish sanctuaries to support biodiversity, stock enhancement programmes, and marine or inland water protected areas have been established in Bangladesh, Cambodia, China, Indonesia, Philippines and Thailand. Conservation and restoration efforts can be found for fisheries dependent habitats such as mangroves, coral reefs, and inland waters in Cambodia, India, Indonesia, Malaysia, Myanmar, Nepal, Philippines, Timor-Leste, and Viet Nam.

Some other national efforts, such as those in China, Malaysia, Philippines and Thailand focus on improving fisheries laws, rules and regulations related to catch size limits, fishing areas, fishing gears or methods. Other efforts focus on regulating boat licensing and controlling fishing capacity. Most countries are focusing on enforcement and other surveillance and monitoring measures to combat illegal, unreported and unregulated (IUU) fishing. There have been efforts to work with fisheries stakeholders to conserve habitats or become involved in other livelihood activities.

Enhancement of fisheries productivity

In addition to the conservation of fisheries resources, many countries make efforts to increase fisheries productivity through stock enhancement, sea/marine/ocean ranching, culture-based fisheries, and improving post-harvest technologies and food safety. Enhancing stocks has been implemented through habitat improvement, through establishing protected breeding and nursery grounds, by installing artificial reefs, by reducing harvest levels, by protecting immature sea life and spawners, and by releasing juveniles into the sea.

Capacity development

Awareness of climate change and its impacts is considered critical for fishers and relevant stakeholders at all levels if they are to engage appropriately in planning, adaptation and mitigation measures. Many countries are working to develop the human resource and institutional capacities of relevant stakeholders to handle climate change related issues. For example:

- Bangladesh has campaigns to create awareness of impacts and risks of climate change in fisheries.
- In India, meteorological, climatological and geophysical agencies are involved in knowledge-building efforts to prepare vulnerable coastal communities.
- Viet Nam has training plans to increase climate change knowledge among staff in the fisheries subsector and mitigation and adaptation knowledge among communities.
- In the Bay of Bengal, Southeast Asia and Coral Triangle countries, ongoing training has been conducted on EAFM, which incorporates the precautionary approach and adaptive management as main principles of fisheries management.

Research, monitoring and evaluation

Research, monitoring and evaluation in fisheries habitats, fisheries activities, and climate change impacts on fisheries are required at both national and regional levels. Based on input from AFPIC countries, a range of research, monitoring and evaluation programmes and activities have been conducted in the region, but knowledge is still lacking and this constrains efforts. Research capacities in climate change analysis and adaptation continue to be strengthened, however. The areas of research being undertakeninclude:

- ongoing development of databases, trends, and forecasts related to the impacts of climate change and climate variability on fisheries habitats (both nearshore and ocean systems), fishing activities, and fisheries resources (including stock assessments and modeling, spatial distribution and migration patterns of important species) in Cambodia, China, India, Indonesia, Malaysia, Philippines, Timor-Leste and Viet Nam;
- rehabilitation and restoration programmes in Indonesia;
- vulnerability assessments, including assessing the fisheries-related costs of climate change;
- adaptation research, e.g., at the Centre for Climate Change and Biodiversity under the National University of Timor, Lorosa'e;
- the socio-economic implications of changes in resources availability;
- carbon footprints in fisheries, as, for example, in tuna fisheries in Indonesia;
- the coping strategies of traditional indigenous fishers in the Philippines;
- gathering research evidence for policy and legislation development in Cambodia and Viet Nam;
- green technology in Malaysia; and
- culture-based fisheries in Cambodia.

Mitigation

National mitigation efforts focused specifically on the fisheries subsector include improving fuel consumption efficiency and the fuel-saving practices of fishing vessels in India, Philippines and Thailand; using solar energy in capture fisheries in India; and the initiation of monitoring, evaluation and energy audits related to fuel use among fishing crafts in India and Thailand. There are also efforts to consider ways of increasing eco-friendly fisheries in Indonesia, for example, as part of the work of the Ministry of Marine Affairs and Fisheries (MMAF) related to climate change adaptation and mitigation. On a larger scale, many APFIC member countries participate in reforestation and the development of alternative energy sources. At the policy level, India and Thailand developed protocols during the Conference of the Parties 21(COP21), making pledges to reduce carbon footprints by lowering greenhouse gas emissions; Indonesia has developed protocols to reduce fuel subsidies; and Pakistan has done the same to promote climate change mitigation to the extent possible in a cost-effective manner.

Climate adaptation in sustainable development to ensure food security

Countries in the region are pursuing sustainable economic development and food security by appropriately addressing the challenges of climate change. The national policy for climate change of Pakistan, for example, fosters the development of appropriate economic incentives to ensure water security, food security and energy security in the face of climate challenges. Timor-Leste is examining the concept of the blue economy, and Lao People's Democratic Republic aims to be out of least developed country (LDC) status by 2020 and is embarking on a path of green growth. In Bangladesh, there is a food security country investment plan and a National Food Policy Capacity Strengthening Programme. In Malaysia, the Department of Fisheries takes responsibility for ensuring food security as fish remains a crucial part of the Malaysian diet.

Involvement of communities

Specific programmes and initiatives have been developed to increase community engagement, and to build the capacities and skills needed within coastal and fishing communities to undertake adaptive actions aimed at reducing vulnerability, mitigating risks, responding to climate change effects, better managing fisheries, and strengthening resilience. Examples include:

- the climate smart village and the National Framework on Local Adaptation Plan in Nepal;
- locally marine managed areas in Myanmar;
- the FAO-supported Good Community Fish Refuges Management Practice, which fosters community fisheries management in Cambodia;

- the outstanding Coastal Community Program in the Philippines;
- the Bangladeshi Safety Networks that aim to achieve enforcement measures and build adaptation and management skills among affected communities in response to climate change effects;
- Indonesian efforts to empower communities in the outer islands;
- a Vietnamese community-building model aimed at actively preventing and mitigating natural disasters and adapting to climate change; and
- co-governance of lagoon and estuary management in Sri Lanka.

Safeguarding vulnerable fishers and populations

Recognizing that a large portion of subsistence and artisanal fishers live below the poverty line, and that resource-poor and marginalized populations from the fisheries subsector are most vulnerable to climate change, several countries have paid special attention and developed programmes and initiatives to assist these groups to better cope with climate change impacts. In Pakistan, one of the objectives of the National Climate Change Policy is to foster pro-poor, gender-sensitive adaptation. In Myanmar, besides using gender-sensitive approaches, there is a child-centered climate change adaptation programme supported by several international agencies. In the Philippines, the People's Survival Fund (PSF) includes poverty incidence and exposure to climate risks as criteria for eligibility to receive from the fund and gender-related activities and processes have been integrated into coastal resource management to enhance coastal resources and reduce poverty among municipal fisherfolk.

National plans, strategies and policies for climate resilience in aquaculture sector

This section summarizes reports of APFIC member countries on specific risks or threats that the aquaculture subsector in the countries are exposed to from climate change-related extreme meteorological events, as well as on national initiatives to address climate change impacts and build resilience in the aquaculture sectors of member countries. It also addresses the major gaps and constraints in building climate-resilient aquaculture and recommended regional strategies and actions to support national efforts to strengthen climate change-resilient aquaculture.

Major aquaculture production systems and commodities

A diversity of species is farmed in countries in the Asia-Pacific region. These include freshwater fish and crustaceans, marine fish, shrimp and other marine crustaceans such as lobsters and crabs, mollusks, seaweeds and other commodities.

In Bangladesh, the major cultured species are Indian major carps, exotic carps, tilapia, pangasius, Thai koi, (climbing perch), indigenous high value species, freshwater prawn (*M. rosenbergii*) and shrimp (*P. monodon*). The production systems include monoculture of tilapia, pangasius, shing, koi and others, as well as polyculture of Indian major carps, exotic carps with other fish species. Shrimp culture is done in brackishwater areas. Crabs and mud eels are also cultured but on a limited scale in selected areas.

Aquaculture farms in Cambodia vary from small-scale farms using on-farm/domestic wastes as inputs to large-scale farms using feeds to produce fish. The main culture systems are cages (50 percent) and ponds mostly in freshwater areas. Aquaculture production is mainly for domestic consumption. The three main species that are cultured are *Channa micropeltes*, *Pangasianodon hypopthalmus* and hybrid catfish. Most of the seedstocks are sourced from the wild except for pangasius, *Barbonymus gonionotus, Leptobarbus hoeveni, Trichogaster pectoralis and Barborymus altus* that are produced in hatcheries. Exotic species that are also cultured include hatchery-produced tilapia, carps (silver carp, common carp, bighead carp, grass carp), Mrigal, and hybrid catfish in ponds. Pond production systems are mostly extensive or semi-intensive (75 percent) and intensive (25 percent). Pangasius, snakehead and hybrid catfish are the three species cultured intensively in ponds. Extensive and semi-intensive pond culture is promoted for family consumption, in areas away from wild fish population sites. The promotion of family fishponds started in

1986 through UNICEF's Family Food Programme. Ponds are from 80 m^2 to 300 m^2. The main species are pangasius, silver barb, carps and tilapia. Stocks are fed farm wastes such as rice bran, duckweed, termites, morning glory and rice-wine waste. Rice-fish culture started in 1997. The main species are silver barb, carps and tilapia. Public hatcheries have been established to serve the seedstock needs of the aquaculture industry. Village hatcheries have also been established in different provinces. Shrimp farming was introduced in the 1990s. Seedstocks are either collected from the wild or are imported. For marine cage farming, the main species are grouper, sea bass, and cobia. The problems with mariculture include unavailability of hatchery-produced seed and reliance on wild and imported seeds.

Aquaculture in China covers a diversity of species groups including finfishes, crustaceans, mollusks, seaweeds and other species. Mollusks comprise 72 percent of mariculture production whereas finfish from freshwater production systems comprise 85 percent of total finfish production. Aquaculture production systems in China include culture in ponds, cages and tanks, as well rice-fish farming, Integrated Multi-Trophic Aquaculture (IMTA) and Recirculating Aquaculture System (RAS).

In India, the major aquaculture systems include pond, cages, pen and tank culture, polyculture, integrated fish farming and RAS. The cultured commodities include carps, pangasius, tilapia, native catfishes, freshwater prawn and ornamental fish, shrimp, marine fish and others.

Malaysia's major aquaculture products are seaweeds (*E. cottonii*), mollusks (cockle, mussel and oyster), shrimp (white shrimp, black tiger) and freshwater finfish (catfish, red tilapia, black tilapia, riverine catfish) and marine finfish (sea bass, grouper, snapper).

Myanmar's major aquaculture commodities include 15 species of freshwater fish, freshwater prawn, marine fish (grouper, snapper, sea bass), marine shrimp, seaweeds and mud crab. Rohu is the main cultured commodity in intensive culture systems. Culture is mainly done in ponds. Extensive and semi-intensive farming of shrimp is done in coastal areas. Groupers and sea bass are grown in cage culture systems. Soft shell crab production is a booming industry and seaweed farming is expanding.

Altogether, 12 exotic fish species have been introduced for culture in Nepal. Major aquaculture systems adopted are carp polyculture in ponds, lakes and enclosures. Cage culture of herbivorous carp species and common carp in rice-fish culture are common practices in the subtropical hill region. Furthermore, the technology of rainbow trout (*Oncorhynchus mykiss*) farming is being scaled up in the temperate region of the country.

Although Pakistan has a coastal belt of about 1 100 km, there is no coastal aquaculture in Pakistan. The commonly cultured species include: indigenous species such as rohu, *Labeo rohita*; Mori, *Cirrhinus mrigala* and Thaila (*catla catla*); exotic species such as silver carp, grass carp, bighead carp, common carp, tilapia; and cold water species such as rainbow trout and brown trout. Ongoing research focuses on the culture and breeding of major carps and Chinese carps. No attention has been paid to the culture of other commercially important species such as the local catfish. Most farms are extensive with a only few semi-intensive ones. However, with the introduction of all-male tilapia culture and catfish culture, intensification and use of artificial feeds may be inevitable.

Philippine aquaculture involves the farming of many species of fish, crustacean, mollusks and seaweeds in different farming systems in freshwater, brackishwater and marine waters. The dominantly farmed species are seaweeds, milkfish, tilapia and shrimp/prawn. Other species include mussel, oyster, carp, mud crab, catfish, grouper, siganids and others. Culture techniques for abalone, sea urchin and sea cucumber are being developed. The majority of aquaculture operations in the Philippines are small scale to medium scale, making the industry very vulnerable to climate change.

Culture-based fisheries in perennial reservoirs are considered to be the main provider of fish protein to rural villagers in Sri Lanka. Shrimp culture is mainly in earthen ponds. Ornamental fish culture is also a major activity, which brings foreign exchange. In addition, marine ornamental fish are also exported. This

subsector is totally dependent on the wild stocks and currently over 200 marine species belonging to 40 families are being exported. One of the emerging aquaculture systems is sea cucumber fattening. Several pilot projects on sea cucumber fattening, sea bass cage culture, oyster culture and seaweed farming have become successful. The existing culture systems include: culture-based fisheries in major, medium, minor and seasonal reservoirs (tilapia, carps); shrimp farming (tiger prawn, extensive); ornamental fish farming (seeds are collected from the wild); cage culture and pen culture (sea cucumber, marine fish); pond culture (fish); and seaweeds culture. Moreover, in Timor-Leste, the cultured species include tilapia, catfish, common carp, white shrimp, seaweed, mud crab, milkfish and grouper.

Aquaculture in Thailand consists of coastal aquaculture and inland aquaculture. The main species cultured in brackishwater ponds are the black tiger prawn and the Pacific white shrimp. The major cultured finfish species are sea bass and grouper in cages or in ponds. Green mussel, blood cockle, and oyster are cultured along the coast. Coastal aquaculture usually produces high-value products – white shrimp and black tiger prawn are mainly for export whereas marine fish and shellfish are mainly for domestic consumption. Freshwater fish species are cultured in ponds, cages, paddy fields and ditches. The main freshwater species cultured are Nile tilapia, catfish, silver barb, giant river prawn and snakeskin gourami. Inland aquaculture production is also mainly for domestic consumption.

Viet Nam's top aquaculture products are catfish, shrimp and mollusks (oysters, clam). Production in the Mekong Delta accounts for 70 percent of total production and export. Brackishwater shrimp (whiteleg shrimp and tiger shrimp) are cultured in intensive and semi-intensive culture systems. Pangasius farms are 100 percent intensive culture systems.

Specific threats/risks of climate change and climate change-related extreme meteorological events to aquaculture

Climate change-related events impact on the environment, fisheries resources, aquaculture production, livelihoods, as well as on food and nutrition security. The threats and risks of climate change and climate change-related extreme meteorological events that are common to countries in the Asia-Pacific region include:

- increase in frequency and intensity of cyclones/storms – can cause floods, landslides and erosion that could result in damage to aquaculture facilities and other infrastructure, mortalities or escape of stocks, production losses, water pollution, and increased production costs (e.g. for repair and rehabilitation of facilities and other infrastructure and procurement of new stocks and other inputs);
- extended periods of heavy rainfall – can also cause floods, landslides and erosion that could result in damage to aquaculture facilities and other infrastructure, mortalities or escape of stocks, production losses, water pollution, increased production costs (e.g. for repair and rehabilitation of facilities and other infrastructure, procurement of new stocks and other inputs) and flooding (loss of fish stocks, increased risk of accidental introduction of exotic species and possible impact on biodiversity); also lower water salinity in open culture systems such as in brackishwater ponds or cause salinity stratification in marine cage area that may be stressful to the cultured organisms and predispose them to diseases;
- extended periods of low or no precipitation (drought) – result in reduced availability of water and reduction in areas suitable for farming; reduced water flow will have a negative effect on water quality; increased temperature will reduced feeding activity, result in poor growth, cause stress to the cultured organisms and predispose them to diseases; reduce production or cause production losses;
- increased or wide fluctuations in temperature – can affect captive breeding and seed production activities; high temperatures can hamper maturation and spawning in many species, affect quality of eggs and larvae and reduce seed production; reduce feeding activity and growth of stocks, may predispose stocks to diseases and result in lower production or production losses; and

- sea level rise – can cause seawater intrusion into coastal ecosystems and culture systems causing stress to cultured stocks as well as wild resources, especially freshwater species; can affect biodiversity.

National efforts addressing climate change and strengthening climate resilience in aquaculture

Initiatives geared towards strengthening climate change resilience in the aquaculture sector that are undertaken by the countries in the Asia-Pacific region include interventions in terms of adoption of improved or adaptive technologies, research and development (R&D) of climate change-resilient technologies or practices, capacity building and mechanisms to support farmers, and legislative framework that facilitate response, mitigation and adaptation measures to the impacts of climate change-related extreme weather events.

Adoption of climate-adaptive technologies or practices

- improvement of aquaculture management practices;
- diversification of culture systems (culture in pens and cages, coastal or offshore culture); adoption of new technologies (e.g. RAS, use of temperature control system in breeding and hatchery facilities);
- use of fast-growing species or advanced or larger-sized fingerlings that are suitable for short-term culture (e.g. in seasonal ponds);
- farm species that can thrive with little water (e.g. catfish);
- adoption and promotion of saline-tolerant strains (e.g. tilapia) in coastal areas and sites vulnerable to saltwater intrusion or cold-tolerant species (e.g. blue tilapia that can be farmed in cold places);
- development, adoption, promotion of adaptive culture systems such as RAS, rice-fish culture, integrated culture or IMTA; and
- improvement of infrastructure (e.g. building big and deep water reservoirs or fish ponds that can hold more water during periods of drought); exploitation of groundwater for additional source of water.

R&D of climate change-resilient technologies or practices

- selective breeding or strain/genetic improvement programmes to ensure continuous supply of quality seeds (including marine plants) that are climate change–tolerant (e.g. temperature-tolerant, saline-tolerant, disease-resistant; developing strains that are adapted to higher temperatures);
- innovation in farm system management (e.g. environment-friendly aquaculture such as zero waste aquaculture, water recirculation and closed system aquaculture, offshore farming of green mussel to remove organic matter in seawater); refinement of RAS and IMTA;
- monitoring of climate change-related impacts and threats including fish health monitoring, health certification for imported seeds and broodstock; toxicity tests for biotoxins (e.g. for paralytic shellfish poisoning (PSP) and compliance with good aquaculture practices in farms and certification schemes;
- analysis of the relationship between atmospheric data and water parameters and impact of primary production and yield; establishment of baseline for monitoring of several climate change-related parameters in the nearshore ecosystem of Timor-Leste funded by NOAA, 2017;
- development of a GIS-based Vulnerability and Suitability Analysis (VSA) system for capture fisheries and aquaculture that will rank areas based on their vulnerability to physical and climate hazards that will help in investment planning, implementation and mitigating the effect of or preventing potential losses caused by climate change;
- finding suitable sites (e.g. shrimp farming in the desert, a collaborative project between the Republic of Korea and the National Institute for R&D for Fisheries and Aquaculture of Algeria to pilot shrimp farming with little water, high temperature and unstable salinity); delineation of appropriate aquaculture zones, diversification of species/development of techniques for farming of suitable new species or varieties;

- climate change-resilient designs of aquaculture facilities and infrastructure (e.g. pond reconstruction); and
- research on carbon sequestration and aquaculture as carbon sinks (e.g. culture of mollusks and seaweeds) or culture of low carbon footprint species.

Awareness and capacity development and mechanisms to support farmers and vulnerable groups

- campaigns to create awareness regarding climate change, climate change-related extreme weather events and their impacts/threats and risks to aquaculture, livelihoods and others;
- programmes to increase adaptation management skills in response to climate change impacts and increase institutional capacity to handle climate change-related issues (e.g. the project "Building capacity for integrating climate change adaptation in the fisheries sector in Cambodia" implemented by the Fisheries Administration (FiA) in collaboration with WorldFish with funding from the Cambodia Climate Change Alliance; the FAO FishAdapt project in Myanmar that aims to strengthen the adaptive capacity and resilience of fisheries and aquaculture dependent livelihoods; the project "Building capacities for climate resilient tilapia farming" in the Philippines, funded by FAO, that aims to increase the resiliency of the pond-based tilapia producing subsector from the negative externalities imposed by climate-weather risks, primarily their impact on farm productivity; this tilapia project has been expanded to include other major aquaculture commodities); and
- early-warning system developed from web and mobile-based information and communication technologies (ICT) applications that will assist farmers in mitigating climate hazards and risks through provision of relevant climate information and farm advisories at the local level and strengthen the adaptive capacity of the community against climate uncertainty.

Framework for action

- Bangladesh's initiatives towards climate-resilient aquaculture are embodied in the Bangladesh Climate Change Trust Fund (BCCTF), Bangladesh Climate Change Resilient Fund (BCCRF), National Action Programme on Aquaculture (NAPA), Bangladesh Climate Change Strategy and Action Plan (BCCSAP-2009), National Food Policy Capacity Strengthening Programme (NAPCSP), and Food Security Country Investment Plan. Climate change issues are also included in the Department of Fisheries development projects.
- Cambodia's National Committee for Disaster Management (NCDM) with representatives from 22 different ministries is responsible for disaster management to support provincial, district, and commune committees. The NCDM developed the Strategic National Action Plan (SNAP) for Disaster Risk Reduction. The Ministry of Agriculture, Forestry and Fisheries also has the Plan of Action for Disaster Risk Reduction in Agriculture (2014–2018). Moreover, the FiA has also developed strategic plans for fisheries and aquaculture to cope with climate change. Some activities related to development of climate-resilient fisheries and aquaculture have been carried out in 2014 including capacity building for FiA personnel at national and sub-national level and training of other stakeholders including women. The FiA also plans more climate change-related projects with local communes especially in areas affected by climate impacts.
- Malaysia's national strategies and action plans include the establishment of the Fisheries Biosecurity Division in the Department of Fisheries to address, among others, prevention and monitoring of disease outbreak as well as to control imported seed and broodstock.
- Initiatives and programmes of Lao People's Democratic Republic to mitigate and adapt to climate change include: the Initial National Communication (INC) in collaboration with UNDP/GEF in 2000, the National Capacity Needs Self-Assessment (NCSA) for Global Environment Management under the three Rio Conventions – UNFCCC, United Nations Convention to Combat Desertification (UNCCD) and the United Nations Convention on Biodiversity (UNCBD) – in collaboration with UNDP/GEF (May 2009); the National Adaptation Programme of Action (NAPA) in collaboration with UNDP/GEF (May 2009); the Second National Communication which is under preparation, the

Reduction of Emissions from Deforestation and Degradation (REDD), Readiness Preparation Planning (R-PP) and Framework – Department of Forestry (under implementation).

- Under the Republic Acts No. 9729 and No. 10174 (Climate Change Act of 2009), the Philippine Department of Agriculture (DA) created the Adaptation and Mitigation Initiatives in Agriculture (AMIA) project, which aims to achieve climate resiliency both in the agriculture and fisheries communities. The BFAR-AMIA, which comprises the Bureau of Fisheries and Aquatic Resources (BFAR) and the National Fisheries Research and Development Institute (NFRDI), is under the DA-AMIA. Initiatives already undertaken include the conduct of vulnerability assessment for capture fishery and aquaculture, formulation of national strategy framework on climate change, development of fisheries management strategies to address climate change, and recommendation of climate change related policies. The development of the disaster risk reduction management operation manual to mitigate the effect of climate change risks for fisheries is ongoing.
- The national efforts of the Republic of Korea towards strengthening climate change-resilient aquaculture include: the establishment of legal frameworks such as Acts concerning climate change e.g. Sustainable Development Act, Framework Act on Low Carbon, Green Growth which have been amended into the Green Economy Acceleration Act and the Climate Change Action Act; comprehensive governance (e.g. action during occurrence of red tides is coordinated by the Ministry of Oceans and Fisheries with the Ministry of Environment (R&D), Ministry of Interior and Safety (logistics, e.g. provision of helicopters and vessels), Ministry of Science and ICT (prevention facilities) and the different national agencies and institutions (forecast), regional offices (monitoring), public service-related organizations (prevention plan) and local cities (restoration and training); international cooperation that addresses Sustainable Development Goal (SDG) 14 (conserve and sustainably use the oceans, seas and marine resources for sustainable development) with six voluntary commitments: minimize the impact of marine acidification in the Pacific, capacity building, sustainable fisheries, development assistance, fisheries resource management.
- Climate change issues are given the highest attention by the Government of Sri Lanka, which has established the Climate Change Secretariat within the Ministry of Environment and formulated the National Climate Change Adaptation Plan Strategy for 2016–2025. Furthermore, the new Fisheries Policy considers the importance of climate change impacts.
- Thailand's Climate Change Master Plan 2015–2050 embodies the government's approach on adaptation, mitigation and capacity building. The Agriculture Strategic Plan on Climate Change 2017–2021 is based on established databases and technology, adaptation actions and mitigation actions. The aquaculture activities under the Department of Fisheries not only demonstrate responsible and sustainable aquaculture systems but also support green/blue economy development by promoting efficient utilization of aquaculture resources, reducing impact on the environment, increasing the resilience of farmers and improving their quality of life.
- The Government of Timor-Leste's Strategic Development Plan (SDP) 2011–2030 commits Timor-Leste to develop a National Adaptation Programme of Action (NAPA), to identify national priorities to address climate change adaptation and to monitor the implementation of adaptation measures. Timor-Leste ratified the UNFCCC on 11 April 2006, the Kyoto Protocol in March 2008, and submitted its NAPA in 2011 and INC in 2014. Climate change impacts and vulnerability assessments were undertaken for both NAPA and INC. The country has started its Initial National Communication to the UNFCCC with the support of the Global Environment Facility, the Australian Agency for International Development (AusAID) and the United Nations Development Programme (UNDP).
- The Vietnamese Government and the Ministry of Agriculture and Rural Development (MARD) have issued many important strategies and policies to cope with climate change including the National Target Programme to Respond to Climate Change, the National Climate Change Strategy and the National Action Plan on Climate Change for the period 2012–2020. The Vietnamese Assembly is preparing the Fisheries Law, which will regulate fishery activities to cope with climate change. Viet Nam's strategies and policies have four objectives: (1) adapt to changes in temperature, rainfall and salinization; (2) adapt to changing frequency and intensity of storms, and floods; (3) environmental and disease monitoring, and waste management; and (4) raising awareness about climate change.

Major gaps and constraints in building climate-resilient aquaculture

The identified gaps and constraints include:

- limited information on climate change and its impacts on aquaculture – knowledge gaps on climate change and its projected impact are still apparent especially to those not directly involved in climate change discussions; massive information dissemination must be conducted both in the national and local level to improve the understanding of the issue;
- in most cases, basic data on the vulnerability and risk assessment of aquaculture to climate change, as well as mitigation and adaptation capacity are lacking; mapping of aquaculture zones is also needed;
- impact of climate change on the biology of fish such as reproduction and early development (e.g. maturity, spawning, hatching, survival of larvae, etc.) is largely unknown;
- need to enhance capacity for innovations to improve the existing adaptability of fish farmers/ entrepreneurs and resilience of the aquaculture sector in general;
- lack of resources and funds or programmes for climate-resilient aquaculture including investments in infrastructure to cope with disasters brought about by climate change-related extreme weather events, lack of funds for rehabilitation of damaged facilities, human resources and institutional capacity building programmes and R&D programmes;
- lack or low adoption of an aquaculture insurance system – an aquaculture insurance instrument provides immediate financial assistance to farmers for speedy rehabilitation, resumption of operations and recovery;
- lack of support mechanisms for farmers including early-warning system, breeding facilities that could supply the seed requirements, disease monitoring and technical assistance in various aspects of operations affected by climate change;
- lack of alternative or supplemental (seasonal) livelihoods for vulnerable groups; and
- identified strategies and action plans do not specifically deal with aquaculture.

Recommendations on regional strategies and actions to support national efforts to build climate-resilient aquaculture

The recommendations include:

- Provide a regional platform for increasing the knowledge base and information-sharing on climate change events, impacts, mitigation and adaptation strategies in order to strengthen climate resilience in the aquaculture sector. This can involve capacity building programmes (regional training, workshops, study tours/field visits/exchange programmes), dissemination of relevant information, promotion and adoption of innovative adaptive technologies and practices that contribute to a climate change-resilient aquaculture sector.
- Develop an early-warning system for climate change or weather-related events and impacts (e.g. disease outbreaks, harmful algal blooms, upwelling) at the local, national and if possible, regional level.
- Promote regional research cooperation programmes or research networks focused on climate change R&D, and foster collaboration among research institutions, industry and communities to jointly address the impacts of climate change.
- Integrate climate change issues (impacts, risks, threats, vulnerability, adaptation and mitigation) in national fisheries and aquaculture policies, strategies and programmes, as well as in regional frameworks and allocate the necessary funds (e.g. under the Green Climate Fund and programmes dealing with the global commons).
- Promote the use of EAA when carrying out restoration work in coastal areas (particularly in mangrove areas).

Initiatives by international, regional and intergovernmental organizations and the private sector to address fisheries/ aquaculture-related climate change issues

Network of Aquaculture Centres in Asia-Pacific (NACA)

NACA and its partners have played a vital role in implementing activities, such as:

- strengthening adaptive capacities to the impacts of climate change in some member countries under the AquaClimate Project;
- implementing culture-based fisheries development focused on low emission food production in Lao People's Democratic Republic and Cambodia;
- sharing meetings on Climate Change and Disaster Risk Reduction in Nepal and Efforts for Strengthening Adaptive Capacity to Climate Change in aquaculture and fisheries;
- environmental monitoring and early-warning systems for fisheries and aquaculture in the Lower Mekong Basin;
- organization of Global Conference on Climate Change Adaptation within Fisheries and Aquaculture (FishAdapt);
- sharing experiences on the ground; adaptive learning in sustainable aquaculture – best practices for small-scale shrimp farmers in Thailand;
- conducting a seminar on food security through sustainable aquaculture development and disaster risk reduction in Bangladesh, as well as activities to address climate change implications and conduct an aquaculture inventory to improve the subsector's capacity to adapt to climate change impacts;
- a regional training programme in aquaculture governance in the Asia-Pacific region;
- strategic network programme to promote smallholder farmers networks for aquaculture genetic improvement, e.g. National Broodstock Improvement Network (NBIN) in a variety of environments and farming systems;
- pilot programmes for emergency rapid appraisal of genetic biodiversity, inbreeding and adaptive capacity in small-scale aquaculture systems; and
- planting mangroves for integrated multiple benefits.

Southeast Asian Fisheries Development Center Aquaculture Department (SEAFDEC/AQD)

SEAFDEC/AQD's programme on climate change addresses the important issues discussed and the recommendations made during the 2011 ASEAN-SEAFDEC Conference on Sustainable Fisheries for Food Security Towards 2020 otherwise known as Fish for the People 2020: Adaptation to a Changing Environment. The objective of this conference was the "sustainable use of aquatic resources and reduced vulnerability to climate change by fishing communities in the ASEAN region."

The aquaculture-related goals are to identify changes in the environment brought about by the changing climate that may affect the subsector, minimize and mitigate the adverse impacts of climate change on aquaculture, and ensure the continued operation of aquaculture production systems under changing climatic conditions. The objectives are: (1) to gather scientific information on the susceptibilities of various aquaculture species to the combined effects of increasing seawater temperature and acidity; (2) to gather scientific data on the effects of climate change to production of natural live food organisms for hatcheries and for pond culture systems; (3) to promote public awareness of the possible effects of climate change to aquaculture activities and to the fish farmers; (4) to assist other government agencies in the country and in the region in gathering baseline information on aquaculture areas/sites that are vulnerable to climate change effects; (5) to gather scientific information that will serve as the basis for the formulation/ design of alternative aquaculture systems that are adaptive to climate change; (6) to collaborate with other

institutions in the country and in the region in gathering baseline information on the effects of climate change to mangrove and coral reef ecosystems; and (7) to explore potential adaptive measures to mitigate the impacts of climate change on the different aquatic farming systems.

Southeast Asian Fisheries Development Center Training Department (SEAFDEC/TD)

There are three SEAFDEC programmes supporting regional and subregional initiatives addressing fisheries/aquaculture issues in relation to climate change:

1) Optimizing Energy Use and Improving Safety in Fishing Activities (SEAFDEC/Training Department, 2013–2019) with the main objectives of enhancing the knowledge and experience of ship owners, fisheries extension officers, and other key stakeholders of ASEAN Member States, and of conducting research and development to improve fishing operation/practices and optimize energy use;
2) Adapting to Climate Change (SEAFDEC/Aquaculture Department, 2012–2020). The long-term objective of the programme is to ensure that the production of important aquaculture commodities will continue even under conditions of higher temperatures and more acidic waters for the dual purpose of maintaining continuous supplies of food fish and creating opportunities for family income generation. To achieve this, scientific information is necessary as a basis for future interventions and SEAFDEC has developed a wide range of activities to generate and disseminate such information, and is collaborating with relevant institutions in the countries and in the region; and
3) Fisheries and Habitat Management, Climate Change and Social Well-being in Southeast Asia (SEAFDEC/Secretariat, 2013–2018). The key objectives of this cooperative programme are to sustain the use of aquatic resources and to reduce vulnerability to climate change by coastal/rural (fishing) communities in the ASEAN region.

International Union for Conservation of Nature/Mangroves for the Future (IUCN/MFF)

The work programmes focus on the relationships between aquaculture and marine protected areas (MPAs), sustainability of fish feed and aquaculture, IMTA, ecosystem-based approaches to aquaculture and carrying capacity and Mangroves for the Future (MFF). MFF was established in 2006 as a response to the Indian Ocean tsunami disaster of 2004 and has evolved from being a relief programme (in six countries) to a strategic programme for sustainable development with a focus on transformative adaptation and community resilience in 11 countries. MFF projects include habitat restoration, MPA management, local livelihoods development, education, awareness, private sector engagement, social empowerment, women empowerment. Cross-cutting issues include gender mainstreaming, conflict sensitivity, climate change, land tenure and resource tenure. MFF supports MPA work in Cambodia, Bangladesh, Viet Nam, Pakistan, Myanmar and Thailand. Other projects in the pipeline include: "Building climate resilient coastal communities in Asia" funded by the Green Climate Fund; "Including mangroves and associated coastal ecosystems in REDD+ Agenda in the Asia Region" supported by the Norwegian Agency for Development Cooperation (NORAD); "Building resilience of coastal communities through women's economic and political empowerment" (also supported by NORAD); establishment of a regional/transboundary MPA, and establishment of mangrove polyculture models using shrimp or crabs.

Bay of Bengal Programme – Inter-Governmental Organisation (BOBP-IGO)

With an emphasis on high seas and national waters, the Bay of Bengal Programme – Inter-Governmental Organisation (BOBP-IGO), which comprises Bangladesh, India, Maldives and Sri Lanka, has a goal to ensure that "an environment for sustainable fisheries governance is in place in the region." This regional organization focuses on micro- or intra-sectoral issues that are related to improving occupational safety, improving sustainable fisheries management systems in the region, and building capacity in fisheries

management agencies to monitor and report possible impacts of climate change. At the macro-level, BOBP-IGO is coordinating with other concerned agencies in the region to build good governance in the fisheries subsector through an ecosystem-based fisheries approach. The BOBP-IGO is also attempting to use green technologies to reduce the carbon footprint of fisheries. Additionally, BOBP-IGO is assisting in community preparedness through collaborative programmes with international non-profits, inter-governmental organizations and government agencies on the conservation of marine biodiversity. It is also participating in government-level dialogues on management of shared ecosystems and is conducting knowledge audits and information dissemination.

Mekong River Commission Secretariat

The Environmental Management Division of the Mekong River Commission Secretariat assessed the impacts of climate change on wild fish catches under different climate change conditions and scenarios in the Lower Mekong Basin and provided policy recommendations for climate adaptations with regards to capture fisheries in the area. The climate change effects were grouped into three categories: flood alteration, salt intrusion, and water temperature increase. In conclusion, the magnitude of changes with respect to wild fish is expected to be greater in flood zones than in rice paddies, and the changes are anticipated to be greater when development is taken into account. Suggested adaptation strategies focused on maintaining and enhancing production in the more resilient rice paddies areas and taking fisheries sustainability into consideration for the selection and design of infrastructure development.

Sustainable Development Foundation (SDF)

SDF monitors the cockle farms in the Bang Taboon Subdistrict of Phetchaburi, Thailand to document impacts of climate change and develop adaptive capacity among cockle farmers. Bang Taboon is the first area that started cockle farming and is the largest cockle farming area in Thailand. It provides the main source of income of about 420 families of coastal households. This is now down to only 40 families because of various problems in cockle production related to increasing trends in temperature, variability in rainfall and consequently salinity and other water quality parameters.

WorldFish

WorldFish is one of the 15 agricultural organizations under the CGIAR (formerly known as the Consultative Group for International Agricultural Research and now simply known as CGIAR) network. It has Asia-Pacific research programmes in Bangladesh, Cambodia, India, Malaysia, Myanmar, Solomon Islands, and Timor-Leste. WorldFish-Bangladesh has been in operation since 1987.

The current WorldFish-Bangladesh research programme is based on four main projects:

- "Enhanced coastal fisheries in Bangladesh (Ecofish)", focusing on hilsa management.
- "Aquaculture for income and nutrition (AIN)" in southwest Bangladesh, which is funded by USAID as part of its Feed the Future initiative.
- "Suchana: ending the cycle of undernutrition in Bangladesh", implemented by a consortium led by Save the Children and focused on two districts in northeast Bangladesh.
- "Fish Agri-Food Systems research program (FISH CRP)", which is managed by WorldFish as part of its global research strategy and funded by the CGIAR.

Other projects include: community-based fisheries management in northeast Bangladesh, work on fish health, multi-stakeholder networking projects, ecoponds and the CGIAR "Climate Change, Agriculture and Food Security (CCAFS)" programme, which has been testing climate smart technologies. The "Climate smart farm project" tested a range of technologies in southwest Bangladesh, primarily alternative growing methods for vegetables in salinity-affected areas.

A number of strategies to address climate change impacts have been tested including livelihood diversification, improved information, infrastructure development and ecological conservation. There may be opportunities for adaptation (e.g. using saline tolerant species for aquaculture or short-cycle species in areas that will be affected by drought). WorldFish has tested a number of technologies including:

- installing fish rings or habitats in seasonally flooded rice fields;
- using raised beds and ditches as an integrated farming system;
- improving the quality of habitat in small ponds and ditches to protect fish;
- community water management schemes; and
- providing alternative income generating opportunities for fishers.

Asian Institute of Technology (AIT)

AIT is an international postgraduate institute for regional cooperation established in 1959. AIT's Aquaculture and Aquatic Resource Management (AARM) programme started in 1982 and focuses on research and development (R&D) on innovative aquaculture systems appropriate for the region, develops relevant research partnerships, and promotes sustainable aquaculture innovations by closely collaborating with industry. The current sustainable aquaculture platform is anchored on improving productivity (genetic and genomic selection, disease diagnosis and health management), fishmeal replacement (alternative ingredients, feed additives, probiotics), alternative energy sources (solar power, energy from waste), and efficient water utilization (biofloc and aquamimicry technology, RAS, aquaponics, IMTA, rice-fish farming). Efforts towards developing climate-resilient aquaculture include enhanced R&D on climate-resilient technologies such as the use of new species that are temperature and salinity tolerant, or improved farming methods such as cage culture technology, IMTA, etc. There is also a focus on institutional capacity development as well as development of entrepreneurial capacities and developing good governance, and strengthening the academic curriculum by adding programmes on climate-smart aquaculture.

Charoen Pokphand Group Co., Ltd.

The company's goal for 2020 is to reduce greenhouse gas emissions from its aquaculture operations per unit of revenue by 10 percent in comparison to 2015. Aquaculture has evolved from extensive but labour-intensive culture systems, to semi-extensive but skills-intensive culture systems, to intensive culture systems that apply more devices and automated systems, and to precision aquaculture systems that make use of more more sophisticated devices (e.g. sensors), data analysis and Internet of things (IoT). Smart aquaculture is anchored on small facilities (RAS, smart greenhouse, warm wall insulation), water quality management (use of probiotics, bioremediation), aeration system (use of aerator and oxygenator), IoT and sensors (environmental monitoring and control system for DO, pH, NH_3, etc. using sensors), feeding system (automatic feeders, demand feeders), and biosecurity control system (disease monitoring and control system).

Evaluation of GHG emissions from aquaculture activities shows that 93.53 percent comes from electricity consumption and 6.47 percent comes from consumption of fuel and others. Key projects to reduce power consumption and GHG emissions include the use of heat pump, blower management, automatic DO controller system, DO sensor development, solar floating projects, and the low emission supporting scheme (LESS) programme. The goal is more productivity with the highest efficiency and fewer adverse environmental impacts.

Southeast Asia global change System for Analysis, Research and Training (SEA-START)

The Upper Gulf of Thailand (UGOT) serves as one of the main mariculture areas in Thailand, especially bivalves. The UGOT receives water, nutrients, and organic matters from the north and central plain of Thailand through four main rivers namely Mekong, Tachin, Chaopraya and Bangpakong. As such, this part

of the gulf provides substantial marine resources and other ecosystem services. However, the environment in this region was altered by human activities. Application of chemical fertilizers and expansion of cultivated land are often considered to be the two main options to increase agricultural production. These practices lead to enrichment of nutrients in the river waters that flow into the UGOT. Other nutrient sources to the UGOT are from food and feed related industrial wastes and domestic wastes. SEA-START documented incidences of mass mortality of fish in the UGOT and determined the range of hypoxic conditions in different areas/sites within the Gulf in relation to season, prevailing climatic conditions and other factors that may have contributed or caused the fish kill incidences.

FAO FishAdapt: Strengthening the adaptive capacity and resilience of fisheries and aquaculture-dependent livelihoods in Myanmar project

The fisheries and aquaculture subsector in Myanmar is critically important to the country's food and nutrition security and its economy. However, the aquaculture subsector is expected to be exposed to hazards such as salt-water intrusion, flooding in ponds, water shortages, invasive species and ad hoc development planning.

The objective of the "FishAdapt: Strengthening the adaptive capacity and resilience of fisheries and aquaculture-dependent livelihoods in Myanmar" project is to enable inland and coastal fishery and aquaculture stakeholders in Myanmar to adapt to climate change by understanding and reducing vulnerabilities, piloting new practices and technologies, and sharing information. The project addresses the main barriers to climate change adaptation including: lack of climate-resilient subsector policies and limited integration of fisheries-specific climate responses to national policies; lack of capacity and resources within the subsector to support communities in planning and responding to climate-related stressors and fisheries and aquaculture adaptation to climate change impacts; limited knowledge sharing and communication within the subsector and with fisheries and aquaculture dependent communities; limited coordination and lack of realtime/working level understanding of climate change and its impacts on fisheries, aquaculture and livelihoods.

The project aims to: 1) enhance capacity of stakeholders to address climate change issues through improved relevant national policies and strategies facilitating a climate-resilient fisheries and aquaculture subsector; 2) increase the knowledge and reduce the vulnerability of fishers as well as small-scale fish farmers in coastal and inland regions of Myanmar to climate change and disasters and develop/demonstrate critical adaptation practices and technologies; and 3) enhance understanding and access to adaptation practices and technologies to enable stakeholders to manage information and scale up adaptation in the fisheries and aquaculture sector. The project is funded by the Global Environment Facility (GEF).

Bay of Bengal Large Marine Ecosystem (BOBLME) Project

The FAO Bay of Bengal Large Marine Ecosystem Programme (BOBLME) is promoting EAFM, which emphasizes the balance between ecological and human well-being through governance systems that incorporate climate change considerations. To support capacity building, they have developed a training course that has benefitted numerous middle-level managers across the eight Bay of Bengal countries, namely, Bangladesh, India, Maldives, Sri Lanka, Indonesia, Malaysia, Myanmar, and Thailand.

During the first phase of the project, a Strategic Action Programme (SAP) was developed and signed by the eight countries. The SAP will be implemented during the second phase, where capacity development on EAFM will continue and there will be a new focus on EAFM pilot plan design and implementation, incorporating climate change concerns.

Though the BOBLME phase one did not specifically focus on addressing climate change, many of the interventions laid the foundation for incorporating factors related to climate change in the future during the SAP implementation phase. The study on seasonal migratory patterns of hilsa, the capacity development on EAFM and exploratory ecosystem modeling are important initiatives for incorporating climate change into fisheries management. Ecosystem characterization of the BOBLME, coral reef studies along Malacca Straits and the Myeik Archipelago are interventions that also address the effects of climate change on critical habitats. Other climate change-related initiatives include "Contributions to monsoon onset monitoring and its social and ecosystem impact (MOMSEI)" and the installation of biogeochemical sensors in data buoys in the "Research moored array for African-Asian-Australian monsoon analysis and prediction (RAMA)".

FAO-Bangladesh: Community-based climate-resilient fisheries and aquaculture development in Bangladesh

Bangladesh formulated the National Adaptation Programme of Action in 2005, which was updated in 2009. NAPA prioritized two fisheries projects: adaptation strategies in areas prone to enhanced flooding in the northeast and central region through adaptive and diversified fish culture practices; and promoting adaptation through the culture of salt-tolerant fish species in the southwest region. The project objectives include: removal of key barriers to adaptation to climate change; strengthening resilience through capacity building/development and policy reform; enhancing local adaptive capacity through transfer and adoption of site-specific climate-resilient interventions and approaches, effective knowledge management (e.g. use of ICT-based climate and disaster information services); strengthening awareness and knowledge of local communities; and ensuring wider dissemination of best practices and lessons learned.

The project has four components: 1) climate resilient fisheries sector through relevant national capacity development; (2) strengthening knowledge and awareness of fisheries/aquaculture dependent communities facing the adverse impacts of climate change; (3) enhancing local adaptive capacity to support climate resilient fisheries and aquaculture management and alternative livelihoods in the face of climate change; and (4) dissemination of best practices and lessons learned, monitoring and evaluation.

Risks and recommendations identified by the workshop participants

To reflect the diversity of issues faced in the region and the different needs of aquaculture and fisheries, the workshop participants were divided into fisheries and aquaculture working groups and then into regional clusters. Their tasks were: 1) to identify the threats/risks resulting from climate variability and change; 2) to identify the subsector's contributions to GHG emissions; 3) to identify gaps and constraints with respect to efforts to achieve climate-resilient fisheries and aquaculture; and 4) to recommend strategies and actions at regional and national levels for addressing climate change impacts and climate variability to strengthen the climate resilience of fisheries and aquaculture.

Major risk and threats of climate change impacts and climate variability to fisheries

Physical changes that impact fisheries habitats:

- increase in weather extremes;
- changes in rainfall and water resources;
- hydrological changes, including flows, connecting channels, and floods;
- decline of inland water habitats;
- sea level rise;
- increased storm impacts;
- coastal erosion;
- increase in air temperature;
- increase in sea surface temperature that causes mass coral bleaching and loss in ecosystem services, including breeding and nursery, tourism, etc.;
- changes in salinity level;
- changes in acidification level;
- changes in siltation and sedimentation; and
- degraded, lost and changed habitats, including forests, watersheds, wetlands, floodplain areas, inland water, and others.

Biological changes that impact fisheries production:

- reduced biodiversity and loss of species;
- changes in migration and distribution patterns;
- changes in species and fisheries resource composition;
- changes in biological attributes, e.g. fecundity, reproduction, recruitment, maturity, etc.;
- decline of endemic and native freshwater species;
- reduction of fishery productivity; and
- changes in biomass and reduction of some commercial marine and freshwater species.

Impact on fisheries:

- decline of fisheries supplies and lower catch;
- changes of gear and fishing areas;
- limited raw material for post-harvest processing;
- need for more energy to preserve fisheries products;
- high and fluctuating fisheries costs and fish prices; and
- decline and loss of income, especially among small-scale fishers.

Socio-economic impacts:

- lower food security as a result of the declining availability of fish;
- reduced job opportunities and loss of livelihoods;
- loss of life and property;
- credit risks;
- idiosyncratic risks (related to day-to-day business);
- transitory shocks;
- intra-sectoral and inter-sectoral conflict risks;
- disruption in basic production support services; and
- resettlement delays.

Major risks and threats of climate change-related extreme meteorological events to aquaculture

Production processes:

- aquaculture infrastructure/facilities may be vulnerable to damage and destruction caused by the increasing frequency and intensity of extreme weather events (tropical cyclones and high precipitation that could result in flooding);
- loss of stocks/escape during floods;
- production losses;
- reduction of culture areas because of lack of water from lack of precipitation/drought;
- low survival and production (in hatchery, nursery and grow-out) as a result of fluctuating water parameters;
- wide variation in water temperature may cause disruption in reproduction, spawning and recruitment resulting in inadequate seed supply, poor quality seed, high incidence of diseases, harmful algal blooms;
- salinity intrusion as a result of rising sea levels;
- water scarcity and pollution of culture environment;
- loss or gain of culture habitat, extinction of populations of indigenous species, increased accidental introduction of exotic species; and
- lack of fish for processing.

Socio-economic/livelihood/vulnerable groups:

- financial losses from damaged facilities and loss of stocks because of disasters brought by extreme weather events;
- unstable prices of fish and fishery products in the market that affect ability of consumers to purchase;
- unstable operations affect employment and livelihoods (thus less income);
- lack of capacity among farmers to diversify into other activities or production systems; and
- weak linkages between the market and farmers.

Resource/environment:

- contraction of farming areas and water source because of prolonged dry/hot condition and decrease in rainy days (competition with other industries as well as for domestic use);
- scarcity of water resulting from groundwater recession and groundwater contamination;
- emergence of parasites and disease outbreaks because of increasing temperatures; and
- use of exotic species may affect biodiversity in the long run as they outcompete native species for resources or prey on indigenous species.

Potential contribution to GHG emissions from fisheries and aquaculture

Capture fisheries

Fishing vessels and operations:

- increasing fuel consumption because of increasing fishing operations and fuel intensive fishing trips;
- use of power engines in both fishing and processing;
- inefficient fishing boat design;
- inefficient storage practices on board;
- dilapidated, old, non-energy saving (less fuel efficient) fishing vessels/boats/engine;
- poor vessel maintenance (both machine and hull); and
- improper disposal (by burning), old/unusable fishing vessels.

Fish processing:

- fuel, hazardous refrigerants and chlorofluorocarbon (CFC) gas used in refrigerating, manufacturing of ice, and processing;
- growing energy consumption for increasing harvesting, processing and storing capacities;
- GHG emission on long fish processing plant and post-harvest chain, including use of firewood in many post-harvest practices;
- use of old and recycled machinery in both harvest and post-harvest activities; and
- inefficient transport facilities to market fishery products.

Destruction of seagrasses, mangroves and forests:

- destruction of mangroves through cutting and burning;
- destruction of seagrass beds;
- deforestation through logging, woodcutting for charcoal, shipbuilding, furniture, paper, etc.;
- terrestrial pollution; and
- high rates of organic matter decay and decomposition resulting in CO_2 emissions.

Others:

- transportation and use of fossil fuels such as coal, oil, natural gas; and
- low quality oil.

Aquaculture

- GHG emissions from farm operations including energy used in machinery/equipment in pond preparation and water management, fuel used on farms or off farms;
- effluents from intensive culture practices and/or use of feeds, improper feeding management;
- inefficient use of fertilizers particularly chemical fertilizers;
- poor processing of discharged wastewater from the farms;
- GHG emissions from transportation/shipment of inputs and products;
- production of aquaculture feed and feed ingredients; and
- energy use of post-harvesting and processing.

Gaps and constraints with respect to efforts to achieve climate-resilient fisheries and aquaculture

Capture fisheries

Knowledge and information

Many of the knowledge gaps are related to lack of awareness, acceptance and understanding in relation to climate change as a societal problem. This is especially true among such primary stakeholder groups as fishers. There is a lack of, or limitations in terms of access to, sharing of, and transferring of information and technology for mitigation and adaptation programmes. Climate related research information is lacking or limited:

- lack of research and survey to gather scientific evidence for climate change impacts in both marine and inland fisheries (e.g. stock status, migration);
- lack of time-series data on fish stocks;
- most of the bioclimatic models are too complicated to use in LDCs; and
- lack of common climate change database to serve as a knowledge bank.

Resources

There are serious financial constraints:

- poor funding for research on climate change impacts and adaptation strategies;
- limited access to insurance and finance coverage for emergency;
- financial constraints for fishers;
- no guarantee mechanism to reduce financial risk for banks to support liquidity of fisheries; and
- limited budget to support implementation of action plans.

In addition to financial resources, the participating countries mentioned the lack of other resources as follows:

- human resources and capacity to address climate change issues;
- resources for strengthening sectoral government;
- resources for monitoring activitiees;
- resources for mitigation measures;
- alternative/additional livelihoods and employment opportunities;
- resources for enhancement of broodstock of native species; and
- lack of financial and technical incentives for renewable and green energy alternatives.

Policy and planning:

- low priority for climate change issues at the national agenda/policy and higher political levels and lack of national support or policy to address climate change challenges;
- lack of clear fisheries management approaches, roadmaps, plans, and policies to mitigate GHGs in a specific time period and to address climate change impacts;
- too many high-level plans but no implementation/national action plans;
- inconsistency between plans/agreements and actions;
- lack of science-based effective policies;
- lack of institute/department to develop policy and implement climate adaptation;
- lack clear policies and directions as agencies work in compartments and lack of coordination to implement holistic climate change adaptation at national and regional levels;
- lack of regulating and monitoring policies; and
- lack of community-based law enforcement.

Others:

- weak compliance in adoption of best practices in harvest and post-harvest activities;
- poor enforcement of regulations;
- weak resource conservation practices;
- unplanned infrastructure causing damage to the environment;
- lack of habitat management/restoration; and
- lack or inefficient early-warning system in the community.

Aquaculture

Technology:

- lack of early-warning systems and information networks that can reach remote farming areas (e.g. use of mobile apps for dissemination of weather information to farmers' communities);
- lack of GIS mapping and modeling for flood/drought control areas;
- lack of cost-effective design of aquaculture facilities that can withstand damage from climate change impacts;
- lack of breeding and genetic improvement programmes for climate change-resilient species;
- lack of conservation of germplasm of important aquaculture species as well as species with potential for aquaculture;
- lack of climate-smart aquaculture technologies (e.g. use of saline-tolerant or temperature-tolerant species, use of fast-growing species or advanced fingerling, short production cycles and climate change-resilient culture practices such as integrated aquaculture);
- lack of advanced technology (marine fish/mud crab production);
- lack of technical knowledge on available ICT tools to monitor/measure, control, analyze (e.g. big data machine learning); and
- lack of promoting adoption of farming systems and practices that have the potential to mitigate GHG emissions (e.g. seaweed farming, mangrove rehabilitation for carbon sequestration, use of low trophic species, IMTA, adoption of Good Agriculture Practices (GAP), use of solar energy source).

Capacity building:

- gaps in capacity everywhere in the region;
- lack of mechanisms for knowledge-sharing among countries in the region – dissemination and demonstration of technology among the countries are very weak;
- limited access to information on mitigating impacts of different weather systems;
- lack of awareness about climate change and its impacts; and
- Lack of capacity building for monitoring programmes, especially for officers of concerned government agencies.

Support for fish farming to deal with climate change impacts:

- lack of insurance schemes for aquaculture;
- fewer opportunities for alternative jobs among the rural villagers;
- lack of capacity building programmes or information, education and communication strategies on climate change, its impacts and adaptation/mitigation measures especially at the local/farm level; and
- poor communication/coordination between government officials and local farmers.

Climate science:

- poor understanding of the science behind climate change both at the national and local level;
- lack of local researchers working on climate change issues;

- lack of investment for construction of pond dikes, pond management, transportation;
- lack of research skills in climate change science and aquaculture e.g. life cycle assessments, vulnerability assessments;
- research capacity/skills very weak in the region;
- cost-effective and best aquaculture management approaches are missing; and
- lack of vulnerability assessment of major aquaculture commodities for climate change.

Financial support:

- lack of funding for climate change programmes;
- lack of specific budget provision related to climate change; and
- lack of national policies to address the problem including the allocation of adequate funds.

Legislation/policies:

- need to integrate aquaculture issues in policy discussions related to climate change; policy discussions are led by other ministries, usually the Ministry of Environment; policies and plans do not explicitly prioritize and discuss issues related to aquaculture and fisheries in the context of climate change;
- need for an integrated approach of government functions for facilitation of climate change adaptation and mitigation strategies; need to improve communication and coordination between government institutions and local farmers' communities;
- need to put in place strategies/master action plans, standard operating procedures (SOPs) or guidelines in coping with climate change related emergencies (e.g. floods, droughts, etc.) at the local, national and regional levels; and
- need for a policy framework that would promote regional level sharing of knowledge and resources; knowledge sharing and dissemination/demonstration of technology among countries are very weak.

Recommendations on regional strategies and priority actions at regional and country levels for building climate resilience in capture fisheries and aquaculture

Capture fisheries

Regional strategies

Country coordination to support the following:

- developing a regional strategy paper on the subject of climate risk mitigation;
- promoting holistic approaches and consistent plans to build climate-resilient countries in the Asia-Pacific region;
- supporting and providing technical expertise for the preparation and implementation of national strategies and action plans;
- adopting relevant international agreements;
- developing a regional mechanism to share early-warning information for disasters and solutions;
- regional capacity building; and
- coordinating and cooperating resource management at the regional level.

Research, development cooperation, training, technology exchange and information both at national and regional levels in the following areas:

- database and common knowledge bank on climate change and its impacts and adaptation at the regional and national levels for the benefit and common understanding of all stakeholders;
- climate smart technology;

- energy saving fishing vessels;
- climate change solutions focusing on innovative implementation by regional public-private partnership (PPP); and
- improving long-term environmental monitoring systems and increasing awareness among fisheries stakeholders on the utility and importance of date collection using data buoys deployed in the aquatic systems.

Social well-being:

- integrating human well-being in climate adaptation and mitigation strategies; and
- mainstreaming gender in climate change regional plans and agreements.

Management:

- promoting EAFM concept at the regional level;
- promoting community-based management; and
- establishing closed season for fishing.

Campaigns:

- media campaigns – "Together – We sink or swim";
- responsible fishing; and
- recycling processing by-products.

GHG mitigation:

- resolve to provide fuel-efficient and emission-compliant engines to replace the existing fuel-inefficient and emission non-compliant engines from the fisheries subsector;
- promote the use of non-conventional renewable energy for fisheries; and
- APFIC countries have to agree on a target timeline to reduce GHG emissions from fisheries at the regional level.

Other recommendations:

- strengthen knowledge on impacts and adaptation measures specific to lakes, reservoirs and other freshwater bodies;
- link to disaster risk reduction frameworks and strategies;
- stock enhancement;
- fisheries should be included as a sectoral entity in climate change related matters in the UNFCCC Conference of the Parties (COP) and be provided with required attention/priority in climate change policies/strategies and actions;
- APFIC should assist the member countries in harmonizing the climate change and fisheries policies and address transboundary implications;
- APFIC should facilitate the member countries to address climate change related issues in their fisheries subsector;
- there should be a regulatory framework and a governing body at the national and regional levels for regulating and monitoring climate change related issues at both levels; and
- funding support for mitigation and adaptation for fisheries subsector from GCF or other relevant funding source.

National actions

- establish more inland and marine protected areas and sanctuaries for conservation of fishery resources both for inland and marine fisheries;

- restore water resources through desiltation and flow regulation;
- national fisheries research institutions to be mandated to undertake climate change impact-related research and to be provided with necessary research funding support;
- identify fish stocks under stress and implement measures to restore the stock;
- implement conservation measures such as uniform fishing ban at the national level;
- implement EAFM at the national level by developing and implementing localized EAFM plans;
- create fish ways connecting tributaries and main streams;
- restore both inland and marine fishery habitats (mangroves, coral reefs, seagrass beds, wetlands, marshlands, lagoons and estuaries etc.) and fisher habitats; and
- create seagrass beds and culture of seaweeds for carbon sequestration and alternate livelihood activity.

Table 4. Additional recommendations on national actions linking with the regional strategies

Regional strategies	National actions
Promote holistic approach in building climate-resilient countries in the Asia-Pacific region	• Mainstream disaster risk reduction (DRR) plans in the national development plans • Link DRR frameworks and strategies at site level
Adopt relevant international agreements	Establish cooperation in the Yellow Sea, South China Sea with the other countries
Develop regional mechanism for sharing early-warning information for disasters as well as for solving disaster-related problems	Develop early-warning systems for fisherfolk
Establish and promote R&D on climate change solutions focusing on innovations to implement via PPP region wide	Promote R&D of climate change impacts and adaptation of fishery subsector
Strengthen knowledge/technology on energy savings for fishing vessels Strengthen scientific research on impact of and adaptation to climate change	• Seek financial support for regional capacity building on climate change • Promote strong research and training on the CC impact on fisheries both at national and regional level, sharing platforms • Provide fuel-efficient and emission compliant engines to replace the existing inefficient and non-compliant engines from fisheries subsector • Promote use of non-conventional renewable energy for fisheries
Improve database and information sharing	Assess climate change impacts and conduct vulnerability assessments
Promote knowledge, information and technologies exchange among countries	Establish convention to share lessons from failures and successes regarding climate change
Establish research and development cooperation	Build capacity for climate change researchers
Adopt responsible fishing	• Document traceability and catch per unit effort • Change old wooden vessels to fiber glass boats • Extend liquefied natural gas fishing vessel • Standardize fishing vessels and fishing gear • Implement stringent action on mangrove cutting and juvenile fish catch
Build regional capacity	• Build institutional capacity • Establish regional fisheries management forums/ organizations on climate change issues

Table 4. *(continued)*

Promote EAFM	• Enforce fishing laws • Improve management framework to CC on fishery • Develop management areas through EAFM • Promote habitat management and restoration • Improve governance through appropriate legislative support
Establish closed fishing season	• Develop rules on closed fishing season • Improve fishing harvesting strategy • Enhance fish stocks

Aquaculture

Regional strategies

- establish a regional information centre on climate change for sharing of information/data and technology transfer and assessing each country's capacity in addressing climate change and adopting the best strategies at the regional level;
- develop regional policy (and legislative) framework for climate-resilient aquaculture;
- establish regional cooperation and pooling of resources for R&D on climate change issues that are of regional interest;
- implement a certification and labeling scheme for aquaculture products with minimal contribution to GHG emissions/climate change;
- develop a model for climate change for Asia-Pacific region;
- establish a regional early-warning system for climate change related events; and
- organize regional capacity building programmes for climate change mitigation and adaptation (including disaster risk reduction, preparedness and management) that can be echoed at the national and local levels.

Regional actions

Capacity building:

- conduct regional capacity building or training on climate change issues including risk and vulnerability assessment of aquaculture areas, establishment of a monitoring and early-warning system, climate change resilient aquaculture technologies such as IMTA and RAS, etc.; similar capacity-building programmes can be adopted at the national and local levels to include women and other vulnerable groups;
- facilitate knowledge sharing through conducting seminars and workshops, exchange of publications and other information materials, farmers interaction with cross visits with different countries for learning good practices on climate mitigation and adaptation;
- facilitate dispatch of international/regional expert to disseminate advanced climate-resilient aquaculture technology/climate-smart tool kits; and
- facilitate access to international funding and technology support (e.g. under the UNFCCC and other multilateral funding mechanisms).

Regional cooperation:

- create a technical working group composed of representatives from member countries that will assess the needs, potentials and strategies for climate change adaptation and mitigation measures in each country and facilitate the organization of a regional consultation to formulate a regional policy framework for climate change adaptation and mitigation; and
- create a network to facilitate sharing of knowledge and technology among countries in the region, especially on climate-resilient aquaculture technologies and practices.

Production system:

- create a platform to promote wider dissemination and adoption of climate change resilient and adaptive technologies (e.g. IMTA and other integrated production systems); and
- create a network for collaborative R&D efforts related to climate change (e.g. strain improvement/ selection for climate-adaptive traits such as temperature tolerance, etc. in aquaculture commodities especially those that are economically important in the different member countries).

National strategies

- policy formulation regarding climate change in aquaculture and integration of subsector into cross-sectoral climate change planning processes;
- capacity building on and promotion of good aquaculture practices for reduced risks to climate disasters and damage; facilitate dissemination and transfer of technology, and provide technical assistance to farmers to improve farming practices;
- promote optimum use of inputs; reduce consumption of fuel and electricity for aquaculture equipment and facilities;
- develop knowledge and information management systems network; organize interdisciplinary workshop on climate change impacts on aquaculture; promote interdisciplinary approaches towards innovative solutions;
- promote farmers' awareness of CC impacts on their production and offer livelihood support to fish farmers;
- promote small-scale aquaculture including integrated agro-aquaculture systems such as rice–fish farming, aquaculture in mangrove systems (aquasilviculture), use of high-value species that are environment-friendly; develop and promote feeds that have low carbon footprints; and
- analyze marketing gaps, map marketing strategies and pilot them in several areas.

National actions

- establish an information centre on climate change; collate results from vulnerability assessments including life cycle assessment of aquaculture commodities affected or vulnerable to climate change impacts, or assessment of adaptive capacity of areas/communities with respect to impacts of climate change;
- increase investment in research and initiatives towards climate-resilient and sustainable aquaculture and food security;
- implement capacity-building programmes on information, education and communication systems; conduct interdisciplinary workshops/seminars among relevant agencies; conduct training for government officials, non-government organizations (NGOs), fish farmers to build analytical skills and increase understanding of climate change issues;
- disseminate climate-resilient technologies and early-warning systems; promote the use of suitable fish species tolerant to high salinities, tolerant to high/fluctuating temperature, fast-growing strains and use large fingerlings in areas where growing period is limited; transfer low investment fish production technologies in seasonal waterbodies to improve livelihood and resilience in flood prone areas; invest in development of ICT systems for monitoring fish farming processes/operations;
- organize dialogues/discussions between and among countries and institutions on areas of cooperation to address climate change and unify activities related to climate change; prioritize areas that are high impact and require immediate action, set up interdisciplinary working groups, pilot successful models, disseminate through seminars and farm visits, and scale up;
- provide financial support (e.g. loans) and material support (relief) to affected farmers/communities;
- implement insurance schemes for aquaculture farmers;
- provide alternative livelihoods for people who are vulnerable to climate change;
- promote community-based resource enhancement and communally-managed fisheries/ aquaculture resources; including mangrove rehabilitation;

- integrate aquaculture into national resources management schemes as the impacts on aquaculture are cumulative in nature and are contributed by both climate and non-climate (e.g. pollution) factors – the difficultly of differentiating driver-impact relations in terms of climate change was noted, for example, the cumulative impacts of construction of dams and climate change on aquatic biodiversity, etc. cannot be dealt with only through the aquaculture subsector;
- facilitate capacity building, especially for farmers, by forming farmers' groups or associations, especially considering that smaller farms are predominant in the region – the same network or groups can be tapped for organizing an early-warning system for dissemination of weather information as well as for incidence of disease outbreaks or algal blooms; in fact they can become a focus for knowledge sharing and dissemination of information on climate change and its impacts on the aquaculture subsector at the local, national and regional levels;
- review the fact that in the discussions for the fisheries subsector, more emphasis was given to issues, recommendations and action plans that were relevant to marine and coastal aquaculture and less focus on inland aquaculture and take corrective action – this makes sense as the bulk of aquaculture production in the region is from freshwater or inland production systems and areas;
- look into the vulnerability and adaptive capacities of different culture systems in light of the impacts and benefits from these productions systems keeping both efficiency and environmental impacts in mind. For example, the promotion of high value species and intensive aquaculture should be approached keeping in mind that being mostly small-scale, the ability of farmers to adopt new technologies, absorb the cost of additional inputs/facilities/machinery;
- consider the impacts of the high demand for fish meal from aquaculture and support initiatives to ensure sustainable sources of alternative feed ingredients (e.g. plant-based feed ingredients).
- disseminate available climate-smart or climate-resilient technologies, especially to small-scale farmers, and at the same time develop climate-resilient culture systems that are easily adopted on small-scale farms;
- engage the media, especially as public opinion about aquaculture is not always positive; there is a need for the public to be aware of the contributions of aquaculture to food security and livelihoods, as well as GHG mitigation and adaptation options (e.g. carbon sequestration function of seaweeds farms);
- improve zoning and proper site selection, especially considering possible impacts of climate change events;
- contact funding sources such as UNFCCC, GEF, GCF, German Technical Cooperation Agency (GTZ) regarding the need for funds for R&D and development programmes towards developing climate-resilience in the aquaculture subsector, and coordinate with focal points in the countries to ensure that the subsector's priorities are in line with the donors' development plans and can be considered;
- coordinate country-level and regional efforts to support the aquaculture subsector and form a Regional Technical Working Group and take the lead in the formulation of regional strategies and guidelines, propose need-based action plans and regional events, formulate mitigation and adaptation measures simultaneously; and
- give consideration to the competition of aquaculture with other sectors/industries for resources and inputs (e.g. water resources) and find a solution.

Background Paper 1

Implications of climate change and climate risks for fisheries and recommendations to build climate-resilient fisheries in the Asia-Pacific region

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Introduction

In 2011, the Food and Agriculture Organization of the United Nations, Regional Office for Asia and the Pacific, released "The potential impact of climate change on fisheries and aquaculture in the Asia Region" (FAO, 2011). This publication responded to the growing recognition by the Asia-Pacific Fishery Commission (APFIC) that the region faced important challenges in adapting to and mitigating the impacts of climate change on fisheries and aquaculture. The 2011 report provided an update on the status of climate change, evaluated the impacts of climate change in the Asian region with specific emphasis on fisheries and aquaculture, and outlined the projected impacts on livelihoods and economies within the region. Finally, it addressed adaptation and mitigation issues in these sectors.

"Implications of Climate Change and Climate Risks for Fisheries and Recommendations to Build Climate-Resilient Fisheries in the Asian Region" was written in 2018. To prepare the paper, the authors conducted a comprehensive review of available reports and peer-reviewed publications, and also synthesized the inputs provided by AFPIC countries and participating regional organizations during the FAO/APFIC "Regional Consultative Workshop: Building Climate Resilient Fisheries and Aquaculture in the Asia-Pacific Region" in Bangkok, Thailand, 14–16 November 2017.

This paper addresses the importance of fisheries and aquaculture to the region and updates information on the latest science behind global and regional climate change. It summarizes the impacts of climate change on major fisheries systems and production practices in the Asia-Pacific region, and outlines the implications of climate change and related risks for the fisheries subsector in the region. The paper also discusses major efforts being made by regional organizations, development agencies, and national governments to address climate change issues for fisheries, including the development of policies, strategies, and plans of actions and implementation. The paper then evaluates major opportunities, as well as gaps and constraints, in building climate-resilient fisheries in the region, and recommends strategies and priority actions ranging from regional-level to ground-level scales.

Overview of the importance of fisheries and aquaculture

Fisheries and aquaculture play vital roles in the Asia-Pacific region by providing food security and income, but the benefits of these sectors are heavily reliant on ocean health and success in addressing the impacts of a changing climate. As patterns of climate change and climate variability are becoming more extreme and their impacts, such as ocean warming and ocean acidification, are more acute and long term, the results will be felt in every aspect of fisheries and aquaculture. There is much at stake for Asia-Pacific communities and therefore strengthening the resilience of fisheries and aquaculture in the region is of vital importance.

One of the most significant roles of fisheries and aquaculture is to support global food and nutrition security.

- In the past five decades, growth in the global supply of fish has outpaced population growth, increasing at an average annual rate of 3.2 percent in the period 1961–2013, which was double that of population growth (FAO, 2016a).
- It is projected that by 2050, an additional 75 million tonnes of fish will be needed to help feed more than 9 billion people (Rice and Garcia as cited in Bell *et al*., 2016).
- In 2013, fish accounted for about 17 percent of the global population's intake of animal protein and 6.7 percent of all protein consumed (FAO, 2016a). In Southeast Asia, approximately half of the population got more than 20 percent of their animal protein from fish (Pomeroy *et al*., 2016). The proportion was even higher in Asia and many Pacific Island countries where fish provided 50–90 percent of animal protein (Bell *et al*., 2016).
- Fish is also a critical source of vital micro-nutrients and lipids, especially calcium, vitamins A and D, iron, and zinc. Despite their necessity for human health, two billion people, have been affected by deficiencies in these micro-nutrients and lipids (Tulchinsky cited in Belton and Thilsted, 2014).
- World per capita fish consumption increased from an average of 9.9 kg in the 1960s to 19.7 kg in 2013, with preliminary estimates for 2014 and 2015 beyond 20 kg (FAO, 2016a). The consumption is quite high in Asia with 39.2 kg in East Asia and 33.6 kg in Southeast Asia (FAO, 2016a).

According to The State of World Fisheries and Aquaculture 2016 (FAO, 2016a), the global trade in fish and fishery products has expanded considerably in recent decades, supported by growing fishery production and driven by high demand. The fishery net export revenues (exports minus imports) reached USD 42 billion, higher than all other major agricultural commodities combined. Global exports of fish and fishery products (excluding seaweeds, aquatic plants, inedible fish, sponges, and corals) has grown significantly, rising from USD 8 billion in 1976 to USD 148 billion in 2014, of which fishery exports from developing countries were valued at USD 80 billion. Global capture fisheries have increased significantly in economic value, with Asia taking the lead in both fisheries and aquaculture. The total capture fishery production in 2014 was 93.4 million tonnes, of which 81.5 million tonnes came from marine waters and 11.9 million tonnes from inland waters. According to FAO (2016a) and others:

- Total fish supply by continent in 2013 was highest in Asia with 99 million tonnes live weight equivalent.
- China and Viet Nam were the top two major exporters of fish and fisheries products in the world.
- Marine fisheries contributed USD 230 billion to the global economy (Barange *et al*., 2014) with China being the highest global producer, followed by Indonesia.
- For marine fisheries production, total catch in Southeast Asia increased from about 2.5 million tonnes per year in the 1950s to more than 25 million tonnes in the 1990s (Pauly and Zeller as cited in Bell *et al*., 2016).
- More than 90 percent of the Asia-Pacific region's capture fishery comes from small-scale coastal fisheries, which have contributed to food security both directly through subsistence fishing and indirectly through incomes from a variety of sources (FAO/APFIC Regional Consultative Workshop "Building Climate Resilient Fisheries and Aquaculture in the Asia-Pacific Region 2017").

Asia's inland capture fisheries have grown by 37 percent in the last decade. All five of the world's top producing countries were in Asia (China, Myanmar, India, Bangladesh, and Cambodia) (FAO, 2016a). The inland fisheries, ranging from individual subsistence fishers to large-scale commercial operations, are an important source of food security, particularly at the local level. The productive lower Mekong River Basin in Asia alone supports the largest freshwater capture fishery in the world, and is essential to the food security and nutrition of the 60 million people of the Basin (Youn *et al*., 2014; Dudgeon as cited in Hijioka *et al*., 2014). As an example, annual freshwater fish consumption in Cambodia and Viet Nam can be as high as 40 kg/person, among the highest in the world. (Navy, Minh and Pomeroy, 2017).

In recent decades, total production from marine capture fisheries has leveled off at about 80 million tonnes per year. The stagnation was attributed to full exploitation of about 60 percent of the world's marine fisheries and overexploitation of 30 percent (estimated for 2009) (FAO as cited in Bell *et al*., 2016). Rapid

development of aquaculture has helped fill the resulting shortfall in the global fish supply (Bell *et al*., 2016). Some indicators of the global significance of aquaculture are as follows:

- Globally, the share of fish for human consumption from aquaculture increased from 7 percent in 1974 to 39 percent in 2004 (FAO, 2016a). Aquaculture grew between two and seven times faster than capture fisheries in advanced aquaculture producing countries, including China, India, Bangladesh, Thailand, Viet Nam, Indonesia, Philippines and Myanmar (Belton and Thilsted, 2014).
- China represented more than 60 percent of world aquaculture production (FAO, 2016a).
- Freshwater aquaculture dominated the world production with 59.9 million tonnes in 2010, and marine aquaculture supplied 18.1 million tonnes (30 percent) (FAO as cited in Hijioka *et al*., 2014).
- Production of aquatic animals from aquaculture had an estimated first-sale value of USD 160.2 billion in 2014 (FAO, 2016a).

In addition to the financial value of fisheries production and trade, fisheries play an important role in income generation and employment, contributing to both local and national economies. About 10 percent of the world's population, predominantly from developing countries, relies heavily on fisheries and aquaculture for income (Allison and Bassett, 2015). Marine fisheries offered livelihood support to 8 percent of the world's population (Barange *et al*., 2014; Sumaila *et al*., 2011). It was estimated that in 2014, 56.6 million people were engaged in the primary sector of capture fisheries and aquaculture (FAO, 2016a). In 2014, women accounted for 19 percent of the workforce in the primary sector and about half in the secondary sector (e.g. processing, trading) (FAO, 2016a). The proportion of the aquaculture-related workers increased from 17 percent in 1990 to 33 percent in 2014 (FAO, 2016a). It is recognized that fisheries can potentially provide employment opportunities for the poor, particularly in places where capital and investment are lacking and in post-conflict and post-disaster conditions (Béné *et al*., 2016).

In the Asia-Pacific region, the proportion of people employed in fishery-related jobs in Asia has doubled since the 1970s with an estimated 170 million directly and indirectly engaged in the value chains (Pomeroy *et al*., 2016). In 2014, Asia was home to 84 percent of the global population engaged in the fisheries and aquaculture sectors. Of the 18 million people engaged in fish farming, 94 percent were in Asia (FAO, 2016a).

Overviews of climate change

The climate is changing, and human and natural systems are being impacted. The primary greenhouse gases have all shown large increases in the last 250 years: carbon dioxide (CO_2) by 40 percent, methane by 150 percent, and nitrous oxide by 20 percent (IPCC, 2014). According to the IPCC, approximately half of the cumulative anthropogenic CO_2 emissions between 1750 and 2011 have occurred in the last 40 years; of this amount, 40 percent of the emissions have been retained in the atmosphere, and 30 percent absorbed by the ocean, causing ocean acidification (IPCC, 2014). About 78 percent of the total greenhouse gas (GHG) emissions increase came from fossil fuel combustion (fuelled by economic and population growth) and industrial processes (IPCC, 2014).

Asia has already experienced increasing temperature extremes and warming trends, and future challenges include food production and security, water scarcity, shifts in vegetation and plant species, changes in marine habitat and biodiversity, and extreme events such as floods and droughts (Hijioka *et al*., 2014). Improved projections, and with them low-cost adaptation measures, are critical to communities as the region warms (Hijioka *et al*., 2014).

Surface air and water temperature

Over the last decades, the Earth has been increasing in mean surface temperature. Although surface temperatures are subject to natural variability, the last 30 years have been the warmest in the 800 years in the Northern Hemisphere, and likely even the last 1 400 years (IPCC, 2014). Human-induced increases in GHG concentrations, in combination with other anthropogenic forcings (e.g. aerosol, land use surface

reflectance and ozone changes), accounted for more than 50 percent of the observed increase in global surface temperature between 1951 and 2010 (IPCC, 2014).

The following are projected global mean surface temperature changes relative to 1986–2005, in scenarios without significant volcano eruptions or changes in natural systems (Commonwealth Scientific and Industrial Research Organisation (CSIRO) *et al*., 2015; IPCC, 2014):

- between 2016–2035, an increase from 0.3°C to 0.7°C;
- by 2050, an increase from 0.5°C to 1°C; and
- by 2090, an increase from 0.5°C to 4°C.

The choice of emissions scenarios has significant impact on the magnitude of projected climate changes (CSIRO, Australian Bureau of Meteorology and SPREP, 2015). As temperatures rise, there will be more frequent hot and fewer cold temperature extremes over most land areas on daily and seasonal timescales. Heat waves will occur with higher frequency and for a longer duration (IPCC, 2014), and the number of cool days and nights will continue to decrease (CSIRO, Australian Bureau of Meteorology and Secretariat of the Pacific Regional Environment Programme (SPREP), 2015).

The warming of climate systems largely refers to the higher air temperature. The IPCC suggests increases in the mean annual temperature over the past century, as well as increases in the numbers of warm days and nights, and increases in the frequency of heat waves since the middle of the twentieth century in the Asia region (Hijioka *et al*., 2014).The warming of the climate system also includes the warming of the ocean, which is largest near the surface and the upper 75 m with 0.11°C per decade between 1971 and 2010 (IPCC, 2014). Increases in ocean temperature are related to increases in atmospheric moisture content that affect the water cycle in various ways, including global-scale changes in precipitation patterns over land, intensification of heavy precipitation over certain land regions, and changes in surface and subsurface ocean salinity (IPCC, 2014).

Elevated sea surface temperatures (heat stress) damage sensitive coral reef ecosystems, causing coral bleaching. Heat stress will build up if the temperature around the corals stays above the bleaching threshold (1°C above the highest summertime mean sea surface temperature) over time; one global measurement for the severity of heat stress is degree heating weeks,[2] which can provide warning of mass bleaching events resulting in coral mortality. Mass coral bleaching and mortality on a yearly basis are predicted to begin occurring as soon as 2040 (Hoegh-Guldberg *et al*., 2017). The effects of ocean acidification compound the damage to coral reef ecosystems.

By the end of the century, cumulative emissions of CO_2 will largely determine global mean surface warming, and the warming cannot be reversed even over multi-century timescales unless specific actions are taken to remove CO_2 from the atmosphere (IPCC, 2014).

In the future, global warming will be amplified by the feedback cycle between climate change and the carbon cycle, according to Earth Systems Models (IPCC, 2014). Land and ocean carbon sinks will continue to absorb rising atmospheric CO_2, but they will be partially offset by climate change. Therefore, warming will be reinforced as more CO_2 stays in the atmosphere than is absorbed by the sinks (IPCC, 2014). Climate change impacts do not occur in isolation, and a key area for future research is study of the aggregated, compounding, and/or cascading effects of climate change on natural systems, and well as the interplay between human impacts on ecosystems and climate change (IPCC, 2014).

Many terrestrial, freshwater, and marine species have been impacted by climate change. Recorded impacts include shifts in species' abundances, migration patterns, geographical ranges, seasonal activities, and species interactions (IPCC, 2014; Poloczanska *et al*., 2013).

[2] https://coralreefwatch.noaa.gov/satellite/education/tutorial/crw24_dhw_product.php

Weather patterns, monsoons, and precipitation

Precipitation is highly variable in the Pacific. Rainfall can be impacted by El Niño-Southern Oscillation (ENSO), the Pacific Decadal Oscillation (PDO), shifts and changes in intensity in the South Pacific Convergence Zone and the Intertropical Convergence Zone, cyclones, and monsoons (CSIRO, Australian Bureau of Meteorology and SPREP, 2015). This variability makes it difficult to discern trends, but the data has resulted in certain observations over the last 30 years: the Southwest Pacific is wetter, and the Central Pacific is drier (CSIRO, Australian Bureau of Meteorology and SPREP, 2015). However, there is significant uncertainty regarding the extent of climate change versus natural variability in future projections. The rainfall change projections are better towards the end of the century, and indicate that average rainfall will increase in many locations in the Pacific, especially the western tropical Pacific (CSIRO, Australian Bureau of Meteorology and SPREP, 2015).

Precipitation trends in Asia

The Asia Chapter of the IPCC 5 (Hijioka *et al*., 2014) recognized the difficulties of drawing conclusions about trends in annual precipitation because of the lack of sufficient observation data. Precipitation trends, including extremes, are characterized by strong variability, with both increasing and decreasing trends observed in different parts and seasons of Asia. Summaries from different sections of the IPCC Fifth Assessment Report (WGI AR5) are as follows:

In Northern Asia, there is some indication that there is an increasing trend of heavy precipitation, but not in Central Asia. There is an enhanced mean and extreme precipitation along the Yangtze River valley (30ºN), but deficient mean precipitation in North China in summer.

In West Asia, a weak but non-significant downward trend in mean precipitation was observed in recent decades, although with an increase in intense weather events.

In South Asia, seasonal mean rainfall shows inter-decadal variability, noticeably a declining trend with more frequent deficit monsoons. Over India, the increase in the number of monsoon break days and the decline in the number of monsoon depressions are consistent with the overall decrease in seasonal mean rainfall. But an increase in extreme rainfall events occurred at the expense of weaker rainfall events over the central Indian region and in many other areas. In South Asia, the frequency of heavy precipitation events is increasing, whereas light rain events are decreasing.

In Southeast Asia, annual total wet-day rainfall has increased by 22 millimetres (mm) per decade, whereas rainfall from extreme rain days has increased by 10 mm per decade, but climate variability and trends differ vastly across the region and between seasons. In Southeast Asia, between 1955 and 2005 the ratio of rainfall in the wet to the dry seasons increased. Although an increasing frequency of extreme events has been reported in the northern parts of Southeast Asia, decreasing trends in such events are reported in Myanmar. In Peninsular Malaya during the southwest monsoon season, total rainfall and the frequency of wet days decreased, but rainfall intensity increased in much of the region. In contrast, during the northeast monsoon, total rainfall, the frequency of extreme rainfall events, and rainfall intensity all increased over the peninsula.

Monsoons are, in part, driven by differences in land-sea temperatures. As global warming increases along with increased moisture in the atmosphere, and as the land-sea temperature difference becomes larger in summer, the expected result is a more intense monsoon season (Kitoh *et al*., 2013). However, the impacts may be partially offset by a weaker monsoon circulation (Hsu, 2016). Models have shown that the Asian monsoon is more sensitive to global warming than other regions, and that the median rate of increase of precipitation is larger than in other regions (Kitoh *et al*., 2013).

Global monsoon total precipitation and intensity are projected to increase this century under global warming, and at a higher rate than in other monsoon regions (Kitoh *et al*., 2013; Endo and Kitoh, 2016).

The increase is the result of increased atmospheric moisture and increased surface evaporation because of warmer sea surface temperature (Endo and Kitoh, 2016). An expansion in the global monsoon area will occur in the central to the eastern and tropical Pacific, the southern Indian Ocean, and eastern Asia (Kitoh *et al*., 2013). Eastern hemisphere monsoons are predicted to produce more precipitation than western hemisphere monsoons, and northern hemisphere monsoons are predicted to produce more precipitation than those in the south (Hsu, 2016). The IPCC concurs that precipitation extremes related to the monsoon will increase in South Asia, East Asia, and Southeast Asia, and "all models and scenarios" are predicting that mean and extreme precipitation in the Indian summer monsoon will increase (Hijioka *et al*., 2014).

Regional monsoons will continue to be tempered by ENSO (Kitoh *et al*., 2013) and extreme rainfall events are also projected to increase substantially (Endo and Kitoh, 2016). The data on extreme rainfall events in the past 50 years show few consistent trends (CSIRO, Australian Bureau of Meteorology and SPREP, 2015). By 2090, extreme rainfall events that have been occurring once every 20 years on average, in a low emissions scenario, may occur once every 7 to 10 years, and in a high emissions scenario once every 4 to 6 years (CSIRO, Australian Bureau of Meteorology and SPREP, 2015). Drought projections follow the projected changes to rainfall in a high emissions scenario (CSIRO, Australian Bureau of Meteorology and SPREP, 2015).

Economic losses from weather-related disasters have increased substantially in recent decades (IPCC, 2014). Monsoon impacts include damage to life and property and destruction of the environment and farmlands, leading to food security issues (Loo *et al*., 2015). The onset and delay of monsoons (changing their duration), along with precipitation shifts, are expected to alter under global warming and will have great impact on monsoon-affected countries, such as India, that receive 75 percent of their total annual rainfall from the summer monsoons (Loo, Billa and Singh, 2015). Impacts from flooding can be significant. In 2012, the Philippines received an intense monsoon rainfall that claimed 170 lives and resulted in the evacuation of almost 600 000 people from Manila (Loo, Billa and Singh, 2015). Conversely, a lack of rainfall can result in severe droughts.

Tropical cyclones

Cyclones are caused by warm water, which contributes energy, and the Coriolis effect, which provides spin (CSIRO, Australian Bureau of Meteorology and SPREP, 2015). The South Pacific is the home of most tropical cyclones, and most occur between 10 degrees and 25 degrees latitude in both hemispheres (CSIRO, Australian Bureau of Meteorology and SPREP, 2015). They are influenced by ENSO phases through winds and sea surface temperature. During La Niñas, the western Pacific sees an increase in the number of cyclones, whereas the opposite is true for El Niños (CSIRO, Australian Bureau of Meteorology and SPREP, 2015). Cyclones can cause damage on multiple levels. Cyclones-related waves and storm surges cause severe short-term sea level extremes, such as flooding, coastal inundation, and infrastructure impacts. Storm surge impacts tend to be localized, but damage from ocean waves can be far-reaching and destructive. Coastal impacts vary depending on the shape of the seabed, the shape of the coastline, and the landform (geomorphology) (CSIRO, Australian Bureau of Meteorology and SPREP, 2015). Cyclones have adverse economic impacts on fishing industries by reducing fishing time, destroying assets and infrastructure, and possibly destroying habitats (Dunstan *et al*., 2018).

Certain model projections suggest that cyclones that are both weaker and more intense will increase in number, whereas medium intensity cyclones will reduce in number (CSIRO, Australian Bureau of Meteorology and SPREP, 2015). Current models indicate that precipitation will be more extreme near the center of tropical cyclones making landfall in West Asia, East Asia, South Asia, and Southeast Asia (Hijioka *et al*., 2014). However, the data are inconclusive about long-term changes in tropical cyclone activity, and their connection to climate change drivers is still unclear (IPCC, 2014).

Trade winds, tropical cyclones, and swell from "extra-tropical storm belts" produce wind-driven waves (CSIRO, Australian Bureau of Meteorology and SPREP, 2015). ENSO has an impact on annual variability of

waves. Projections for the remainder of this century, under medium to high emissions scenarios, show an increase in small waves generated at higher latitudes, and reduced incidence of the northeast trade wind waves (CSIRO, Australian Bureau of Meteorology and SPREP, 2015). Waves can impact the islands and coastal areas in the Pacific through coastal erosion and inundation, the shaping of marine habitats, and distribution of marine species (CSIRO, Australian Bureau of Meteorology and SPREP, 2015).

Sea level rise, coastal inundation, coastal erosion, shoreline change

Thermal expansion caused by warming of the ocean and increased melting of land-based ice, such as glaciers and ice sheets, are the two major causes of global sea level rise. According to the NOAA, the oceans are absorbing more than 90 percent of the increased atmospheric heat associated with emissions from human activity.[3] Between 1993 and 2010, ocean warming and land-based ice melt accounted for 34 percent and 45.5 percent (nearly 80 percent) of the global mean sea level rise. Extreme sea-level events are caused by a combination of: tides (which operates independently of climate); changing winds, pressure, and ocean temperature patterns; and short-term events (e.g., storm surge, waves, tsunamis) (CSIRO, Australian Bureau of Meteorology and SPREP, 2015). Since the mid-1800s, the mean sea level rise has been increasing faster than the mean rise during the previous two thousand years (IPCC, 2014). The data demonstrate that the mean global average sea level rise was 3.2 mm/year (2.8 mm to 3.6 mm) between 1993 and 2010 (IPCC, 2014). The sea level rise in the last 20 years is double the mean rise of the twentieth-century (Cazenave and Cozannet, 2013).

Across the Pacific Ocean, sea levels vary by up to 1 m, largely because of the effects of ENSO and the Pacific decadal oscillation, which influence sea levels in the tropical Pacific (CSIRO, Australian Bureau of Meteorology and SPREP, 2015 Cazenave and Cozannet, 2013). During strong El Niño events, sea level has seen a lowering in the tropical western Pacific by 20 cm to 30 cm, which has exposed shallow reefs, and a rise in the eastern Pacific, which also negatively affects coral ecosystems (Widlansky *et al*., 2015). In La Niña events, the reverse occurs. Since 1993, the rates of sea level rise for the western Pacific are up to three times larger than the global mean; for most of the eastern Pacific, rates are near zero or negative during this period (IPCC, 2014; Cazenave and Cozannet, 2013). In addition to ocean temperature variations, salinity also plays a role in spatial sea level variation (IPCC, 2014; Cazenave and Cozannet, 2013).

By the end of this century, sea level rise will occur in more than about 95 percent of the ocean area. About 70 percent of coastlines worldwide are projected to experience sea level change within ±20 percent of the global mean, which is expected to be higher than today in the range of 40 cm – 75 cm (IPCC, 2014; Widlansky, Timmermann and Cai, 2015). Impacts from sea level rise and associated storm surges can be extensive. It is not only coastal infrastructure that is at risk. Coastal inundation can also increase salinity in freshwater supplies and affect coastal or delta agricultural resources. Habitats can be impacted by the destruction of beaches, reefs, wetlands, mangroves, and lagoons (CSIRO, Australian Bureau of Meteorology and SPREP, 2015). The link between global coastal erosion and sea level rise is unclear, and efforts are ongoing to improve modelling tools (Cazenave and Cozannet, 2013). Shallow reefs are at risk in situations of prolonged sea level drops and prolonged coastal inundation (Widlansky, Timmermann and Cai, 2015). Each of these has potential adverse economic, health, and safety impacts on the community.

Mangroves are a vital part of shorelines, and provide coastal protection from erosion and inundation (Godoy and De Lacerda, 2015). Both human activities and climate change have an impact on the survival of mangroves. Between 30 percent and 50 percent of mangrove forests have ceased to exist in the last 50 years (Godoy and De Lacerda, 2015). In Asia and Oceania alone, 70 species of mangroves are under threat of extinction (Godoy and De Lacerda, 2015). Anthropogenic pressure, for example dams, aquaculture, and land use changes, is decreasing communities of mangroves (Godoy and De Lacerda, 2015). As the climate warms, mangroves are migrating towards the poles to escape warmer winters, and migrating landward to escape sea level rise (Godoy and De Lacerda, 2015). Although the response to climate change

[3] https://oceanservice.noaa.gov/facts/sealevel.html

might be positive for mangroves that are not limited by the constraints of accessible coastlines, mangroves in low lying oceanic islands subject to salinity increases, for example in the Pacific Ocean, are unlikely to survive (Godoy and De Lacerda, 2015).

Ocean acidification

Corals are composed of calcium carbonate skeletons, and when conditions are sufficient and production is high enough, they establish carbonate structures that form coral reef ecosystems (Hoegh-Guldberg *et al*., 2017). Coral reefs provide the structure for barrier reefs and islands, and 25 percent of tropical marine species call them home (Hoegh-Guldberg *et al*., 2017).

The ocean absorbs approximately one quarter of the carbon dioxide emissions from human activities annually (CSIRO, Australian Bureau of Meteorology and SPREP, 2015), but not uniformly. This causes a decrease in the pH of the ocean, resulting in ocean acidification. Ocean acidification affects the rate at which corals can build their carbonate skeletons (Hoegh-Guldberg *et al*., 2017). In the last 250 years, the pH of ocean surface water has decreased by 0.1, which translates to a 26 percent increase in acidity (IPCC, 2014). ENSO cycles also have an impact on ocean acidity, with El Niños resulting in less acidity and La Niñas more acidity (CSIRO, Australian Bureau of Meteorology and SPREP, 2015).

Models are projecting a range of 15–109 percent increase in acidity by the end of the century (IPCC, 2014). It is important to note that small amounts of change in acidification levels result in substantial biological impacts (Hoegh-Guldberg *et al*., 2017). The greater the acidity level in the ocean, the lower the value of aragonite saturation (CSIRO, Australian Bureau of Meteorology and SPREP, 2015). An aragonite saturation rate of <3.5 is considered marginal for supporting healthy coral reefs. In the Pacific Ocean, annual aragonite saturation has reduced from 4.2 to 3.8 since about 1750; under a high emissions scenario, by 2050 all reefs will be faced with marginal conditions (CSIRO, Australian Bureau of Meteorology and SPREP, 2015). The degradation of coral reefs will impact the 500 million people who receive services from these critical ecosystems (Hoegh-Guldberg *et al*., 2017). Among other benefits, coral reefs are a critical habitat for many fish and other marine species that provide protein for local communities. They also serve as a vital buffering function to counter storm surge and inundation (Hoegh-Guldberg *et al*., 2017).

Climate variability and ENSO events in the Asia-Pacific region

ENSO is the primary cause of climate variability in the Pacific Islands, and is largely responsible for annual variability in ocean sea surface temperatures. ENSO has two phases: El Niño and La Niña, with the climate in a neutral state when neither is exhibiting. In El Niño events, the West Pacific warm pool extends eastward and eventually covers the entire equatorial Pacific, atmospheric convection develops and moves eastward, and the intertropical convergence zone shifts eastward, resulting in increased rainfall in the eastern equatorial Pacific (Cai *et al*., 2014). Easterly winds become westerly. Recent extreme El Niños have caused environmental disruptions such as mass bleaching in the Pacific (Cai *et al*., 2014; Hughes *et al*., 2018). An extreme El Niño is indicated when rainfall exceeds 5 mm per day (Cai *et al*., 2014). The opposite occurs during a La Niña (CSIRO, Australian Bureau of Meteorology and SPREP, 2015).

Coral Bleaching and ENSO

"Increasingly, climate-driven bleaching is occurring in all El Niño-Southern Oscillation (ENSO) phases, because as global warming progresses, average tropical sea surface temperatures are warmer today under La Niña conditions than they were during El Niño events only three decades ago ... Since 1980, 58 percent of severe bleaching events have been recorded during four strong El Niño periods (1982–1983, 1997–1998, 2009–2010, and 2015–2016) with the remaining 42 percent occurring during hot summers in other ENSO phases. Inevitably, the link between El Niño as the predominant trigger of mass bleaching is diminishing as global warming continues and as summer temperature thresholds for bleaching are increasingly exceeded throughout all ENSO phases." (Hughes *et al*., 2018)

PDO is a long-lived pattern of Pacific climate variability that differs from ENSO in that twentieth-century PDO events persist for 20 to 30 years, whereas typical ENSO events persisted for 6 months to 18 months, and the climatic fingerprints of the PDO are most visible in the North Pacific/North American sector, whereas secondary signatures exist in the tropics (the opposite is true for ENSO).[4] ENSO is modulated by the PDO; La Niña induced wet areas become wetter and dry areas become drier and smaller as a result of the cold ENSO phase (Wang *et al*., 2014). El Niño causes more severe droughts in the warm PDO phase than in the cold one (Wang *et al*., 2014). One example is that ENSO-related droughts in the tropical western Pacific region from Indonesia to northeastern Australia are stronger during the warm phase of the PDO (Wang *et al*., 2014).

The El Niño and La Niña phases of ENSO can impact cyclones, floods, tropical cyclones, and extreme sea levels, and cause large-scale shifts in rainfall patterns through changes in sea-surface temperature and winds (CSIRO, Australian Bureau of Meteorology and SPREP, 2015). Although models suggest that ENSO events will continue to occur and have a significant impact on variability in the region, there is no consensus on projections of changes in the frequency, intensity, and patterns of future events (CSIRO, Australian Bureau of Meteorology and SPREP, 2015). Extreme El Niño events may become more common and warmer in the future, and El Niño driven rainfall variations near the equator may be enhanced under global warming (CSIRO, Australian Bureau of Meteorology and SPREP, 2015). One recent climate study projected that GHG warming will slightly decrease the total number of El Niño events, but will double the extreme El Niño occurrences in the future (Cai *et al*., 2014). In the control models in this study, El Niños now occur at the rate of one event every twenty years, but the study states that in a climate change scenario, events will occur once every ten years (Cai *et al*., 2014). These increased occurrences will result in more devastating weather events that will reduce the number of days at sea and increase safety risks for many fishing vessels. These will in turn have significant adverse socio-economic consequences (Cai *et al*., 2014).

Biophysical impacts of climate change to major fisheries systems in the Asia-Pacific region

The Asia-Pacific countries account for more than 60 percent of global capture fisheries production and in 2014, 84 percent of the global population engaged in the fisheries and aquaculture sectors was in Asia (FAO, 2016a). Several countries in the Asia-Pacific region are also ranked high in terms of vulnerability to climate change impacts and natural disasters. This section provides an overview of biophysical impacts of climate change on Asia-Pacific fisheries resources and related ecosystems. The impacts are grouped according to three fisheries production zones, namely: inland freshwater systems, nearshore and coastal systems, and oceanic and pelagic systems.

Overview of general pathways of climate impacts on fisheries resources

The diversity, abundance, and distribution of marine life are directly influenced by the physical and chemical properties of the ocean environment, from the atmosphere-ocean interface down to the deepest depths. Generally, fishes and invertebrates respond to these ocean changes through: (1) changes in distribution and abundance as species follow optimal ocean conditions (Pinsky *et al*., 2013; Molinos *et al*., 2015); (2) changes in life-history characteristics or long-term adaptation (Donelson *et al*., 2011; Edmunds *et al*., 2014); or (3) localized or global extinctions if the rate and magnitude of change in ocean conditions exceeds the ability of species to adapt or move to areas with more favourable conditions. Together, these will result in massive re-organizations of global marine species with direct implications for fish availability.

Examples of the key biophysical factors are as follows:

Temperature plays a fundamental role in structuring global marine biodiversity (Tittensor *et al*., 2010). Global patterns in abundance of fishes and invertebrates correlate, respectively, with temperature and

[4] http://research.jisao.washington.edu/pdo/

nutrients (Edgar *et al*., 2017). Ambient water temperature affects many physiological processes and natural mortality of fishes (Griffiths and Harrod, 2007). Key examples of the warming temperatures accelerate several physiological and metabolic processes in cold-blooded fishes that control vital rates such as life stage duration, growth rates, energy demands, fertility, and reproductive success (Pörtner and Peck, 2010).

Currents influence larval dispersal and population migrations that cause heterogeneous distribution of marine flora and fauna.

Primary productivity is important for fisheries as it serves as the base of the food web. Its changes have far-reaching consequences and could ultimately result in reduced fisheries production (Cheung *et al*., 2010). The impact of climate change on primary productivity varies among freshwater and inland waters, coastal ecosystems, and open ocean pelagic systems as the major sources of primary production vary across these zones. Interactions among light availability, nutrients, and pH result in changes in primary production across waterbodies and large ocean basins. Changes in vertical ocean mixing and water stratification, changes in precipitation, and sea level rise also have the capacity to negatively impact fishes and fisheries by reducing primary productivity of the oceans (Blanchard *et al*., 2012).

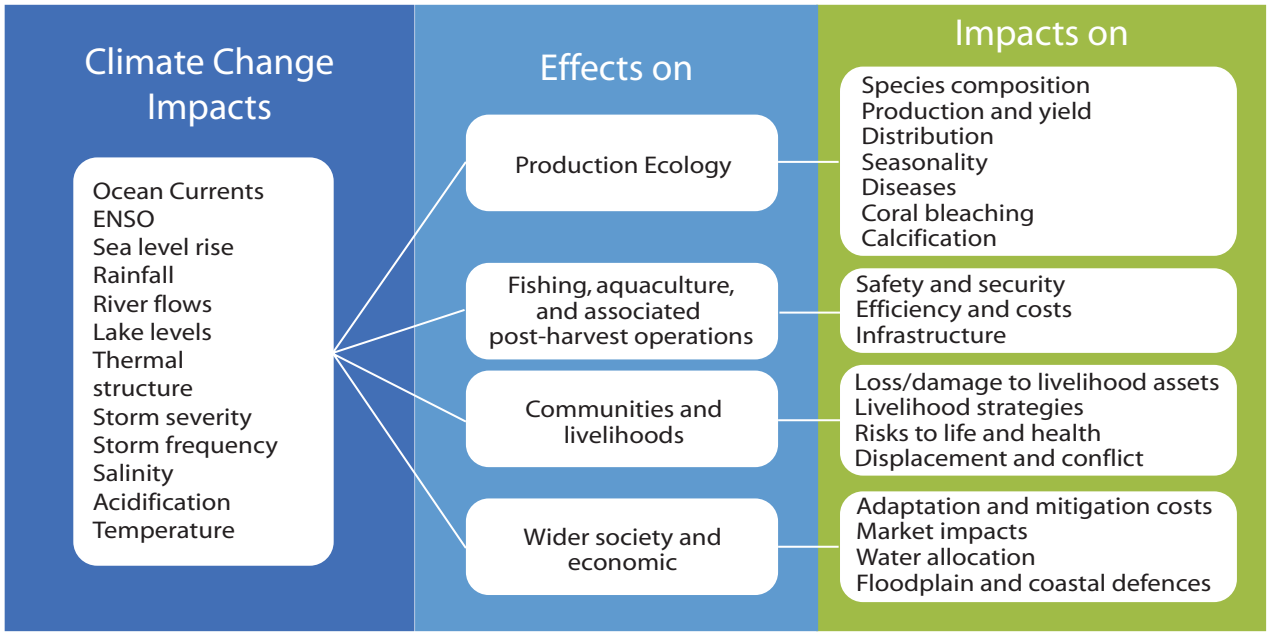
Demographic changes in fish and invertebrates will have direct impacts on fishing activities. Geographic expansion of fishing to farther and deeper fishing grounds have already been recorded and is expected to increase as local fishing grounds become depleted and the demand for fish increases with population growth (World Bank, 2013; Watson *et al*., 2015).

Oxygen concentration, if decreased, can limit the depths of suitable habitat for fishes. Such changes in the depth distribution of fishes can affect interactions between predators and prey, as well as interactions between fisheries and their target species.

Ocean acidification, the observed and projected changes of which are described in the previous section, negatively affects fishes and fisheries through three mechanisms: (1) alterations in calcification, growth, mortality rates, and reproductive success in corals that threaten reefs which are important habitats and nursery grounds of many fish species; (2) reductions in available coral reef habitats; and (3) sensory disruptions in individual fishes resulting in increased vulnerability to predation (Asch, Cheung and Reygondeau, 2017). Other chemical properties of seawater (e.g., salinity) also affect the structuring of coastal and pelagic habitats.

According to Badjeck *et al*. (as cited in Shelton, 2014) there are a variety of pathways by which climate change can affect ocean and inland seas through physical and chemical changes (Figure 1). The changes could impact fish and fisheries, habitats, ecosystems, communities, and wider aspects of societies. Impacts extend from fisheries resources and natural systems, to livelihoods, safety and other aspects of human systems. Multiple climate and non-climate changes may also increase the severity of impacts. For example, storm surges from typhoons and extreme weather events could couple with increased coastal erosion resulting from sea level rise and other factors (e.g. subsidence because of excessive groundwater extraction), increasing risks of damage to the habitats on which fish depend on as well as loss of life and property among subsistence fishing households whose socio-economic vulnerability is already high.

Figure 3. Climate change impact pathways in fisheries and aquaculture



Source: Badjeck *et al*. (as cited in Shelton, 2014)

Inland freshwater systems

Overview of freshwater systems

Asia is home to important river systems that span several countries, that is the Yangtze River, the Mekong River, the Indus River, the Ganges River, and support ecosystems that are key contributors to the region's livelihoods and the development of the region (Albinia as cited in Asian Development Bank and Postdam Institute for Climate Impact Research, 2017). With the productive Lower Mekong River Basin, Asia accounts for approximately 74 percent of global inland capture fisheries production (SEAFDEC, 2017). Inland waters and resources are often closest to anthropogenic inputs and stressors. Therefore, the impact of climate change is hard to distinguish from fishing and other environmental effects (Youn *et al*., 2014). Given this proximity, the main drivers of change in freshwater fisheries production are often related to environmental change rather than fishing pressure.

General observed impact of climate change on freshwater fish

Myers *et al*. (2017) synthesized, documented and projected the effects of climate change on inland fishes on a global scale. They found that Asia is underrepresented in terms of studies showing either projected or observed impacts of climate change on freshwater species, appearing as a focus in less than ten studies out of 179 papers analyzed found in the English-language, peer-reviewed literature in the 30-year period between 1985 and 2015. Papers in Asia were focused exclusively on documented changes in fish demography and projected changes in fish distributions.

Because of the paucity of studies related to the impacts of climate change on inland fishes of Asia, we cite here results from North American inland fish populations and assemblages as reviewed by Lynch *et al*. (2016). The review noted shifts in species' spatial distributions and the timing of key behaviours (e.g. migrations, spawning) were affected by climate variability. Compared to projected fish distributional shifts in response to climate change, the number of studies documenting observed changes is quite limited. In contrast, shifts in the timing of seasonal migrations or spawning are better documented than distributional shifts (Crozier and Hutchings as cited in Lynch *et al*., 2016). In general, milder winters, earlier spring warming, and warmer summers have led to earlier spring phenological events (e.g. migration, spawning), although responses have been mixed. Spring migration events have happened earlier in response to

accelerated warming in the spring and to overall warmer spring and summer temperatures. Climate change is also altering North American fish population dynamics through changes in abundance, growth, and recruitment. For example, decreased growth and abundance of some cold-water species have been linked to increased temperature, and, in some cases, increased temperatures and altered aquatic conditions have facilitated increased recruitment and abundance for other cold-water species. Evolutionary responses to climate change in freshwater ecosystems are poorly documented, but a small number of studies indicate that North American inland fishes are already exhibiting genetic change (Lynch *et al*., 2016). Similar patterns of change can be projected for Asia.

A trend revealed by Myers *et al*. (2017) with their studies in North America and Europe shows that documented and projected impacts are variable, but the general trend of Salmonid (salmon family) abundance is observed to decrease by 89.5 percent whereas the projected decrease is on average 35.7 percent.

Phytoplankton changes in inland systems can be induced by changes in physico-chemical properties of the water including temperature and nutrients (for example see Cuvin-Aralar *et al*., 2004). Temperature increases, decreased dissolved oxygen levels, changes in disease transmission, changes in toxicant stresses, and alterations to hydrographs could all contribute to the decreased productivity of native fish populations (Ficke *et al*., 2007). Capture fisheries and even aquaculture production in river deltas in Asia is expected to be impacted by sea level rise (De Silva and Soto as cited in Hijioka *et al*., 2014).

In Asia, climate change may affect the hydrology and fisheries of inland waters through increased precipitation, air temperature, and glacier melting in the Qinghai–Tibet Plateau (QTP). The QTP has many lakes and contains the glacier-fed headwaters of the Yangtze, Yellow, and Mekong rivers (Winfield *et al*., 2016). Increased precipitation may result in high river runoff and deliver more terrestrial inputs downstream which will eventually affect the riverine fisheries (Winfield *et al*., 2016). Changes in flow regimes of rivers and other running waters will impact habitats and species that are sensitive to droughts and floods. On the other hand, habitats that depend on seasonal flooding, including floodplain grasslands and freshwater swamp forests, will be particularly vulnerable. Reduced dry season flows are expected to combine with sea level rise to increase saltwater intrusion in deltas (Hijioka *et al*., 2014). Enclosed bodies such as lakes have also been affected. For example, O'Reilly *et al*. (2015) noted that most lakes in Asia have been steadily warming from 1985 to 2009.

Not all climate change impacts are negative, for example, in the Asian part of Russia where Lake Baikal is located, they found that during periods of low winter temperatures and long ice cover, conditions for Baikal Omul (*Coregonus migratorius*) fisheries production improved because of increases in river flow, lake level, and subsequent juvenile survival (Smirnov *et al*. as cited in Winfield *et al*., 2016).

Other threats to freshwater fisheries

Changes in precipitation coupled with increased deforestation and land-use changes could increase sedimentation and siltation in lakes and rivers, reducing water volume and exacerbating warming effects on underwater fauna and flora. Increased runoff could also enhance nutrient inputs leading to eutrophication and anoxic conditions that could result in massive fish kills.

Aside from climate change impacts, inland fisheries will continue to be vulnerable to a wide range of ongoing threats, including overfishing, habitat loss, water abstraction, drainage of wetlands, pollution, and dam construction, making the impacts of climate change hard to detect. Syvitski *et al*. (as cited in Hijioka *et al*., 2014) concluded that non-climatic impacts will continue to dominate in most estuaries and for most Asian lakes, making it difficult to separate the impacts of water pollution and hydro-engineering from climate change.

Nearshore and coastal systems

Overview of nearshore and coastal systems

Nearshore and coastal zones in the Asia-Pacific region are highly diverse because it spans from temperate zones to tropical zones and is affected by climatic conditions ranging from short-term weather events, such as monsoons and cyclones, to inter-annual variability resulting from the ENSO. Its major geological features include deltas, islands, and rocky coasts. It is also home to a very high degree of biological diversity because of the presence of various coastal ecosystems such as mangroves, seagrass beds, and coral reefs. These biological resources support commercial and subsistence fisheries, which are very important in this region.

Another distinct element of the region's coastal zone is the enduring and significant influence of human activity. According to Mimura (2006, p. 17):

> The Asia and Pacific region accommodates over half of the world's population, about 60 percent of which exists on or near the coasts. Economic development in the past 30 years has increased anthropogenic pressures and changes in land cover and land use in the river basins have also affected the coastal zones through discharge of wastes, organic matter, nutrients, and hazardous chemicals, into rivers and outfalls. Past and ongoing changes in coastal environments are the result of natural and socio-economic influences and should be understood by analyzing changes in those drivers.

Coastal and nearshore fisheries are often cited as highly vulnerable to climate impacts because of their strong habitat dependency, shallow bathymetry, and high anthropogenic stressors that substantially decrease the resilience of habitats to environmental perturbations.

Primary production

There is still considerable debate on the impact of climate change on phytoplankton and primary production especially in the coastal zone. At best, scientists agree that the impacts are highly heterogeneous and the impacts of other anthropogenic pressures (e.g. nutrient enriched terrestrial runoff) can either enhance or mediate the physico-chemical changes in the ocean directly attributable to climate change. For example, in the Bay of Bengal, heavy rainfall and passing of a cyclone caused phytoplankton blooms in the western Bay of Bengal which enhanced (by 40 percent) fishery production during October–December 2007 compared to that in the same period in 2006 (Maneesha *et al*., 2011).

Global earth system models are often resolved at such coarse resolutions (i.e. ~0.5°C grid cells) that important coastal processes and features are not properly incorporated (e.g. coastal upwelling, harmful algal blooms, bathymetry and coastline rugosity). There are very few fine resolution earth system models currently available for Asia that resolve the complex coastal oceanographic processes. The Coral Triangle Regional Ocean Modeling System or CT-ROMS is a 5-kilometre resolution model covering the larger Coral Triangle region that has been run only for the IPCC's Representative Concentration Pathways 8.5 (RCP8.5) – an emissions scenario – but it does not have an accompanying biogeochemistry module, and so no information on projected primary production changes is currently available (Castruccio, Curchitser and Kleypas, 2013).

Harmful algal blooms

Harmful algal blooms (HABs) caused by *Prorocentrum* (a dinoflagellate genus containing several toxic and harmful species and forms extensive red tides in many parts of the world) often result in massive fish kills in coastal areas and also pose direct threats to human health and life, as was the case for the fishkill in January 2013 in Northern Philippines (Escobar *et al*., 2013). The possible impacts of climate change on toxic marine HABs include: (1) changes in range or areas of both warm-water and cold-water species; (2) changes in abundance and toxicity; and (3) changes in the timing of the seasonal window of growth as summarized by Berdalet *et al*. (2016).

In northeast Asian waters, some spatial expansion of HABs is projected with future climate change (Glibert *et al*., 2014). Although conditions suitable for *Prorocentrum* are projected to lead to greater geographic extent of the blooms, a time reduction is also projected.

Coral reef and habitat-associated fisheries

Coral bleaching associated with El Niño events has also decimated reefs all over Asia in the previous decades e.g. Andaman Sea in India (Krishnan *et al*., 2011); Southeast Asia (Guest *et al*., 2012); and Arabian Gulf (Coles and Riegl, 2013). According to Hughes *et al*. (2018), "the number of years between recurrent severe bleaching events has diminished fivefold in the past four decades, from once every 25 to 30 years in the early 1980s to once every 5.9 years in 2016." The interval between recurrent bouts of coral bleaching is too short for a full recovery of mature assemblages (Hughes *et al*., 2018). Reef-associated and dependent fish species decrease in abundance within three years of disturbance events such as massive coral bleaching, storms, and crown-of-thorns outbreak that reduced coral cover by 10 percent or more (Wilson *et al*., 2006, Hoegh-Guldberg *et al*., 2017).

In Bangladesh, climate change and other anthropogenic stressors have caused hilsa shad (*Tenualosa ilisha*) fecundity to decline and spawning grounds to shift, seriously affecting the survival rate of juvenile hilsa shad and the country's hilsa shad supply and production (Miah, 2015). Models predict continued decline of hilsa shad abundance over time as climate change progresses (Fernandes *et al*., 2015).

Reduction in coral reef area because of increasing sea surface temperature and ocean acidification is projected to reach up to more than 90 percent by year 2100 under the highest emission scenario (RCP8.5) in West Asia, the Coral Triangle, East Indian Ocean, and Polynesia with estimated annual consumer surplus losses reaching USD 8.3 billion by the end of the century (Speers *et al*., 2016). Local ecosystem models also predict declines in fisheries production with increased coral mortality resulting from massive bleaching events (Ainsworth and Mumby, 2015).

Spatial range shifts and community composition change

Changes in the composition of temperate coastal ecosystems and fish communities because of climate change are more readily observable compared to predicted climate change-induced extinctions in low-latitude regions. The "tropicalization" of temperate marine ecosystems refers to the occurrence and increasing relative contribution of tropical species to temperate ecosystem species compositions (Vergés *et al*., 2014). These have been documented in Japan as tropical corals and reef fishes are expanding on Japanese temperate coasts in response to rising sea temperatures (Yamano, Sugihama and Namura, 2011; Nakamura *et al*., 2013; Soeparno, Nakamura and Yamaoka, 2013). Tropical corals are expanding to temperate reefs in Japan at a rate of 14 km/year based on 80 years of national coral records from temperate areas of Japan (Yamano, Sugihama and Namura, 2011). Subtropical coral species (e.g., *Alveopora japonica*) have also started appearing more in higher latitude areas such as Jeju Island in the Republic of Korea (Denis *et al*., 2014). Whether these changes will ultimately be beneficial to coastal fisheries in these temperate regions is still unclear. Even if this "tropicalization" does enhance overall fish productivity and biodiversity, these changes would disrupt existing and well-established fishing and socio-cultural systems that have been built around these temperate coastal habitats for centuries.

In the last century, Japanese fishers have also been observing large decreases in areas of seaweed beds and kelp forests which has been called the "isoyake" phenomenon. In more recent decades, these seaweed area reductions have been documented following persistently warm coastal water conditions such as the 1997 El Niño that resulted in drastic declines of the kelp *Ecklonia cava* in Tosa Bay, Japan (Serisawa *et al*., 2004). Although various factors could contribute to these seaweed declines, herbivory plays a major role in denuding these important temperate fish habitats. Annual grazing rates of tropical reef herbivores such as rabbitfish, parrotfishes, and kyphosids on these temperate seaweed beds have dramatically increased as winter ocean temperatures have risen (Yamaguchi, 2010).

Small pelagic fishes such as sardines, herring, mackerel, and anchovies are important food fishes for many Asia-Pacific countries. Small pelagic fishes are exceptionally sensitive to ocean changes and as such, their abundance and species composition are known to fluctuate with the large-scale ocean-atmosphere decadal cycle (Chavez 2003; Peck *et al*., 2013). Observations on the distribution and catches of Indian mackerel (*Rastrelliger kanagurta*) in India revealed a northward expansion of its common range across the country's western and eastern coasts and an apparent increase in deeper water abundance as indicated by the increase in relative contribution of bottom trawler catches along the Indian coast from 2 percent in 1985–1989 to 15 percent in 2003–2007 (no significant changes in bottom trawling practices over this period) (Vivekanandan, 2010). Shifting in spawning seasons of two threadfin bream species in India have also been noted (Vivekanandan, 2010). The percentage of female spawners collected every month off Chennai (southeast coast of India) from 1981 to 2004 showed the shifting of the spawning season from warmer (April–September) to relatively cooler months (October–March) where a decrease in spawners was observed with increasing temperature during the warmer period (Vivekanandan and Rajagopalan as cited in Vivekanandan, 2010). However, compared to other commercially-targeted species, small pelagic fishes are considered less vulnerable to the impacts of climate change (Jones and Cheung, 2017).

In the Philippines, the catches of sardines off the Zamboanga peninsula were generally correlated with cycles of ENSO wherein the highest landed catch volumes were recorded during El Niño years from 1998 to 2009 (Villanoy *et al*., 2011). This apparently contradictory result is attributed to the thinning of the freshwater barrier layer during El Niño years when precipitation is lower than average, allowing upwelled nutrient rich deep waters to reach closer to the surface (Cabrera *et al*., 2011, Villanoy *et al*., 2011).

Fisheries production

Effects of climate change on individual physiology of marine fauna and population-level responses (e.g. growth and reproduction) and ecosystem-level impacts (e.g. phenology changes, competition and predation, changing habitat suitability) ultimately translate to changes in available fish biomass for fisheries. Fishing catch composition data contain indications of climate change impacts on species distribution and relative abundance. An analysis of long-term fish catch compositions from FAO country data and the temperature preference of target species revealed that the percentage contribution of warm-water fish species in annual landed catches has been increasing in many Large Marine Ecosystems (LMEs) in Asia (Cheung, Watson and Pauly, 2013).

With expected range shifts in species, habitat loss, and direct physiological impacts of warming waters on fish growth, a global dynamic bioclimate envelope model projects significant but highly heterogenous changes in maximum catch potential (Cheung *et al*., 2010). Using available knowledge on environmental affinities of 1 066 marine species and IPCC-class global earth system models, Cheung *et al*. (2010) project as much as a 40 percent decline in catch potential in tropical regions and an increase of up to 70 percent in maximum catch potential in mid-latitudes and high latitudes. Finer spatial resolution models that take into account the complex bathymetry of shelf areas also project similar and predominantly decreasing potential catches (Barange *et al*., 2014) with as much as 76 percent and 50 percent projected declines in Palau and Sri Lanka, respectively. Projection models in the Pacific estimate even more drastic declines in potential catches under the RCP8.5 scenario of ~3°C increase in global surface atmospheric temperatures by end of the century (Asch *et al*., 2017). Coastal areas will be impacted by an average of 5 percent to 20 percent species loss by 2100 and a species gain ranging between 1 percent and 6 percent, such gains occurring mostly next to the northern Australian coast and Arafura Sea (Asch, Cheung and Reygondeau, 2017). By 2050, the projected decrease in maximum catch potential for Tuvalu, Cook Islands, Micronesia and Niue exceeds 50 percent, highlighting the elevated sensitivity of these countries to climate change impacts on their fisheries (Asch *et al*., 2017).

Oceanic and pelagic systems

Overview of oceanic and pelagic systems

The pelagic zone is the area in the open ocean that can be divided into depth regions. As you go deeper in the water column, the water conditions differ in terms of dissolved oxygen, salinity, pressure, temperature, and light, among others. The pelagic system or open ocean is basically oligotrophic or has very low nutrients in contrast to eutrophic (nutrient-rich) coastal areas. Most of the organisms thrive by migrating to areas of high productivity such as upwelling areas to feed. Occurrence of such productive areas have been found to be affected by climate variabilities such as ENSO.

Oceanic and large-pelagic fishes are high-valued commodities that are increasingly contributing significantly to national fisheries values. The Pacific region relies heavily on capture of these fishes such as tuna and billfishes. Oceanic fishes are projected to be exposed to increased water temperatures, changes in the strength of major currents, and reduced oxygen and pH levels, leading to less productive food webs and shifts in species spatial range and distribution.

Primary production

Primary production is limited by availability of light and nutrients. In the open ocean, light is limited to the surface layers whereas nutrients are mostly abundant on the ocean floor where the organic matter accumulates as it sinks in the water column. Without vertical mixing, these two crucial requirements result in very low primary productivity or photosynthetic activity in the open ocean. Fortunately, the ocean is not static. Water motion, both horizontal (e.g. wind-driven currents) and vertical (e.g. upwelling and thermal stratification) help entrain some of the nutrient-rich organic matter at or near the well-lit ocean surface layer as well as bring up nutrient-rich deep water into the surface. The Pacific Equatorial Upwelling System yields highly productive areas that support 4.7 percent of total global fisheries production (Hoegh-Guldberg *et al*., 2014). This upwelling system is influenced by interannual variabilities such as ENSO events that then control primary productivity and consequently affect associated fisheries production (Hoegh-Guldberg *et al*., 2014).

Climate change is predicted to affect wind patterns leading to changes in ocean currents and vertical water transport. These changes would impact oceanic primary production that will have repercussions throughout the overall food web.

Primary production is projected to increase in high latitudes but decrease in oceans at mid-latitudes and in the tropics (tropical western Pacific, tropical Indian Ocean) (Bopp *et al*., 2013). Tropical primary production is projected to decline by 2 percent to 4 percent per Kelvin temperature increase in the equatorial zone. Under a business-as-usual emissions scenario this results in a 5 percent to 17 percent decline in tropical marine primary production and a 3 percent to 9 percent decline in global marine primary production by 2100 (Kwiatkowski *et al*., 2017).

Sea surface temperature and tunas

The spatial distribution of tuna species is known to be affected by the ENSO, primarily because of changes in sea surface and subsurface temperatures and its effect on suitable spawning areas. In general, observations and model outputs suggest that climate change is likely to lead to increased vertical stratification or layering and water column stability in oceans, reducing nutrient availability to the euphotic zone (area where light can penetrate) and thus reducing primary and secondary production (Barange and Perry, 2009).

In the Pacific Ocean, El Niño events lead to shifting of tuna fishing areas from the western Pacific to the central Pacific coinciding with the displacement of the western equatorial Pacific warm pool as the trade winds weaken (Lehodey *et al*., 1997). Whereas adult pelagic predators such as tuna usually have a wider range of temperature preference and tolerances, larvae and juvenile tunas have a much narrower range of environmental preferences. Spawning tuna have even more narrow ranges of temperature tolerances,

thus allowing for more precise projections of climate impacts on tuna spawning habitats than the overall tuna distribution (Bromhead *et al*., 2015; Lehodey *et al*., 2017).

Longline catch rates of both bigeye and yellowfin tuna increase in regions of increased sea surface temperature and greater vertical stratification. For albacore, higher catch rates are recorded from the southern subtropical areas of the Pacific Ocean six months before El Niño episodes, or at their onset. This pattern is linked to a shallowing of the mixed layer depth in equatorial waters and a reduction in extent of the 18°C to 25°C isotherms (areas in the ocean with the same temperature) in the water column, which is the preferred temperature range of adult albacore (Lehodey *et al*., cited in Bell, Johnson and Hobday, 2011).

Tuna (e.g. yellowfin and skipjack tuna) and other pelagic fish species (e.g., wahoo and mahi-mahi) distributions are predicted to gradually shift towards the central and eastern Pacific because of climate change similar to the situation during El Niño (Bell *et al*., 2013 and 2017). This pattern is reversed during La Niña when warm waters are piled up in the western Pacific, increasing primary productivity and recruitment in this region (Nicol *et al*., 2014).

In the Republic of Korea, changes have been observed in population survival, productivity and species composition of demersal and pelagic fish species from the Yellow Sea, East China Sea, Tsushima Warm Current system in relation to changes in seawater temperature (Kim *et al*., 2007).

Dissolved oxygen

Aside from changes in primary production, warming oceans also impact the amount of dissolved oxygen in the water. The solubility of oxygen decreases as water temperature increases, thus a warmer ocean has less dissolved oxygen. The distribution of dissolved oxygen in the water column influences the horizontal and vertical distribution of tuna because the latter require adequate levels of dissolved oxygen for their survival and growth (Ganachaud *et al*., 2012; Lehodey *et al*., 2013). In contrast, because of the broad distribution of spawning grounds, changes in oxygen concentration is not likely to affect the reproduction of albacore, bigeye, skipjack and yellowfin tunas (Lehodey *et al*., as cited in Bell *et al*., 2011). Low dissolved oxygen may result to hypoxic conditions that lead to coastal fish mortalities (Hoegh-Guldberg *et al*., 2014).

Ocean acidification

Although ocean acidification impacts calcifying species predominantly, theory suggests that changes in ocean chemistry could also impact tuna species through larval survival and growth (Pörtner and Knust 2007; Lehodey *et al*., 2011). Yellowfin tuna eggs and larvae exposed to lower pH resulted in significantly reduced larval survival, larvae size and growth, and increased time required for egg hatching (Bromhead *et al*., 2015). Decreasing pH could also affect pelagic fish otolith formation, which is important for orientation, acceleration and detecting sound, particularly by tuna larvae, and thus might affect larvae survival (Laffoley and Baxter, 2016).

Ocean acidification may also have sublethal effects on fish. Decreasing pH is expected to reduce sound absorption and increase sound propagation, which might affect tuna and organisms in their food webs, such as their ability to detect prey and predators. Ocean acidification affects the availability of carbonate ions, which also affects the abundance of some species of calcifying phytoplankton and zooplankton that are small components of lower trophic levels of tuna food webs (Ganachaud *et al*. as cited in Laffoley and Baxter, 2016). Based on observations in other species, tunas may also experience sublethal effects from reduced pH, such as reduced growth and size at age, neurological and behavioural changes and altered evolutionary characteristics of populations (Laffoley and Baxter, 2016).

Climate-related changes have also been predicted for non-tuna pelagic species. In Japan, climate change is predicted to result in the net reduction and northward retreat of suitable habitat for neon flying squid (Alabia *et al*., 2015).

For a summary of key climate change impacts on fish and the fisheries sector see Table 5.

Table 5. Key climate change impacts on fish and the fisheries subsector (updated and adapted from Sriskanthan and Funge-Smith, 2011) with examples of documented observations or projections

Drivers	Biophysical effects	Implications for fisheries	Examples of documented or observed impact (References)
Changes in sea surface temperature	Less dissolved oxygen.	Negative impact for fish populations sensitive to low oxygen levels. Potentially reduced reproductive output and success.	n/a
	Increased incidence of disease and parasites.	Changing susceptibility of some stocks to disease.	Coldwater fishes are more vulnerable to disease (Chiaramonte, Munsen and Trushenski, 2016)
	Altered local ecosystems with changes in competitors, predators and invasive species and changes in plankton composition.	Impacts on the abundance and species composition of capture fisheries stocks. Food webs impacted. Ability of fisheries to provide food and protein impacted.	Spread and increase in invading species (Hoegh-Guldberg *et al.*, 2014). Projected decline in large fish abundance in central north Pacific because of change in plankton size structure (Woodworth-Jefcoats *et al.*, 2013)
	Change in the location and area of suitable range for particular species.	Increased productivity of some fisheries/ species: longer growing seasons and lower natural mortality in winter; enhanced metabolic and growth rates. Poleward shifts of some large pelagic fish. Movement of fishing operations to follow fish. Potential species loss and altered species composition.	Tropical reef fish found in temperate communities (Nakamura *et al.*, 2013). Oil sardine move northward (Vivekanandan, Rajagopalan and Pillai, 2009). Poleward range shift of yellowtail and Spanish mackerel (Hoegh-Guldberg *et al.*, 2014).
	Enhanced primary productivity.	Potential benefits for fisheries but perhaps offset by changed species composition. Increased incidence of harmful algal blooms.	n/a
	Changes in timing and success of migrations, spawning and peak abundance, as well as in sex ratios.	Potential loss of species or shift in composition in capture fisheries. Potential for mitigation through culture-based or enhanced fisheries.	Distribution change of key pelagic fisheries such as skipjack tuna, yellowfin tuna, big-eye tuna, and South Pacific albacore tuna in the Pacific (Hoegh-Guldberg *et al.*, 2014).

Table 5. *(continued)*

Drivers	Biophysical effects	Implications for fisheries	Examples of documented or observed impact (References)
	Damage to coral reefs that serve as breeding habitats, nursery and habitat.	Reduced recruitment of fishery species.	Projected increase in frequency of disease in reef-building corals (Maynard *et al*., 2015). Loss of diversity and changes to fish community composition because of coral bleaching (Munday *et al*., 2008)
Rising sea level	Loss of land.	Loss of freshwater fisheries.	Loss of the Sundarbans and other coastal wetlands could reduce breeding grounds for many estuarine fish (Sarwar, 2005).
	Changes to estuary systems.	Loss of nursery grounds for coastal fisheries.	Loss of the Sundarbans and other coastal wetlands could reduce breeding grounds for many estuarine fish (Sarwar, 2005).
	Saline intrusion.	Impact on freshwater capture fisheries species composition.	n/a
	Changing coastal ecosystems such as mudflats and mangrove forests – in some areas mangroves/wetlands may increase by flooding inland areas.	Reduced recruitment and stocks for capture fisheries. Exposure of fishing communities and infrastructure to waves and storm surges.	Mangrove areas threatened by SLR in small islands, reducing fish habitat (Nurse *et al*., 2014)
Ocean acidification	Reduced capacity of the ocean to buffer climate change. Rate of acidity change faster than any on record. Decrease calcification rate of calcifying organisms.	Changes in species growth, reproduction and behaviour. Adverse affects on formation and dissolution of calcium carbonate shells and skeletons. Impacts on marine ecosystems and the benefits they provide.	No effect on juvenile growth and survival of damselfish (Munday *et al*., 2011). Reduced size-at-age of cobia (Bignami, Sponaugle and Cowen, 2013) Impaired ability to sense predators (Munday *et al*., 2010). Global production of shellfish fisheries are projected to decline (Hoegh-Guldberg *et al*., 2014).
Changes in precipitation and water availability	Changes in fish migration, recruitment patterns, and recruitment success.	Altered abundance and composition of wild stock. Food webs impacted.	n/a

Table 5. *(continued)*

Drivers	Biophysical effects	Implications for fisheries	Examples of documented or observed impact (References)
	Temperature/dry period changes: • dry periods/water scarcity • altered and reduced freshwater supplies with greater risk of drought.	Water quality changes because of population pressures, reduced flow or increased urban/agricultural discharges.	n/a
	Changes in lake and river levels and the overall extent and movement patterns of surface water.	Changes in food webs and species composition and decreased biodiversity in all inland aquatic environments: • altered distribution, composition and abundance of fish stocks • fishers forced to migrate more and expend more effort • habitat and nursery grounds change.	n/a
	Sudden, high precipitation leads to rapid runoff. Local flooding in deltas, coastal areas. Rapidly changing water levels/flow rates in rivers. Flooding of low lying plains/floodplains. Glacial lake outbursts.	Flooding, especially flash flooding: • flash flooding impacts to housing/communities • migration following flooding • turbidity and fluctuating water quality with consequent effect on fish stocks • fishing gears damaged or lost • major impacts in high dependent freshwater fisheries e.g. Tonle Sap, Mekong, Ayerwaddy delta, Hilsa fisheries in Bangladesh. Possible benefits for increased recruitment if flooding sustained long enough.	Positive correlation between rainfall and annual catch of silver whiting in Pakistan (Ayub, 2010).
Higher inland water temperatures	Potential for enhanced primary productivity.	Higher fishery production. Eutrophication.	n/a
	Increased stratification and reduced mixing of water in lakes, reducing primary productivity and ultimately food supplies for fish species.	Reductions in fish biomass.Change in food webs and species composition.	Decline in abundance of Cisco (Jacobson *et al.* as cited in Lynch *et al.*, 2016)

Table 5. *(continued)*

Drivers	Biophysical effects	Implications for fisheries	Examples of documented or observed impact (References)
	Reduced water quality, especially in terms of dissolved oxygen; oxygen carrying capacity of water declines.	Possible enhanced fish stocks for capture fisheries or, alternatively, reduced growth where the food and oxygen supply does not increase sufficiently in line with temperature.	Increased zooplankton densities, increased growth of juveniles of sockeye salmon (Schindler *et al.* as cited in Lynch *et al.*, 2016)
	Metabolic rates increased.	Potential loss of species and alteration of species composition for capture fisheries. Many species in tropical countries are already living at the upper end of their temperature tolerances and may not be able to adapt to even higher temperatures.	n/a
	Changes in the range and abundance of pathogens, predators and competitors, and invasive species introduced.	Altered capture fisheries stocks and species composition.	n/a
	Changes in timing and success of migrations, spawning and peak abundance.	Potential loss of species or shift in composition for inland capture fisheries because of: • species shifting with temperatureo • pattern of migration timings change • spawning times changing • gonadal development/maturation/sex ratios change.	Earlier spawning migrations, e.g. striped bass, sockeye salmon (Peer & Miller, 2014, Cooke *et al.* as cited in Lynch *et al.*, 2016). Reduced recruitment and population sizes of Brook trout (Bassar *et al.* as cited in Lynch *et al.*, 2016)
Increase in frequency and/or intensity of storms	Large waves and storm surges. Inland flooding from intense precipitation. Salinity changes.	Impacts on wild fish recruitment and stocks. Higher direct risk to fishers and loss of fishing gears.	n/a
	Siltation and sedimentation; salinity changes.	Impacts on wild fish recruitment and stocks. Higher direct risk to fishers and loss of fishing gears. Capital costs increased for moorings jetties, etc. that can withstand storms. Increased insurance costs.	n/a

Table 5. *(continued)*

Drivers	Biophysical effects	Implications for fisheries	Examples of documented or observed impact (References)
	Changes in lake water levels and river flows.	Reduced wild fish stocks. Intensified competition for fishing areas and more migration by fisher folk.	Reduced recruitment and population sizes of Brook trout (Bassar *et al.* as cited in Lynch *et al.*, 2016). Decline in recruitment of Chinook Salmon (Ward *et al.* as cited in Lynch *et al.*, 2016)
Changes in El Niño – Southern Oscillation (ENSO)	Changed location and timing of ocean currents and upwelling alters nutrient supply in surface waters and consequently primary productivity. Decline in upwelling of Pacific Equatorial Upwelling System (EUS) during El Niño and strengthening during La Niña.	Changes in the distribution and productivity of open sea fisheries.	Tuna distribution predicted to shift to eastern and central Pacific (Bell *et al.*, 2013 and 2017). Projected 28 percent decrease in primary productivity and 15 percent decline in fish catch with reduction of EUS (Polovina *et al.* as cited in Hoegh-Guldberg *et al.*, 2014).
	Changed ocean temperature and bleached coral. Mass coral bleaching and mortality.	Reduced productivity of reef fisheries.	ENSO impacted tuna population dynamics in Indian Ocean (Kumar *et al.*, 2014). Mass coral bleaching and mortality of coral reefs within South China Sea in 1998 and 2007 (Hoegh-Guldberg *et al.*, 2014).
	Altered rainfall patterns bring flood and drought.	Similar impacts for precipitation trends, drought and flooding as above.	n/a

Implications of climate change for the fisheries subsector in the Asia-Pacific region

Climate change will have a wide range of ramifications for the fisheries subsector in the Asia-Pacific region. As highlighted in the previous section, climate change has impacts on both marine and freshwater systems, which in turn will increase the vulnerability of associated fisheries. Climate change also affects vulnerabilities associated with economic and social dependency on fisheries resources and other changing variables, which then affects the adaptive capacity of the society in relation to these changes. This section summarizes results of recent literature and research investigating the potential societal impacts of climate-induced changes on fishing communities, the general public, the nation and the region. It also includes examples of implications presented by the country participants during the FAO/APFIC Regional Consultative Workshop: Building Climate-Resilient Fisheries and Aquaculture in the Asia-Pacific Region in Bangkok, Thailand, 14–16 November 2017 (hereafter referred to as FAO/APFIC Consultative Workshop 2017).

Fishing communities

More than 90 percent of the region's capture fishers are small-scale fishers (FAO, 2016a). Small-scale marine fishing accounts for about half of the fish harvested from the ocean, and provides jobs for more than 47 million people – about 12.5 million fishers and another 34.5 million people, many of whom are women, who are engaged in post-harvest activities (Makino *et al*., 2009; Pomeroy and Andrew as cited in Hijioka *et al*., 2014). Probably the greatest challenges from a changing climate are those faced by people who have livelihoods closely linked to the health of the marine environment, who are nutritionally dependent on access to marine resources, or who live by the coast and are directly affected by a combination of sea-level rise and extreme weather events (Allison and Bassett, 2015).

Household economy, livelihoods and income

The social scientific literature highlights the important contributions that fisheries make to household economies and livelihoods. In developing countries, most of the small-scale marine fishing activities have focused on demersal fish and invertebrates associated with coral reef ecosystems, and to a lesser extent on those associated with mangrove, seagrass and intertidal flat habitats (Bell *et al*., 2017). As described in Section 3, all these habitats are being increasingly impacted by climate change. Changes in fish distribution and fish abundance are altering the natural capital of fishing communities' livelihoods. Possible consequences include: (1) reduced net incomes of fishers because of the increased costs of traveling to more distant fisheries; (2) increased fishing efforts to capture the same amount of fish for both consumption and for sale; and (3) the need to purchase new gear types and adopt new harvesting strategies to capture species that are more tolerant to local, altered conditions (Badjeck *et al*. as cited in Heenan *et al*., 2015). Adaptive responses have involved changing the types of fishing undertaken and the extent of the efforts made, and may include diversifying out of fishing altogether (Allison and Bassett, 2015).

Value/supply chains

When the multiplier effect of employment in value chains is considered, the total number of people deriving part of their livelihoods from fisheries activities could be several times higher than the number directly engaged in fishing (FAO as cited in Belton and Thilsted, 2014). Fisheries and aquaculture are vulnerable to both climate and non-climate related drivers of change. These changes have impacts throughout the fish value chain and pose significant challenges for fisheries and aquaculture, from production to marketing and consumption; affecting food security, health, livelihoods, trade, and gender issues (Navy, Minh and Pomeroy, 2017).

Fishers, traders and processors are adapting to the impacts of climate change. A study by Navy, Minh and Pomeroy (2017) in the lower Mekong area shows that for fishers, adaptation measures included changing

fishing gear, changing fishing area, and spending more time fishing. Traders planned to buy other fish species and increase input costs (for example, purchasing more fish or traveling to other areas to purchase fish). Processors planned to increase input costs by, for example, purchasing more fish or other fish species, or changing the type of processing. In the same study, all of the respondents along the value chain involved in snakehead aquaculture in Viet Nam reported that they felt that the major climate changes over the next ten years will be drought and hotter weather. The responses were consistent across all provinces studied that, in the next ten years, there will be a decrease in seed quality and disease. Traders reported that the main climate change impacts on their businesses have been higher purchase prices of fish, higher fish losses and decreases in income. Processors reported that the main impacts of climate change on their businesses have been lower quantities of fish available (processing products) and increasing prices of raw fish (Navy, Minh and Pomeroy, 2017).

Non-tangible benefits

Benefits of fisheries extend beyond these material/financial dimensions. Social, cultural and other non-tangible aspects of fisheries may also be threatened by climate change impacts. Fisheries have a role in supporting social relationships and well-being within communities, often through reciprocal arrangements and collective action (Weeratunge *et al*. as cited in Béné *et al*., 2016). Tangible benefits arise from the nature of the activity and from the sense of personal or collective identities and job satisfaction that can be derived from engaging in fishing activities (Pollnac *et al*. as cited in Béné *et al*., 2016). There are also cultural traditions that are based on fish and fishing activities. The Kirats, an indigenous ethnic group in Nepal, for example, celebrate the Ubhauli (upward) and Udhauli (downward) festival, which is based on the migratory behaviour of fish. The literature highlights, however, the extent to which fisheries' contributions that are embedded within local cultural and social contexts tend to be downplayed in the wider debates on the roles of fish and fisheries (Béné *et al*., 2016).

Gender issue

Contrary to the long held notion that fisheries is a male domain, "if gleaning and post-harvesting activities were enumerated, the fisheries and aquaculture subsector might well turn out to be [a] female sphere" (Béné *et al*., 2016). Women and men are differently prepared to address the risks posed by climate change and natural disasters. Research shows that women are, in general, more vulnerable than men to these risks (Sriskanthan and Funge-Smith, 2011) and may be more greatly and more negatively affected by climate change (Campbell *et al*., 2016). This is because of financial limitations, lessened access to resources, and limited access to information and extension services (which often target men only), as well as a more general tendency to have less female participation in some social institutions and in the development of strategies and policies related to adaptation and disaster risk reduction. There may be several linkages among climate change and gender since climate change may also exacerbate existing gender inequalities.

Health and safety

The climate change vulnerability of populations in Asia is high because of elevated exposures to climate impacts. Asia has more than 90 percent of the global population exposed to tropical cyclones, and many of those who are engaged in fisheries live in low-lying coastal zones and flood plains. Based on the Long-Term Climate Risk Index,[5] five of the ten countries most affected from 1996 to 2015 are in Asia, namely Myanmar (second most affected), Philippines (fifth most affected), Bangladesh (sixth most affected), Pakistan (seventh most affected), Viet Nam (eighth most affected) and Thailand (tenth most affected). Many coastal areas are facing real risks of sea level rise, salt water intrusion, intensified storms, and severe coastal erosion. Climate change poses threats to fisheries-related work at sea and along the coast, as well as to other aspects of natural safety, food security and health-related risks. (Hijioka *et al*., 2014). For example, increasing temperatures and drought reduce safe post-production processes and food safety in fisheries

[5] https://germanwatch.org/en/download/16411.pdf

product supply chains because of higher rates of microbial growth and increased health risks related to highly perishable products. Water-related impacts of climate change, such as lower availability of water for sanitation, increased contamination, and the spread of water-borne diseases, are expected to increase the health burden and decrease food safety (Heenan *et al*., 2015). Concern has been expressed that rising disease incidence will lead to overuses of pesticides and veterinary medicines, especially in fisheries and aquaculture (Tirado *et al*. as cited in Campbell *et al*., 2016).

General public

Nutrition and food security

Many vulnerable countries are also among the least developed in the world. Their inhabitants are among the world's poorest and are twice as reliant on fish, getting 27 percent of their dietary protein from fish compared to 13 percent for people in less vulnerable countries. Approximately 11 percent of the world's population is estimated to be undernourished, with the majority living in developing areas including China and Southeast Asia (FAO, 2014). The majority of these people rely on seafood as their primary protein source. Based on the presentations of the country participants at the FAO/APFIC Consultative Workshop 2017 in Bangkok, protein contribution from fish was estimated to be as high as 40 perent in Viet Nam, 60 percent in Bangladesh and Sri Lanka, 70 percent in the Philippines, and 82 percent in Cambodia.

Because 87 percent of capture fisheries production (FAO, 2014), and 47 percent of aquaculture production (FAO, 2016), comes from marine and coastal waters, climate change impacts on marine resources are expected to have a significant effect on seafood production (Laffoley and Baxter, 2016). Because of the effects of ocean warming and acidification, the productivity of coral reef fisheries is expected to decrease by 20 percent by 2050 under a high "business as usual" GHG emissions scenario. In addition, the areas of mangroves in Pacific island countries and territories (PICTs) are expected to decrease by 50 percent to 70 percent by 2050 under a high GHG emissions scenario, mainly because of sea-level rise and more intense storms. Increased runoff from higher rainfall, more intense storms, and increasing sea surface temperatures associated with global warming are also likely to reduce the areas of seagrass habitats in PICT by 5 percent to 35 percent by 2050 (Bell *et al*., 2017).

All four dimensions of the contributions of marine fisheries and mariculture to food security—*availability, stability, access, utilization* – will be affected (Cochrane *et al*. as cited in Bell *et al*. 2016). According to Laffoley and Baxter (2016, p. 426):

> The availability of fish will vary as a result of changes in fish habitats, fish stocks and the distributions of species. The *stability* of supply will be altered by changes in seasonality, increased variance in ecosystem productivity and increased variability in catches. Access to fish will be affected by changes in opportunities to derive livelihoods from marine fisheries and mariculture, *utilization* of fish will be affected because some communities will need to adjust to species not consumed traditionally, and increased prevalence of aquatic diseases and HAB [harmful algal blooms] are likely to render some fish production inedible more frequently.

In India, shifts in spawning periods of fishes have already been observed in a number of commercially important fish stocks, such as threadfin bream, and changes in distribution patterns of two key fisheries species, Indian oil sardine and Indian mackerel, have changed greatly over the past 50 years shifting from Kerala Coast to Tamil Nadu (Vivekanandan *et al*., 2009).

As fisheries decline, as climate impacts amplify and as human populations increase, aquaculture production is becoming an integral part of food security for the region and is globally one of the most rapidly growing food production sectors (Ahmed and Lorica as cited in Williams *et al*., 2016). In Asia, production continues for both commercial and subsistence purposes. (FAO, 2014) Even with this focus on aquaculture development and improvement, there will be challenges in maintaining stable future production as ocean acidification and warming of surface waters alter the physiology of cultured species. In Southern China, absorption of anthropogenic CO_2 has been more rapid than other regions. The

conversion of mangrove forests in China, Viet Nam and some other Southeast Asian countries into fish and crustacean culture ponds reduces biodiversity and other ecosystem services (Ellison as cited in Williams *et al*., 2016). It is likely that the expected food-security benefits of aquaculture will be reduced under degraded coastal conditions unless more tolerant species or strains are selected, key habitats are protected from destruction and aquaculture is expanded (Williams *et al*., 2016).

Cultural implications

It is less often appreciated that climate change can threaten cultural traditions, professional identities (as fishers), and sense of place. In many societies, fish and fisheries have been an integral part of cultural development and ceremonies. In Nepal for example, fish is considered a symbol of good luck (*sagun*) and aquatic products such as fish and *makhana* (*Eurela ferox*) are essential for many rituals. In China, it is considered an emblem of fertility. Small-scale subsistence capture fisheries provide a wide variety of culturally preferred, nutritious fresh and processed fish that are often accessible to poorer consumers (Belton and Thilsted, 2014). At the same time, culture shapes how societies respond and adapt to climate-related risks, offering a range of opportunities and constraints that may not be apparent to external agents but that need to be taken into consideration for successful climate adaptation. Many coastal communities have strong ties to the sea and attachments to fisheries-related occupations. Diversifying and relocating may make sense in terms of economic rationality or human security, but it may cause irrevocable loss of cultural identity and sense of home, and compromise social, mental and psychological well-being (Allison and Bassett, 2015).

National and regional levels

In addition to impacts on fishing communities and the general public, there are several implications of climate change for the fisheries subsector at the national and regional levels.

Economy and trade

The contribution of capture fisheries to national economies is generally examined through: (1) generation of revenues to national accounts from access payments, exports, taxation and license fees; (2) economic rents, and more generally net economic benefits; (3) wages and income received by those employed in the subsector; and (4), effect of multipliers and economic linkages within the regional/national economy (Allison as cited in Béné *et al*., 2016).

It is becoming evident that climate change affects the economics of fishing because both the quantity and quality of marine fish catch and its distribution within and between national waters are increasingly being impacted. The economic consequences of climate change for fisheries might include changes in the price and value of catches, fishing costs, fishers' incomes, earnings to fishing companies, national labour markets, industry re-organization, and re-orientation to changes in export earnings or deficits (Sumaila *et al*., 2011). Climate change is predicted to decrease fish production, for example, in South and Southeast Asia (Barange *et al*., 2014). Fisheries trade, which represents a significant source of foreign currency earnings in Southeast Asia, is growing (Pomeroy *et al*., 2016). However, under a high "business as usual" emissions scenario (RCP8.5), harvests from marine fisheries in this region are projected to decrease by 10 percent to more than 30 percent by 2050 relative to 1970–2000 (Cheung *et al*. as cited in Bell *et al*., 2016). Because climate change could increase the cost of fishing, it is likely to lead to reductions in fishing efforts and fishing overcapacity (Sumaila *et al*., 2011).

Conflicts

Climate change exacerbates the pressures already being placed on the Asia-Pacific region's coastal and marine resources by rapid population growth and increasing food needs. For example, most of the nearshore fisheries in Southeast Asia are overfished, and fishing overcapacity is one of the leading causes of potential conflicts (Oppenheimer *et al*. as cited in Campbell *et al*., 2016). Resource-poor and marginalized

populations from the fisheries subsector are vulnerable to climate change, and threats to these groups may undermine communal resource regimes and exacerbate further conflict (Oppenheimer *et al*. as cited in Campbell *et al*., 2016). Increasing sea temperatures and changing patterns of upwelling are projected to cause shifts in the distribution and abundance of important pelagic fish stocks with potential to create winners and losers among national economies as catches of the transboundary tuna stocks change among and within their exclusive economic zones (Hoegh-Guldberg *et al*., 2014). For instance, tuna (e.g. yellowfin and skipjack) and other pelagic fish species (e.g. wahoo and mahi-mahi) distributions are predicted to shift gradually towards the central and eastern Pacific because of climate change similar to the situation during El Niño (Bell *et al*., 2013 and 2017). Transboundary illegal, unreported and unregulated (IUU) fishing not only negatively impacts fisheries resources, it can also be a cause of conflicts among the countries involved.

Fisheries governance

Under the increasing impacts of climate change on fisheries, the conventional way of managing single species has become inadequate and a risk to sustainable fisheries. Climate change impacts on fisheries has brought about serious considerations for many countries to change fisheries governance to better support sustainable fisheries for long-term food security, to use the best available science in management decisions, to take into consideration the precautionary approach to address uncertainty, and to use adaptive management. The Ecosystem Approach to Fisheries Management (EAFM) has started to be an alternative that dominates recent capture fisheries literature (Evans *et al*. as cited in Béné *et al*., 2016) and in discussions about how to improve fisheries governance. The EAFM addresses multiple social and environmental objectives, takes different factors and their linkages into consideration, and applies a collaborative approach and stakeholder engagement (including co-management and community-based management). The application of the EAFM has been endorsed internationally through the United Nations Food and Agriculture Organization Code of Conduct for Responsible Fisheries, and in the Asia-Pacific region through the intergovernmental Regional Plan of Action agreement among the six-member states of the Coral Triangle Initiative for Coral Reefs, Fisheries, and Food Security (CTI-CFF) and in their respective National Plans of Action (Heenan *et al*., 2015). Indonesia, Philippines and Thailand have all adopted EAFM as a national approach for fisheries planning and the management of their fisheries management regions/ units.

Many features of an EAFM make in an intrinsically useful framework for effective adaptation to climate change (Heenan *et al*., 2015). The detection of changes in the distributions of target species because of climate change and resilience-building are both integral to an EAFM. Resilience is the capacity of elements of integrated socio-ecological systems to withstand disturbance and adapt to change while maintaining their core attributes. Resilience applies to fish populations and habitats, fishing communities' livelihoods, economic development, and policy and management. According to Heenan *et al*., the resilience focus of an EAFM:

> Assists communities to cope with the alterations in species composition of catches and with changes to fishing methods and costs through, for example, livelihood diversification, adopting alternative fishing strategies and occupational pluralism. In an integrated management framework, like EAFM, resilience has limitations when specified as a fishery management objective in itself because it is not a value-neutral term. Resilience-orientated management actions will raise practical questions, namely resilience to what and for whose beneft? Maintaining or increasing resilience will require cross-system dynamics and trade-offs to be made explicit, for example, the long-term gains of marine protected areas versus the immediate impacts on food and livelihood security. As a participatory process in which conflict management mechanisms are employed, an EAFM provides a process in which climate resilience can be considered in a transparent manner. (2015, p. 186)

The co-management component of an EAFM shares the burden of responding to climate change impacts by facilitating information exchange among stakeholders to empower informed decision-making. Such institutional cooperation and coordination help develop the coherent and complementary policy

arrangements needed to adapt effectively to the complex ways in which climate change and ocean acidification affect food security and marine biodiversity.

National and regional organizations' efforts to address climate change and build climate-resilient fisheries

To date, all APFIC countries have ratified the United Nations Framework Convention of Climate Change (UNFCCC) and signed the Paris Agreement. Some of the least developed countries (including Bangladesh, Cambodia, Lao People's Democratic Republic, Myanmar, Nepal, and Timor-Leste) have developed a National Adaptation Programme of Action on Climate Change, which synthesizes existing information and identifies key adaptation measures. Countries in the APFIC region have made wide-ranging efforts for climate change adaptation and mitigation. This section summarizes efforts by the countries and regional organizations presented during the FAO/APFIC Regional Consultative Workshop 2017 and includes specific examples to illustrate some key efforts.

National efforts

National plans, strategies and policies for climate resilience

Many countries have national plans, strategies, policies, and programmes to build resilience to climate change. Several of the programmes and initiative are technically and financially supported by other countries or by international and regional organizations/agencies.

- Bangladesh has a Climate Change Trust Fund, Climate Change Resilient Funds, a National Adaptation Programme of Action on Climate Change, a Climate Change Strategy and Action Plan, a National Food Policy Capacity Strengthening Programme, and a Food Security Country Investment Plan.
- Cambodia has recently developed its Building Resilience to Climate Change: A Strategy to Respond to Impact of Climate Change 2017–2023.
- China has completed projects on coastal ecosystem succession under climate change, and on sustainable utilization and adaptive management in Chinese coastal waters under multi-stressors. An ongoing project involves regulating environmental changes on the recruitment process of fishery stocks. China has a national plan for scientific and technological innovation on climate change and a national assessment report on the ocean under climate change.
- India has Marine Fishing Regulation Acts to control the construction of fuel-efficient fishing crafts and to establish minimum catchable legal sizes, an Environmental Protection Act to regulate coastal activities, and a Coastal Aquaculture Authority Act.
- Indonesia developed a National Action Plan for Climate Change Adaptation in 2014 with action plans for addressing climate change impacts on fisheries. The MMAF has a strategic plan for 2015–2019 regarding climate change adaptation and mitigation, including coastal habitat rehabilitation, eco-friendly fisheries, and fish health management.
- Lao People's Democratic Republic has a National Strategy on Climate Change 2010 for building environmental strategy, biodiversity strategy, forestry strategy, environmental education and awareness strategy, and renewable energy. Agriculture and food security has been identified as one of the seven priority areas for adaptation and mitigation. Its national development plan (NSEDP 2010–2015) addresses climate change.
- Malaysia's National Policy of Climate Change 2010 provides a framework for mobilizing government agencies, industry, community, and other stakeholders to address climate change in a holistic manner.
- Myanmar has a Climate Change Strategy and Plan 2016–2030, and a Climate-Smart Agriculture strategy to promote and attain sustainable agriculture, food security and nutrition, agricultural development, and climate change adaptation and mitigation.

- Nepal developed a National Adaptation Plan in 2015, a National Climate Resilience Planning and Climate Change Policy in 2011, and a Climate Change Adaptation and Disaster Risk Management in Agriculture Priority Framework of Action (2011–2020). Its Climate Change Policy has goals of improving livelihoods by mitigating and adapting to the adverse impacts of climate change, and adopting a socio-economic development path with low-carbon emissions. Nepal's NAPA includes agriculture (with fisheries) and food security as one of the four major thematic areas.
- Pakistan has a National Policy for Climate Change 2012 to mainstream climate change in the economically and socially vulnerable sectors of the economy, and to steer Pakistan towards climate resilient development.
- The Philippines' Republic Act No. 9729 mainstreams climate change into government policy formulations, establishing a framework strategy and programme on climate change. Republic Act No. 10174 establishes a people's survival fund to provide long-term finance streams to enable the government to effectively address the problem of climate change. The Department of Agriculture, Bureau of Fisheries and Aquatic Resources has a Climate Change and Disaster Risk Reduction and Management Framework.
- Sri Lanka's national climate change adaptation strategy 2011 seeks ways to ensure that its development trajectory can be supported and also be more climate change resilient.
- Thailand's National Strategy on Climate Change and its Climate Change Master Plan (2015–2050) use three strategies: adaptation, mitigation of GHG emissions and increase of GHG sinks, and strengthening capacity of human resources and institutions to manage climate change and cross-cutting issues.
- Timor-Leste's Strategic Development Plan 2011–2030 commits the country to developing a National Adaptation Programme of Action to identify national priorities for addressing climate change adaptation and monitoring the implementation of adaptation measures. Timor-Leste's NAPA has specific project activities on mangrove and coastal zone management.
- Viet Nam's National Climate Change Strategy 2011 and its National Target Programme include implementation plans to respond to and cope with climate change. Several plans have been specifically developed to respond to climate change impacts and reduce GHG emissions in agriculture and rural development.

Financing climate adaptation and mitigation

All countries work toward securing funds from both national and international sources to support their climate adaptation and mitigation activities. Some allocate national budgets or national revenue (e.g. Cambodia), and national trust funds (e.g. Bangladesh). China has set an environmental fee for stock protection and enhancement activities. Sri Lanka initiated processes to mobilize significant investments that can go beyond advocacy and put in place resources to support and sustain development. Others seek international funding sources such as the Global Climate Fund, Global Environment Facility (GEF), or funding from the World Bank, Network of Aquaculture Centres in Asia-Pacific (NACA), United States Agency for International Development (USAID), and Japan International Cooperation Agency *(JICA)*.

Financing climate change adaptation at the local level: People's Survival Fund in the Philippines

Although climate change is a global issue, effective adaptation actions require the involvement of local communities, many of which do not have sufficient resources for climate change adaptation planning and strategy implementation. In the Philippines, the People's Survival Fund (PSF) was established in 2012 to address this bottleneck and became operational in 2015. It is a special fund in the National Treasury that can finance climate change adaptation programmes and projects by local government units (LGUs) and local community organizations (LCOs).[a] The eligibility of LGUs depends on poverty incidence, exposure to climate risks, and presence of identified and delineated key biodiversity areas, whereas LCOs need to be accredited. By law, the fund has an annual rolling minimum budget allocation of P1 billion (~USD 20 million) and can be augmented

by other grants and donations. Proposals should not be for business-as-usual projects. Instead, the proposed projects must be based on climate science and incorporate: (1) data on climate-related hazards and their effects (e.g. tropical cyclones, flooding, storm surge, drought); (2) climate scenarios and projections (e.g. rainfall, temperature); and/or (3) people and areas exposed to various climate hazards (e.g. population, agricultural land, coastal communities). Funding use in relation to fisheries includes: sectoral vulnerability assessments; forecasting and early-warning systems; institutional development; risk financing; and community adaptation support programmes. Training events are ongoing to help LGUs and LCOs develop appropriate proposals to access the fund. Of the 38 proposals submitted in 2016, only two were awarded financial suppport, both LGU projects: one for a ridge-to-reef disaster risk reduction programme focused mainly on agriculture and forests,[b] whereas the other aims to establish a climate field school for farmers and fisherfolks.[c] More local-scale science inputs from both natural and social science disciplines are needed to properly guide adaptation projects.

[a] http://psf.climate.gov.ph
[b] http://icsc.ngo/lanuza%E2%80%99s-psf-proposal-reflects-good-local-governance
[c] http://icsc.ngo/del-carmen-siargao-island-and-realities-adaptation

Climate smart/resist/resilient fisheries

The APFIC member countries are addressing climate change in fisheries production and management planning. Related efforts include climate-smart fisheries for sustainable food security, climate-smart management practices, innovative adaptation technologies, and climate change-resistant fisheries products. Some of the specific efforts being made by various countries are:

- Bangladesh has climate change-resilient fisheries in its development plan.
- The FishAdapt project in Myanmar strengthens the adaptive capacity and resilience of fisheries and aquaculture dependent livelihoods.
- In line with the Coral Triangle Initiative strategies, Timor-Leste is building the climate-change resilience of coastal communities and improving food security.
- The Philippines has developed recommendations for enhancing the resiliency of fisheries infrastructures.
- Sri Lanka has pilot projects working toward climate resilience and seeks ways to ensure that its national development trajectory can be supported and become more climate change resilient.
- Indonesia has developed guidelines on the adaptation of tuna fisheries to climate changes.
- Malaysia and Indonesia have insurance for fishers.
- Several countries, including Malaysia, Nepal, the Philippines and Cambodia are working to establish community-targeted early-warning and notification systems regarding climate changes.

Ecosystem approach to fisheries management (EAFM)

Climate-resilient fisheries require a holistic fisheries governance framework to address changing climate. The EAFM represents a move away from conventional fisheries management that targets single species, and towards systems and decision-making processes that balance environmental health and human well-being within improved governance frameworks.[6] The EAFM considers interactions among: (1) the core elements of the fishery (fish and fishers); (2) habitats and environmental conditions that interact with the fishery; and (3) the socio-cultural, economic and governance systems that surround the fishery (Garcia *et al*. as cited in Heenan *et al*., 2015). The principles of EAFM emphasize stakeholder engagement, multi-sectoral planning, adaptive management, and a precautionary approach. Planning and decision-making without waiting for complete scientific information has become necessary, and more acceptable as a means to address climate impacts proactively.

[6] Available at http://www.eafmlearn.org/

Many countries in the Asia-Pacific region have already implemented parts of the EAFM and are further building on what they have started. A few others have adopted EAFM or are promoting it as a national approach to managing fisheries. These include the Philippines, Indonesia, Thailand, Malaysia, Lao People's Democratic Republic, Nepal, Myanmar, and Timor-Leste. FAO and other international agencies, including USAID and the United States National Oceanic and Atmospheric Administration (NOAA), have collaborated with relevant country partners in the AFPIC region both to build capacity in EAFM and to help develop and implement EAFM plans.

Planning and implementation of the EAFM in the Philippines

In 2016, in keeping with the BFAR's efforts to mainstream EAFM throughout the Philippines – pursuant to the amended Fisheries Code, Republic Act (RA) 8550 as amended by RA 10654, and the Fisheries Office Order No. 164 – and with support from the USAID, NOAA, and/or local non-governmental organizations (NGOs), the national and regional BFAR offices organized a series of EAFM planning and implementation workshops in selected fisheries management areas (FMAs). Together with representatives from multiple stakeholder groups (including, provincial fisheries offices, the Department of Environment and Natural Resources, Coast Guard, Department of the Interior and Local Government, Philippines National Police, academia, and NGOs), key threats and issues of the FMAs were identified, and management goals, objectives, and actions were developed. To date, EAFM plans have been developed for implementation in the Visayan Sea (covering five provinces and coastal towns of Iloilo, Capiz, Negros Occidental, Cebu and Masbate), General Santos (including Sarangani Bay Protected Seascape), Biliran, and the Ticao Pass and Saint Bernardino Straight of North Samar.

Collaboration among different sectors and agencies

Efforts have been made to integrate climate change policy with other inter-related national policies and across different sectors, including fisheries and aquaculture. These efforts are taking place at both regional and national levels. For example, a number of Southeast Asian countries are collaborating on several issues regarding the lower Mekong region. Viet Nam has implemented intersectoral spatial planning for coastal areas. Pakistan has strengthened interministerial decision-making and coordination mechanisms on climate change. And, the guiding principle of Sri Lanka's national climate change adaptation strategy is to mobilize people and institutions to work toward integrated solutions that capitalize on both interests in and opportunities for mobilizing resources for climate change adaptation. This is done through a consultative process with collaborative institutions, including the Meteorological Department, the Climate Change Secretariat, the Disaster Management Centre, and the Sri Lankan Navy.

Conservation of fisheries resources

Given the likelihood of diverse climate impacts on fisheries resources, multiple efforts have been made by the countries in the Asia-Pacific region to conserve, restore, and enhance biodiversity and the health of both ecosystems and their services to realize sustainable social and economic development and improved carbon sequestration. Fish sanctuaries to support biodiversity, stock enhancement programmes and marine or inland water protected areas have been established in Bangladesh, China, Thailand, Cambodia, Indonesia and the Philippines. Conservation and restoration efforts can be found for fisheries dependent habitats such as mangroves, coral reefs, and inland waters in Indonesia, Myanmar, India, Philippines, Malaysia, Timor-Leste, Nepal, Viet Nam and Cambodia. Timor-Leste has approved and is implementing a National Ocean Policy, as well as national resource management plans and policies.

Some other national efforts focus on improving fisheries laws, rules and regulations related to catch size limits, fishing areas, fishing gears or methods. The Philippines set fisheries reference points and harvest control rules. China has established 492 National Aquatic Germplasm Reserves and 23 Aquatic Conservation Areas, and has implemented a fishing ban in the whole Bohai Sea. India promotes non-destructive fishing practices such as gillnets and longlines. Closed fishing seasons and fishing moratoriums

have been implemented in China, the Philippines, Malaysia, and Thailand. Other efforts focus on regulating boat licensing and controlling fishing capacity. For example, China plans to reduce fishing boats to 40 percent of the 2014 number during 2015–2019. Most countries are focusing on enforcement and other surveillance and monitoring measures to combat IUU fishing. Additionally, there have been efforts to work with fisheries stakeholders to conserve habitats or to adopt other livelihood activities. Malaysia, for example, has an exit programme to encourage fishers to engage in fish processing and aquaculture. In addition, their *Nakhoda* programme trains young fishers to engage in deep sea fishing.

Enhancement of fisheries productivity

In addition to the conservation of fisheries resources, many countries make efforts to increase fisheries productivity through stock enhancement, sea/marine/ocean ranching, and culture-based fisheries. They have enhanced stocks by habitat improvement and the protection of breeding and nursery grounds through protected areas, by the installation of artificial reefs, by reducing harvest levels, by protecting immature sea life and spawners, and by releasing juveniles into the sea. For example, sea ranching has been used in China, Indonesia and India. In China alone, over 300 billion individuals have been released, and 42 national-level sea ranching programmes have already been established with the aim of reaching 120 sites by 2025. In Cambodia, several culture-based fisheries projects are under development with support from JICA, USAID, and NACA, as a way to strengthen the adaptive capacity of fishing communities and to ensure food security. In the Philippines, there have been efforts to improve post-harvest technologies and food safety in relation to major food fish species.

Capacity building

APFIC member countries are preparing for climate change by building and improving awareness among fishers and relevant stakeholder groups about climate change and its impacts on fisheries. Awareness of climate change and its impacts is considered critical for fishers and relevant stakeholders at all levels if they are to engage appropriately in planning adaptation and mitigation measures. Additionally, many countries are working to develop the human resource and institutional capacities of relevant stakeholders to handle climate change related issues. For example:

- Bangladesh has campaigns to create awareness of impacts and risks of climate change in fisheries.
- Viet Nam has training plans to increase climate change knowledge among staff in the fisheries subsector and mitigation and adaptation knowledge among communities.
- In India, meteorological, climatological and geophysical agencies are involved in knowledge building efforts to prepare vulnerable coastal communities.
- In the Bay of Bengal, Southeast Asia and Coral Triangle countries, ongoing training has been conducted on EAFM, with the precautionary approach and adaptive management among the main principles of the fisheries management.

Research, monitoring and evaluation

The need for research, monitoring and evaluation in fisheries habitats, fisheries activities, and climate change impacts on fisheries has been identified at both national and regional levels. Based on input from AFPIC member countries, a range of research, monitoring and evaluation activities and programmes have been conducted in the region, but knowledge and response gaps remain wide. Research capacities in climate change analysis and adaptation continue to be built, however. The areas of research efforts include:

- ongoing development in China, Cambodia, India, Indonesia, Malaysia, Philippines, Viet Nam, and Timor-Leste of databases, trends, and forecasts related to the impacts of climate change and climate variability on fisheries habitats (both nearshore and ocean systems), fishing activities, and fisheries resources (including stock assessments and modelling, spatial distribution and migration patterns of important species);

- rehabilitation and restoration programmes in Indonesia;
- vulnerability assessments, including assessing the fisheries-related costs of climate change;
- adaptation research, e.g. at the Centre for Climate Change and Biodiversity under the National University of Timor Lorosae, Timor-Leste;
- the socio-economic implications of changes in resources availability;
- carbon footprints in fisheries, as, for example, in tuna fisheries in Indonesia;
- the coping strategies of traditional indigenous fisheries in the Philippines;
- gathering research evidence for policy and legislation development in Cambodia and Viet Nam;
- green technology in Malaysia; and
- culture-based fisheries in Cambodia.

Mitigation

National efforts in fisheries have been made to mitigate climate change. At the policy level, these include the development of Indian and Thai protocols during the Conference of the Parties 21(COP21) for making pledges to reduce carbon footprints by lowering greenhouse gas emissions by 25 percent by 2030. Protocols were also developed by Indonesia during COP21 to reduce fuel subsidies, and in Pakistan the National Policy on Climate Change was developed to promote climate change mitigation to the extent possible in a cost-effective manner. Other efforts focus specifically on the fisheries subsector, including improving fuel consumption efficiency and the fuel-saving practices of fishing vessels in India, Thailand and Philippines; using solar energy capture fisheries in India; and the initiation of monitoring, evaluation and energy audits related to fuel use among fishing crafts in Thailand and India. There are also efforts to consider ways to increase eco-friendly fisheries in Indonesia, for example, as part of Ministry of Marine Affairs and Fisheries (MMAF) strategy for climate change adaptation and mitigation. On a larger scale, many of these countries participate in reforestation and the development of alternative energy sources.

Climate adaptation in sustainable development to ensure food security

Countries in the region are pursuing sustained economic development and food security by appropriately addressing the challenges of climate change. The national policy for climate change of Pakistan, for example, fosters the development of appropriate economic incentives to ensure water security, food security and energy security in the face of the climate challenges. Timor-Leste is examining the concept of a blue economy, and Lao People's Democratic Republic aims to be out of LDC status by 2020 and is embarking on a path of green growth. In Bangladesh, there is a food security country investment plan and a National Food Policy Capacity Strengthening Programme. In Malaysia, the Department of Fisheries takes responsibility for ensuring food security as fish remains a crucial part of the Malaysian diet.

Involvement of communities

The increasing involvement of communities has been recognized in many places as essential for successfully managing fisheries and climate adaptation. Specific programmes and initiatives have been developed to increase community engagement, and to build the capacities and skills needed within coastal and fishing communities to undertake adaptive actions aimed at reducing vulnerability, mitigating risks, responding to climate change effects, better managing fisheries, and building resilience. Examples include:

- the climate smart village and the National Framework on Local Adaptation Plan in Nepal;
- locally marine managed areas in Myanmar;
- the FAO-supported Good Community Fish Refuges Management Practice which fosters community fisheries management in Cambodia;
- the outstanding Coastal Community Programme in the Philippines;
- the Bangladeshi Safety Networks that aim to achieve enforcement measures and build adaptation and management skills among affected communities in response to climate change effects;

- Indonesian efforts to empower outer islands communities;
- a Vietnamese community-building model aimed at actively preventing and mitigating natural disasters and adapting to climate change; and
- co-governance of lagoon and estuary management in Sri Lanka.

Safeguard vulnerable fishers and populations

Recognizing that a large number of subsistence and artisanal fishers live under the poverty line, and that resource-poor and marginalized populations from the fisheries subsector are the most vulnerable to climate change, several countries have paid special attention and developed programmes and initiatives to assist these groups to better cope with climate change impacts. In Pakistan, one of the objectives of the National Policy on Climate Change is to foster pro-poor, gender sensitive adaptation. In Myanmar, besides using gender sensitive approaches, there is a child-centered climate change adaptation programme supported by several international agencies, including the Australian Department of Foreign Affairs and Trade, the German Federal Ministry of Environment's International Climate Initiative, the United Kingdom's Department for International Development, the Nordic Climate Facility, and the Asian Development Bank (ADB). In the Philippines, as mentioned in an earlier part of this section, the People's Survival Fund (PSF) includes poverty incidence and exposure to climate risks as criteria for eligibility. Additionally, with funding from the ADB and executed by the Philippines Department of Environment and Natural Resources' the Municipal Development Fund, gender-related activities and processes were integrated into coastal resource management from 2007 to 2013 with the aim of helping to enhance coastal resources and reduced poverty among municipal fisherfolk.

Regional organizations' efforts

Regional organizations have traditionally dealt with challenges such as economic development, effective resource management, poverty, health care, and governance in the context of regional planning. However, climate change adds a layer of complexity in managing each of these issues, and organizations have begun to strategize about how to incorporate climate change into their overall planning structures. A primary objective of many collaborations among regional organizations and governments is building climate resilience and adaptive capacity at the regional, national, and local levels, while reducing vulnerabilities. A key vulnerability is food security. Regional organizations are also attempting to aid countries in developing strong governance structures, where regional strategies that include climate change are incorporated into national government strategies and planning documents. Good governance would encompass sustainable use of resources and would also recognize the importance of including gender considerations in planning.

The following provides some examples of how regional organizations are working toward addressing climate change in fisheries. The examples are drawn from presentations and summaries submitted to FAO by the regional organizations that participated in the 2017 Consultation Workshop in Bangkok.

The Southeast Asian Fisheries Development Center (SEAFDEC) has set an objective of "sustainable use of aquatic resources and reduced vulnerability to climate change by fishing communities in the ASEAN region." There are three SEAFDEC programmes supporting regional and subregional initiatives addressing fisheries/aquaculture issues in relation to climate change:

1. Optimizing Energy Use and Improving Safety in Fishing Activities (SEAFDEC/Training Department, 2013–2019) with the main objectives of enhancing the knowledge and experience of ship owners, fisheries extension officers, and other key stakeholders of ASEAN Member States, and of conducting research and development to improve fishing operations/practices and optimize energy use.
2. Adapting to Climate Change (SEAFDEC/Aquaculture Department, 2012–2020). The long-term objective of the programme is to ensure that the production of important aquaculture

commodities will continue even under conditions of higher temperatures and more acidic waters for the dual purpose of maintaining continuous supplies of food fish and creating opportunities for income generation. To achieve this, scientific information is necessary as a basis for future interventions and SEAFDEC has developed a wide range of activities to generate and disseminate such information, and is collaborating with relevant institutions in the countries and in the region.

3. Fisheries and Habitat Management, Climate Change and Social Well-being in Southeast Asia (SEAFDEC/Secretariat, 2013–2018). The key objectives are to sustain the use of aquatic resources and to reduce vulnerability to climate change by coastal/rural (fishing) communities in the ASEAN region.

The Network of Aquaculture Centres in Asia-Pacific (NACA) has chosen to focus on food security given the rise in food demand resulting from population growth, and in recognition of the close linkage among food security, poverty, climate change, and sustainable development. Key additional targets for NACA are: support for aquaculture development; assistance for the development and better management of aquaculture; the incorporation of science and scientific knowledge into aquaculture; FAO blue growth; and FAO sustainable intensification of aquaculture.

NACA's Regional Initiatives operate in four areas, namely: increasing climate resilience of fish farmers, farming systems and breeds available for farming; increasing capacity to manage short-term and long-term climate risks and reduce losses from weather-related disasters; improving sustainability of genetic diversity in broodstocks as a resource for long-term, continuous adaptation to climate change; and reduce and/or sequester greenhouse gas emissions.

NACA and its partners have played a vital role in implementing many activities, such as strengthening capacities to adapt to the impacts of climate change in some member countries (AquaClimate Project); implementing culture-based fisheries development in Lao People's Democratic Republic (low emission food production); sharing meetings on climate change and disaster risk reduction in Nepal and efforts for strengthening adaptive capacity to climate change in aquaculture and fisheries; environmental monitoring and early-warning systems for fisheries and aquaculture in the Lower Mekong Basin; organizing a global conference on climate change adaptation within fisheries and aquaculture (FishAdapt); sharing experiences on the ground; adaptive learning in sustainable aquaculture best practices for small-scale shrimp farmers in Thailand; conducting a seminar on food security through sustainable aquaculture development and disaster risk reduction for Bangladesh.

Worldfish has operated in Bangladesh since 1987 and has tested a number of technologies to address climate change impacts in the country and to mitigate impacts on a highly vulnerable population. These include: installing fish rings or habitats in seasonally flooded rice fields, using raised beds and ditches as an integrated farming system; improving the quality of habitat in small ponds and ditches to protect fish, community water management schemes, and to provide alternative income generating opportunities for fishers. A climate smart farm project tested a range of technologies in south-west Bangladesh, primarily alternative growing methods for vegetables in salinity-affected areas. The best performing system was tower gardens. Other systems that have been widely adopted include growing vegetables over fish ponds on bamboo racks. Tower gardening systems are now being increasingly adopted by households in this region and taken up by other projects and communities.

International Union for Conservation of Nature (IUCN) supports IMTA, which uses the sustainability principle that in a food chain, the waste for one species can become food for another. Following this approach, shellfish and marine plants utilize the organic and inorganic waste generated by finfish marine farms, both reducing their impact on the environment and providing a diverse form of income for farmers.

FishAdapt, an initiative sponsored by FAO, Rare, and development partners including the Norwegian Agency for Development Cooperation (NORAD), NOAA and the Government of Japan, is a global forum to discuss the current state of knowledge on climate change adaptation for fisheries and aquaculture. In

Myanmar, it is working to strengthen the adaptive capacity and resilience of fisheries and aquaculture-dependent livelihoods. FishAdapt's goal is to enable inland and coastal fishery and aquaculture stakeholders to adapt to climate change by understanding and reducing vulnerabilities, piloting new practices and technologies, and sharing information.

The Bay of Bengal Large Marine Ecosystem Program (BOBLEM) is promoting EAFM, which emphasizes the balance between ecological and human well-being through governance systems that incorporate climate change and gender considerations. To support capacity building, they have developed a training course and have trained numerous middle level managers across the eight Bay of Bengal countries.

The goal of the Bay of Bengal Programme – Inter-Governmental Organisation (BOBP-IGO) with its emphasis on high seas and national waters is ensuring "an environment for sustainable fisheries governance is in place in the region." This four-country regional organization, which includes Bangladesh, India, Maldives and Sri Lanka, focuses on micro-sectoral or intra-sectoral issues that are related to improving occupational safety, improving sustainable fisheries management systems in the region, and building capacity in fisheries management agencies to monitor and report possible impacts of climate change. At the macro-level, BOB-IGO is coordinating with other concerned agencies in the region to build good governance in the fisheries subsector through an ecosystem-based fisheries approach. BOBP-IGO is also attempting to use green technologies to reduce the carbon footprint of fisheries. Additionally, BOBP-IGO is assisting in community preparedness through collaborative programmes with international non-profit organizations, intergovernmental organizations and government agencies on conservation of marine biodiversity. It is also participating in government-level dialogues on management of shared ecosystems and is conducting knowledge audits and information dissemination.

Gaps, constraints, and recommendations regarding regional strategies and actions to support national efforts to build climate-resilient fisheries

Several gaps and constraints have been identified in fisheries management and climate adaptation in the Asia-Pacific region. All should be addressed in order to increase the chances of successfully building climate-resilient fisheries. This section summarizes participants' inputs from the 2017 FAO/APFIC Consultative Workshop, as well as from the relevant literature. The first part of the section focuses on gaps and constraints. The second part presents recommendations regarding regional strategies and actions to support national efforts to build climate-resilient fisheries.

Gaps and constraints

The gaps and constraints can be categorized as follows: knowledge building, sharing and use; effective fisheries management and governance; climate resilient fisheries policies; adaptation; and mitigation. Specific gaps and constraints in each of the areas are listed below.

Gaps and constraints in knowledge building, availability of information, and its use

- There is a low level of awareness and understanding of climate change and impacts on fisheries. The gap is widened by limited collaboration between those who produce the information and those who use it. There is also a lack of regional learning networks and an absence of climate information services and of effective practices for distributing scientific information on climate change, adaptation and mitigation.
- There is insufficient reliable and timely data to inform fisheries management and policies. These data include time-series data on fish stocks, data from systematic monitoring of capture fisheries, especially inland fisheries (Youn *et al*., 2014), data from monitoring of atmospheric and oceanic parameters, data on climate impacts on fisheries and other socio-economic conditions.
- There is a strong need for international support on technical know-how transfer and capacity building. Currently, there is insufficient capacity among researchers in the countries in the region

to conduct research on climate change and its impacts on fisheries, to analyze physical and biological available data for climate impact predictions (Williams *et al*., 2016), and to apply new techniques/methods to assess the vulnerability of fisheries resources. These capacity limitations result in a lack of updated knowledge databases within countries and across the region. A lack of knowledge about downscaling local effects from regional and global models makes forecasting for specific areas inadequate and adaptation difficult.

There are limited or no funds for research on climate risks and vulnerability assessments on fisheries. Although this is the case generally across the region, the need for such funds has been identified as particularly relevant in Bangladesh, Lao People's Democratic Republic, Malaysia, Myanmar and Nepal.

- As most vulnerability assessments have focused primarily on biophysical conditions that impact the fisheries resources, the social dimensions of climate change are under-investigated. There is a lack of understanding about the socio-cultural and economic development of fishing communities, and about the outcomes and impacts of fisheries management and adaptation interventions in relation to food security and poverty alleviation (Béné *et al*., 2016; Allison and Bassett, 2015). The adaptive capacity of fishing industries and fishing communities, particularly small-scale fisher folk who make up more than 90 percent of the worlds' fishers and fish traders, is not understood (Djoudi and Brockhaus, 2011). It is necessary to acknowledge that improving knowledge of social-ecological climate drivers and the vulnerabilities of fisheries systems is necessary to help identify effective adaptation options (FAO, 2016a).
- Despite the high involvement of women in fisheries, there are only very limited studies on impacts of climate change on gender and women in fisheries. Women play critical roles in fisheries that have been overlooked and underrepresented not only in research, but also in management and policy. There is a need to better understand the gender differentiated risks of climate change and natural disasters as well as related gender vulnerabilities (Harper *et al*., 2013; Kleiber, Harris and Vincent, 2015).
- There is a limited number of or no early-warning systems for climate-related disasters and extreme events caused by climate change and climate variability. Several countries mentioned the need for early-warning systems and safety at sea programmes to be met before a potentially disastrous event occurs. These would help provide information and improve preparedness and minimize risks and negative impacts.

Gaps and constraints in effective sustainable fisheries management/governance

- Weak fisheries governance, weak capacity of fisheries institutions, and poor enforcement are the norm throughout the region.
- There is only a slow shift occurring from conventional ways of fisheries management that focus on maximizing production and realizing short-term economic results in relation to single target species to more holistic approaches to sustainable fisheries that include efforts to achieve a balance between ecological health and human well-being. EAFM has been recently adopted in some countries, but its planning and implementation are still in the infancy stage. Because of the high numbers of people depending on fisheries resources for their livelihoods, increasing demands for seafood, and the contributions of large scale fisheries to national economic development, it is difficult to lessen fisheries pressures or to shift the focus of fisheries management away from catch maximization.
- Lack of collaboration among sectors, agencies, and different governance levels is common. Although there are many high level plans, clear policies and actions are missing. At the same time, stakeholder engagement is too limited to allow for co-management of fisheries resources and habitat conservation. (Pomeroy *et al*., 2016; Béné *et al*., 2016; Hijioka *et al*., 2014). Institutional inertia often presents a significant barrier to cooperation across sectors, and can lead to maladaptation.
- Despite the importance of the private fisheries subsector, especially for pelagic fisheries, their level of interest in being a part of fisheries management and their engagement is low (Pomeroy *et al*.,

2016); those in the private sector often feel that they are targeted as the "cause of the problem" or the "bad guys" by conservation and environmental advocacy groups (Pomeroy *et al*., 2016).

- Transboundary fisheries management and collaboration are limited or lacking despite the migratory nature of many fish species. There is also a need to address IUU across national borders and in neighbouring countries' exclusive economic zones (EEZs), and a need for joint responses to maritime security threats (Pomeroy *et al*., 2016). This exacerbates existing tensions between nations because of numerous unresolved maritime boundary disputes and contested ownership claims over living and nonliving natural resources (Oppenheimer *et al*. as cited in Campbell *et al*., 2016).
- There is limited support on developing a blue economy (Allison and Bassett, 2015).

Gaps and constraints in developing policies for and implementation of climate-resilient fisheries

- Although several national planning processes to address climate change exist, and although national plans, strategies and programmes for adaptation have been developed, fisheries and aquaculture sectors were not well represented in these plans despite their importance to the national economy and their high level of vulnerability to a changing climate. At the same time, national fisheries policies often fail to consider climate change impacts. For example, export policies that balance decreasing local fisheries supplies as a result of climate impacts are lacking but much needed (Bell *et al*., 2016).
- There is limited national collaboration for climate change resilience in fisheries among relevant stakeholders, including environmental management, fisheries management, and disaster risk management.
- A common regional vision and coordination of climate change adaptation and mitigation in fisheries is lacking.
- There are limited human and technical resources at all levels for climate-smart fisheries, including innovative ways to improve fisheries adaptation, disaster risk reduction, and other resilience measures.
- Fisheries policies do not have a roadmap to mitigate GHGs and cut down carbon footprints in a specific time period.
- Policy considerations for simultaneous adaptation and mitigation in the fisheries subsector and in the management of marine and coastal environments are lacking (Campbell *et al*., 2016; Komatsu 2013; Allison and Bassett, 2015).
- There are limited policies and programmes, including inadequate insurance and financial support to offer emergency services that protect disadvantaged groups and vulnerable populations that are highly susceptible to climate risks, including small-scale fishers.

Gaps and constraints in climate adaptation and mitigation

- Natural systems that serve fisheries habitats and carbon sink sources, including mangroves and forests, are degraded or damaged.
- Ecosystem-based adaptation that takes into account the health of ecosystems, ecosystem services, and human well-being in the long run, as well as no-regret adaptation strategies, are still limited in practice or are granted lower priority than short-term hard/infrastructure solutions (Hijioka *et al*., 2014; Hoegh-Guldberg *et al*., 2014; Bell *et al*., 2017).
- There are limited adaptation options for alternative sustainable livelihoods and employment opportunities among fisherfolk. For example, with climate impacts on nearshore habitats and declines of nearshore fisheries abundance, pelagic fishing efforts by small-scale fisheries have been suggested as an alternative (Bell *et al*., 2017). Building such an alternative requires several types of support for enabling conditions, required resources, and sea safety.
- Outdated and energy-inefficient technologies and vessels are common. Lack of know-how and limited resources place constraints on moving away from existing options, on optimizing post production storage and facilities, and on minimizing waste along the fisheries supply chain (Bell *et al*., 2017; Bell *et al*., 2016). Moreover, in many countries there is still a lack of incentives for renewable and green energy alternatives.

- Increased energy and fuel consumption because of intensifying fishing operations (including post-harvest processing and storage) and longer offshore fishing trips to compensate for depleted nearshore resources is now the norm.
- Maldevelopment and maladaptation set back potentials for climate resilience. Examples include clearing forests and mangroves for crop cultivation or aquaculture, as well as poorly designed coastal development.

Recommendations to build climate-resilient fisheries

Integration of the fisheries sector into climate change planning

The APFIC Climate Change Workshop in Nepal 2011 produced a series of recommendations for countries and for regional organizations (including FAO and APFIC) to support the member countries in better integrating the fisheries subsector into climate change planning (Sriskanthan and Funge-Smith, 2011; FAO, 2011). To address the gaps and constraints noted above, the following section highlights recommendations from the Nepal workshop as well as presents recommendations gleaned from recent literature on fisheries and climate change and recommendations suggested by the country participants and regional organizations in the FAO/APFIC Consultative Workshop 2017.

Build knowledge by improving research and using science for climate-informed fisheries management and adaptation

Most countries are interested in improving their technical capacity to conduct research as a way of ensuring that they have the information needed for assessing climate impacts on fisheries and establishing adaptation measures. They also would like to increase their ability to share and use the information. There seems to be several causes for the persistence of limited up-to-date and accurate information on climate change and its impacts on fisheries and on the people who depend upon it. Several of these factors were highlighted previously. Recommendations that help address these factors include the following.

Build capacity and provide technical support on climate change and adaptation research

Capacity building is a key component of successful climate adaptation and mitigation strategies, and allows for continual improvement to policies (Campbell *et al*., 2016). The fisheries working groups at the FAO/APFIC Consultative Workshop 2017 emphasized the importance of international and regional funding and technical support to national governments as a way to help develop and improve the capacity and knowledge of member countries, not only for conducting research on the impact of and adaptation to climate change, but also for planning and implementing adaptation and mitigation projects in fisheries, for sharing climate smart technologies and innovations, and for empowering fishing communities to cope with climate change. Concretely, there should be scheduled and comprehensive training events and awareness building programmes. The countries would also benefit from having knowledge and capacity related to improving relevant databases, downscaling local effects from regional and global models, and making accurate forecasts for specific areas to support better adaptation. Several countries, for example Bangladesh, Myanmar, Nepal, Timor-Leste, and Lao People's Democratic Republic, recommended increasing investments in interdisciplinary climate research, science and technology, as well as actions, in order to support climate resiliency, sustainable fisheries and food security.

Projecting the impacts of climate change on Philippine's marine fisheries

Understanding the risks brought by climate change is essential to developing appropriate climate change adaptations in the fisheries subsector. Available local climate projection models are being used to generate scenarios for the climate change trajectories of different species, ecosystems, and even socio-institutional systems. Spatial resolution (e.g. ~50 km to 100 km) is often sacrificed for coverage (i.e. global) in these models, and there is increasing research in downscaling their outputs at scales relevant for local decision-making that consider regional and local climate nuances. In the Coral Triangle, a high resolution (~5 km) model was created for the region by a partnership with the National Center for Atmospheric Research, Rutgers University, University of California-Berkeley, and The Nature Conservancy, and the United States NOAA's Pacific Islands Fisheries Science Center (PIFSC). An ongoing partnership between the Philippines' Bureau of Fisheries and Aquatic Resources and United States NOAA, facilitated by the USAID and its support for a Filipino graduate student working on this project with the PIFSC, is using the Regional Ocean Modeling System developed for the Coral Triangle (CT-ROMS) to project potential changes in marine fish distributions and relative abundance in and around the Philippines up to the year 2100. Downscaled maps have been produced based on multiple types of information, including: environmental thresholds for fish species from the Aquamaps database (www.aquamaps.org); projected changes in sea surface temperatures, salinity, and ocean currents from the high-resolution CT-ROMS; and primary production from coarser-resolution Coupled Model Intercomparison Project Phase 5 (CMIP5) models. NOAA is producing maps of projected changes in the distribution of suitable habitats for targeted commercial marine fishes for the Philippines using a 10 km grid resolution. At this scale, many of the major fishing grounds and islands are resolved enough to allow the data to be used for provincial or even municipal-level fisheries vulnerability assessments.

Establish regional physical and biological research

The Asia-Pacific region is lacking in fundamental data on the physical environment, and on the basic biology and ecology of organisms. Many parts of the region, for example, the Southern China and Southeast Asian coastlines, are characterized by both very rapid development and fast-paced climate change. The data are important in helping generate specific, regionally-focused predictions of changes in community structure, ecosystem functioning, and aquaculture production (Williams *et al*., 2016). Scientists in the Asia-Pacific region would benefit from working with other regions where such knowledge and management approaches are available, and translating that expertise into present day actions in the region (Williams *et al*., 2016). Regional interactions and meetings, such as the FAO/APFIC Consultative Workshop in Nepal 2011 and in Bangkok 2017, play an important role in generating and promoting appropriate strategies by forming coalitions of local governments and policymakers.

Build a regional learning network to support science communications and science application in fisheries management

The APFIC recommended international and regional coordinating and cooperating networks and consultations to exchange knowledge and information to build institutional capacity for climate-resilient management, and to help develop policy frameworks. Regional learning networks between and within countries and regions should be established to facilitate knowledge exchange, such as on adaptation and mitigation strategies, and to build on lessons learned from different countries. The understanding of key issues by country decision makers can be enhanced through the use of regional learning networks, e.g. the Asia-Pacific Adaptation Network, and by information available from ASEAN and FAO. Learning networks can also be used to identify and build links across complementary and overlapping agendas of regional initiatives, including the Pacific Islands Framework for Action on Climate Change, the Asian Development Bank's knowledge management theme for fisheries and economic analysis, and the Secretariat for the Pacific Community's research on food security.

The regional learning networks should include international research institutions engaged in assessing changes to the atmosphere and the ocean (e.g. World Meteorological Organisation and NOAA), as well as

planners and policymakers. The latter would gain a better understanding of climate change impacts – for example, the consequences of mass coral bleaching and ocean acidification for local/national coastal fish habitats and fisheries production – and of how to minimize the threats and capitalize on the local/national opportunities presented by a changing climate (Heenan *et al*., 2015). The ready availability of technical support from scientific institutions can help to apply information to regional and national climate change vulnerability assessments and to forecast impacts on local fisheries resources.

Collect and make available reliable and timely information on small-scale and inland fisheries

Despite their substantial value to local economies and food security, small-scale fisheries are chronically undervalued and excluded from research studies and policymaking and analysis, which hinders sustainable management (Grafeld *et al*., 2017). These fisheries are often dispersed and diverse and therefore accurate information about them is inherently difficult to acquire. Consequently, they are often invisible or given low priority in policy discussions relative to other uses of water (e.g. hydropower, aquaculture, irrigation, and flood control). These alternative uses generally reduce native fish habitat availability, which in turn impacts inland fisheries production and its contribution to local communities' food security, health, and well-being (Youn *et al*., 2014). For inland fisheries, alternative approaches to collecting production data and monitoring inland fisheries will be necessary. These include geospatial and remote sensing tools and household surveys (Youn *et al*., 2014).

Recognize women's contribution and increase understanding of gender in fisheries

As stated in previous sections, women have a large role in fisheries in the Asia-Pacific region. To understand the region's fisheries and their long-term sustainability, women's contributions in value chains that support fisheries and feed communities need to be recognized (Williams, 2014). Gender must be factored into the data collection and analyses. Without a focus on gender, we cannot understand the diverse effects of fisheries change and management, or provide policymakers with accurate and interdisciplinary management models (Kleiber, Harris and Vincent, 2015).

Harper *et al*. (2013) and an online USAID sourcebook on Integrating Gender in Climate Change Adaptation Proposals[7] outline the following strategies that could be used to better reflect and build on women's contributions:

- highlight women's indirect inputs to the economy and unpaid work as a way to better understand the overall dynamics of fisheries economies;
- make the link between women's contributions to fisheries and development on a broader scale as women play key roles in health, nutrition, and poverty reduction;
- identify underlying causes of gender-specific exposure to climate related disasters and vulnerabilities and consider inequalities in exposure and sensitivity to climate-related disasters, as well as inequalities in access to resources;
- reduce gender-specific barriers for women's active participation, and include women in decision-making bodies and processes in all areas (i.e., coastal management, biodiversity conservation, fisheries and disaster mitigation and recovery), and gender-inclusive practices for policy consultation and adjust policy agenda priorities to represent both men's and women's interests;
- utilize women's ecological knowledge in fisheries management, particularly in developing policies concerning biodiversity, conservation and climate change;
- introduce new products, skills, and technologies suitable to women's needs and resources and improve women's access to markets and more profitable value chain roles;
- collect gender-specific fisheries participation data; and
- improve gender-specific communication strategies.

[7] http://asiapacificadapt.net/gender-sourcebook/

Effort to mainstream gender in an integrated coastal resources management in the Philippines

Funded by the ADB and executed by the Philippine's Department of Environment and Natural Resources (DENR) Municipal Development Fund, the following gender-related activities and processes of an integrated coastal resource management project were implemented from 2007 to 2013 to help enhance coastal resources and reduced poverty among municipal fisherfolk:

- The project applied baseline social and gender information and followed through with commitments for ongoing systematic gender data collection via routine project monitoring, as well as planning for gender-focused studies and gender elements for other types of analytical studies for planning and policy reform.
- The project applied the same approach to training – using gender-focused training and weaving gender elements into technical and managerial training.
- The project set women's participation targets for both clients and staff.
- The project recognized women's economic and governance roles and aimed to improve women's level of participation in both types of activities.
- The project tracked employment opportunities for women, as generated through new enterprises.

Source: USAID Adapt Asia-Pacific's On-Line Sourcebook: Integrating Gender in Climate Change Adaptation Proposals. (Available at http://asiapacificadapt.net/gender-sourcebook/).

Undertake research focusing on adaptation strategy outcome and impacts on food security

Climate change has impacts on all dimensions of food security and the whole food system, including food availability, access, utilization and stability (Vermeulen *et al.* as cited in Campbell *et al.*, 2016). The approach of analyzing food security outcomes in terms of whole food systems and not solely in terms of yields is relevant to understanding climate change impacts and adaptation options in the fisheries subsector. Extensive engagement of fisheries stakeholders, especially those who are most vulnerable to climate change, is required to change the culture of research to focus on context-specific outcomes and facilitate prioritizing the end benefit of communities, projects and countries (Campbell *et al.*, 2016).

Apply an interdisciplinary research approach and conduct holistic vulnerability assessments

Both disciplinary and interdisciplinary studies that investigate fisheries response to global change are needed to develop a holistic understanding of vulnerability (Sumaila *et al.*, 2011) and to provide comprehensive input to help identify climate impacts on ecosystems, ecosystem services, and human populations. Assessments that link oceanographic, biological, and socio-economic systems can be applied to identify practical adaptations to assist enterprises, communities, and households to reduce their exposure to climate change risk and take advantage of any concomitant opportunities (Hoegh-Guldberg *et al.*, 2014). Different tools have been developed to include social adaptive capacity indicators and examine community-based climate vulnerability and adaptation (Wongbusarakum and Loper, 2011; Mcleod *et al.*, 2015). As there are important differences between local stakeholders and nonlocal academic experts on key factors affecting adaptation and coping mechanisms (Mcleod *et al.*, 2016), it is critical that local community input be integrated to ensure the validity of adaptive capacity assessment findings. Such understanding facilitates the prioritizing of impacts and the improvement of decision making in relation to adaptation options and funding allocation, while also avoiding maladaptation.

From a social science perspective, a better understanding would be inclusive of people's knowledge and perceptions of climate impacts on both fisheries and their own well-being, inclusive of their strategies for adapting to changes; and inclusive of their support for management or policies. Social sciences (including sociology, anthropology, political science, and economics) can contribute to understanding the social vulnerabilities associated with climate change impacts on fishers, communities and the fisheries subsector. The social sciences are also useful in facilitating dialogues about possible responses to a changing climate in different social, cultural, and political settings (Allison and Bassett, 2015).

Understanding social vulnerability to climate change

"Understanding and mapping the linkages between social and ecological systems can be complex, but even a basic understanding of social vulnerability and its drivers can substantively inform future planning for coastal and marine management. Conventional vulnerability assessments have focused mainly on biological, physical, and environmental aspects. But the relationship of people to impacted physical environments and ecosystems and their capacity to cope with and adjust to the new situation play a fundamental role in the level of vulnerability to climate events and impacts. In other words, communities with varying capacity to respond to climate events will likely yield different levels of vulnerability. It is therefore important that biophysical and socioeconomic assessments be integrated and complement each other, to provide a holistic understanding of vulnerability to climate change."

Source: Wongbusarakum and Loper (2011)

Increase better communications on climate change and its implications for fisheries

Scientific data needs to be accessible and useable by fishers, policymakers and decision makers in their adaptation planning. Once the information gaps and capacity needs of a country are identified, it is suggested that scientists work with both practitioners and policymakers to devise appropriate mechanisms for meeting climate challenges, including sustainable fisheries and food security, at local, national and regional levels (Béné *et al*., 2016). These mechanisms should include ways in which scientific information can be communicated effectively and used in adaptation planning and activities. Climate change communications need to be timely and effective, especially when there are extreme climate events (e.g. typhoons, mass coral bleaching) and potential impacts on fisheries by climate variability (heavy rainfall, flood, or drought).

Effective and sustainable fisheries governance and management

In order to increase climate resilience in the fisheries subsector, improved fisheries governance, more effective management and responsible fisheries are required. Costello *et al*. (2016) using data from 4 713 fisheries worldwide, representing 78 percent of the global reported fish catch, shows that reforms to fishery management would dramatically improve overall fish abundance and increase food security and profits. More holistic approaches, such as an EAFM, better transboundary management, stronger public-private partnership, and more inclusive community involvement are all recommended in recent literature and during the FAO/APFIC Consultative Workshop 2017. The following section summarizes these recommendations.

Apply the Ecosystem Approach to Fisheries Management (EAFM)

The EAFM approach offers a means to manage fisheries more holistically and takes major ecosystem components and services into consideration. The effects of climate change on fisheries and their impacts on food security should be considered in combination with non-climate-related stressors (e.g. eutrophication, overfishing, effluent from aquaculture, reclamation and habitat destruction, coastal and economic development). Minimizing these non-climate stressors helps buffer the overall impacts of climate change and increases the resilience of marine ecosystems across the region (Williams *et al*., 2016).

EAFM defines and sets the scope of a fisheries management unit (FMU) in ways that are not restricted by the national boundaries, but instead takes into consideration different factors that will allow for comprehensive fisheries management, including ecological boundaries, social boundaries, habitat areas and political jurisdictional boundaries. The FMU could range from a specific area to a coastal zone to a large marine ecosystem (LME), and therefore the appropriate management could be site-based, national or regional. A transnational FMU could help identify management objectives and actions better suited to

the tasks of addressing threats and issues shared by involved countries, particularly those related to climate change impacts, fishing overcapacity, IUU fishing, maritime security issues, and fisheries-associated human rights abuses.

The EAFM uses a risk assessment approach to prioritize and address associated issues and threats, including climate and ocean change. It also embodies a precautionary approach to address uncertainty, to act without waiting for all scientific research to be completed, and to apply adaptive management. The EAFM sets the stage for the greater levels of caution needed to allow for increased uncertainty associated with: (1) future CO_2 emission scenarios; (2) forecasting the effects of climate change and ocean acidification on coastal fisheries because of biases remaining in global circulation models; and (3) the responses of ecosystems and societies to future conditions (Heenan *et al*., 2015).

Key principles of the EAFM include co-management and promoting participation, coordination and collaboration in fisheries management. EAFM encourages multiple sectors and different levels of governments to be engaged. This allows the responsibility for addressing climate change to be shared and facilitates information exchange and dialogue between stakeholders that helps empower and improve decision making. Institutional cooperation and coordination among governmental agencies, research institutes, industries and communities – as well as the involvement of multiple stakeholders to develop and implement climate adaptation and mitigation strategies – have been recommended by several countries, including India, Lao People's Democratic Republic, Myanmar, and Timor-Leste. Such multistakeholder involvement helps develop more coherent and complementary policy arrangements of the kinds needed to reconcile adaptations to the differing climate change impacts on food security and marine biodiversity (Heenan *et al*., 2015).

Promote responsible fisheries, transboundary and regional fisheries management

Responsible fisheries have been recommended by a fisheries working group during the FAO/APFIC Consultative Workshop 2017. Specific actions to promote responsible fisheries include documenting the traceability and catch per unit effort, and adjusting the pressure of capture fisheries to sustainable levels. Setting catch limits based on changes in recruitment, growth, survival and reproductive success can be done via adaptive management, monitoring and precautionary principles (Shelton, 2014). Other recommendations are standardizing fishing vessels and fishing gear, placing stringent regulations on habitat protection (such as mangrove cutting) and on reducing juvenile fish catch, and replacing old fishing boats with more durably built and energy efficient boats.

Establishing regional strategies and restructuring regional fisheries management organizations have been recommended to help coordinate management measures across the entire tropical Pacific (Hoegh-Guldberg *et al*., 2014). The fisheries working group representing the Bay of Bengal countries recommended regulatory frameworks and governing bodies at the national and regional levels for setting regulations and monitoring climate change related issues at both levels. The APFIC should facilitate the member countries in addressing climate change related issues and the transboundary implications of their fisheries policies and vice versa. Regional climate resilient fisheries strategies and actions could be strengthened through collaboration among governments with the goals of sharing marine waters, engaging directly with the private sector to improve coastal community livelihoods, and reducing illegal fishing and overfishing in subregions while simultaneously increasing maritime security (Pomeroy *et al*., 2016).

Partnerships with civil society entities (including non-governmental organizations) and the private sector should be formed. Dialogues can develop and support regional alliances and networks of national fishery associations in the areas of policy and regulation development and capacity building.

Facilitating fisheries management coordination and collaboration in the Philippines

The Philippines established an Integrated Fisheries Management Unit (IFMU) scheme to enable a more flexible local fisheries management responses to climate change. In this way it can address cross border jurisdictional conflicts and the appropriate distribution of target fish stocks in various jurisdictions. In terms of administration, groups of municipalities were formed and the groups coordinated at the provincial level. They were also given technical support. According to Heenan *et al*. (2015), this approach "provides a model for scaling-up the coordination and management of shared resources across jurisdictional boundaries to ecological scales." Climate change and increasing ocean acidification are now strong incentives for effective transboundary management of fisheries across jurisdictions. Hopefully, this will become a common approach in fisheries management globally.

Engage the private fisheries subsector

Nearly all private sector stakeholders have inherent, long-term financial interests in maintaining and growing the fishing industry. Private industry groups tend to be well organized in each country through existing local and national fisheries associations and federations of associations, and many of the private sector companies are global players in the fishing industry. They are regularly exposed to various debates about sustainable seafood and to proposals for ensuring product traceability (Pomeroy *et al*., 2016). The importance of the private fisheries sector was recognized among the APFIC member countries as a strategic partner that must be included in fisheries management and that could provide innovative solutions to fisheries challenges under changing climate conditions by fostering public and private partnership. The private commercial capture fisheries subsector can be engaged in regional dialogues on both fisheries management and improved governance by way of established commercial associations, and can provide technical support to national and regional commercial alliances and networks in the areas of policy and regulatory development and capacity building for sustainable regional fisheries management (Pomeroy *et al*., 2016). With respect to Southeast Asia, Pomeroy *et al*. (2016, p. 28) have summarized the situation as follows:

> Many capture fishery operators and fishing associations within Southeast Asia are open and willing to engage with and support regional fisheries management efforts that safeguard their long-term business interests through the promotion of marine resource sustainability, decreased fishing capacity, and increased maritime security. Doing so effectively will not only advance the strategic economic and environmental interests of Southeast Asian nations over the coming decades, but also further advance mutually-beneficial economic and political partnerships between the ASEAN economies and those countries with a strategic interest in the region.

Encourage collaborative and community-based management

Effective adaptation requires community participation and resilience building at the local level. In Asia, small-scale fisheries are often locally regulated through local institutional structures. And in some areas, community-based fisheries management is the most accountable and effective form of management. Community-based climate and natural resource management planning tools have been developed to facilitate community involvement in climate adaptation by building climate knowledge among the community members, taking into consideration the social and ecological aspects of community health, and integrating multisector planning (Wongbusarakum *et al*., 2015). Adaptation strategies and options that are collaboratively planned and managed also have a chance to be both more relevant to local needs and more sustainable. Based on Hijioka *et al*. (2014) the community-based approach can:

- help capture information at the grassroots;
- help better integrate disaster risk reduction and climate change adaptation, addressing their location-specific nature and designing location-specific solutions;
- connect local communities and outsiders;

- help vulnerable groups to change after being "locked into" specialized livelihood patterns, as with fish farmers in India; and
- help facilitate community learning processes.

Although the ultimate goal of adaptation and mitigation is related to protecting and supporting human well-being, these goals are often not explicit and the people who are being affected the most by climate change are not being involved in adaptation planning. When a community-based approach is applied, achieving community well-being through reducing poverty and sustaining local livelihoods is much more likely to receive priority and be included as a key objective. Locally-based management can also help minimize the equity gap (Bell *et al*., 2017) and improve equitable benefit sharing. Vulnerable groups are more visible in a community-based approach, including those who are highly dependent on fisheries resources for their livelihoods and who have limited economic opportunities, such as fishers and women in many places. Risk reduction and adaptation measures need to be developed that aim specifically to protect and support these groups.

Climate-resilient fisheries policies and implementation

Mainstream fisheries in national climate adaptation and mitigation, and disaster risk reduction

This recommendation was strongly voiced by the APFIC fisheries working groups during the FAO/APFIC Consultative Workshop 2017. At the international level, fisheries should be included as a sectoral entity in climate change related matters at the annual COPs, and provided with required attention/priority in framing climate change policies, strategies and actions. To ensure that the fisheries and aquaculture sectors contribute fully to the Intended Nationally Determined Contributions' (INDC), it is essential that they participate fully in national planning processes and that coordination mechanisms are strengthened for involving the participation of the subsector in aligning national climate planning with other national policies. Fisheries agencies should be fully involved in the development process of NAPA in the future, and fisheries must be an essential part of integrated resources management, climate change adaptation, and food security policies. These suggestions are in line with the recent climate and fisheries literature, in which holistic and integrated approaches are much emphasized. Both disaster risk mitigation and climate change adaptation need to be fully incorporated into fisheries policies and plans and clearly linked to people's livelihoods (FAO, 2012b).

The APFIC country representatives in the fisheries working groups at the FAO/APFIC Consultative Workshop 2017 agreed that there should be standardized regional fisheries and aquaculture policies and strategies to address climate impacts and risk mitigation and that these should then be adopted by the countries. Guidelines for a holistic approach to building climate-resilient countries should be developed and used to guide and support national strategy and action plan preparation and implementation. Technical support and regional capacity building should be provided. There should be regional strategies, mechanisms and coordination across the Asia-Pacific region to share both early-warning information related to natural disasters and ways to cope with these.

Ensure adequate financial support

Limited or no funding are noted as constraints in many of the recommendations. Financial support is critical to allow for climate resilient policies and strategies to be implemented effectively. Areas of financial support include: climate proof structures (e.g. safer harbours and landings); climate smart technologies; capacity development; resource acquisition that supports resilient fisheries, financing adaptation action plan development and implementation; improving early-warning and forecasting systems; offering economic incentives (e.g. insurance); and the development of employment opportunities in fisheries and in diversifying livelihoods (FAO, 2014 and Shelton, 2014).

Balance export policies with local fisheries supply

In many developing countries, rapid population growth is driving a gap between sustainable fish harvests and the amount of fish needed to contribute to good nutrition. The effects of climate change have the potential to widen or reduce this gap. Trade policies that result in the majority of fish being exported limit local supplies of fish and have direct implications for the availability of fish per capita (Delgado *et al*., 2003; Béné and Heck, 2005; Hobday *et al*., 2015). Effective climate resilient policies should ensure that industrial fishing operations do not have negative effects on small-scale fishers. In many cases, the fish necessary for local food security may only be a small proportion of the total industrial catch, and can easily be offloaded during routine transshipping operations. Quantifying this trade-off will assist governments in identifying and implementing the best food security policies for adapting to the effects of ocean warming on fisheries resources (Bell *et al*., 2016). Policies should seek to ensure that these processes result in equitable modes of development that do not marginalize smaller producers (Belton and Thilsted, 2014). Offshore fisheries should not jeopardize local opportunities to benefit from increased productivity and any increased value of local fisheries (Barange *et al*., 2014).

Advance the blue economy

Fisheries are an integral component of the blue economy, which generally encompasses themes of balancing sustainable development, community well-being and livelihoods, gender equality, food security, cultural worth, and ocean health (Keen, Schwarz and Wini-Simeon, 2017). One example of a blue economy slowly being put into place in the Pacific is in the Solomon Islands. The government is moving towards an EAFM that incorporates social, economic, and ecological goals (Keen, Schwarz and Wini-Simeon, 2017), and is also developing a national policy for integrated oceans governance by engaging multiple stakeholders and agencies in ocean planning (Keen, Schwarz and Wini-Simeon, 2017). In another example, the Honiara fish market in the Solomon Islands has perceived conflicts between maximization of economic benefits and maintaining ecological ocean health. The Ministry for Fisheries and Marine Resources made a positive step towards the blue economy by collecting quantitative data to monitor the local fisheries and inform management decisions. Areas that the Honiara fish market needed to address to support the blue economy approach include safety and personal welfare, especially for women, wastage caused by inadequate infrastructure, gender equity, and support for all of the participants in the fisheries value chain, such as fish sellers, vendors, retailers, etc.

Adaptation

Climate change adaptation refers to adjustments in ecological, social or economic systems in response to actual or expected impacts. This term refers to changes in processes, practices and structures to moderate or offset potential damages or to take advantage of opportunities associated with changes in climate (FAO, 2012b). It involves making adjustments to reduce the vulnerability of natural and human systems, and developing and implementing activities that address impacts of climate change and variability.

Ecosystem-based adaptation

Ecosystem-based adaptation (EbA) emphasizes managing, maintaining, conserving, restoring or improving natural ecosystems to help people reduce vulnerability and adapt to disturbances and changes, including climate change. The approach is based on the belief that the health of the ecosystems is fundamental to the sustainable use of resources and to the well-being of people. According to IUCN, "If adaptation policies and programmes are to be effective, they must integrate efforts to sustain and restore ecosystem functions and promote human rights under changing climate conditions."[8] The EbA protects habitats and enhances ecosystems and their services. Similar to EAFM, EbA can be applied to different ecosystems types and at different scales. The approach also requires the involvement of a range of sectors and stakeholders and support from multiple disciplines.

[8] https://www.iucn.org/theme/ecosystem-management/our-work/ecosystem-based-adaptation-and-climate-change

Biodiversity and ecosystem services are to be integrated into an overall adaptation strategy to secure livelihoods (Hijioka *et al*., 2014). To improve adaptive capacity across Asia, the IPCC AR5 suggested EbA, implementing marine protected areas, and establishing landward buffer zones to allow for inward migration of mangroves and human settlements (FAO, 2016b). As an example, an EbA for securing the resilience of coral reef fisheries in the tropical Pacific, with or without climate change, involves the following (Hoegh-Guldberg *et al*., 2014):

- strengthening the management of catchment vegetation to improve water quality along coastlines;
- reducing direct damage to coral reefs;
- maintaining connectivity of coral reefs with mangrove and seagrass habitats; and
- sustaining and diversifying the catch of coral reef fish to maintain their replenishment potential.

Creating sustainable alternative livelihoods

With increasing pressure on fisheries resources by both human-related and climate-related stressors, alternative livelihoods for fishers need to be developed in or outside the fisheries subsector. Some APFIC member countries proposed diversifying patterns of fishing activities (species, location, and gear), whereas others recommended considering sustainable livelihoods that are non-fisheries related, including aquaculture, tourism, and other types of micro-enterprises for small-scale fishers.

Livelihood diversification is considered one of the most effective risk management strategies for small-scale stakeholders and families involved in agriculture (FAO, 2016a). Supporting policies and institutions are vital for enabling the diversification of livelihood strategies. Climate-resilient alternative livelihoods should be fostered through the creation of bundles of sustainable livelihood capital: natural, physical, human, financial, and social (Ashley and Carney, 1999).

An alternative livelihood recommendation is to expand environmentally sustainable mariculture or freshwater aquaculture. This recommendation has been suggested as one of the most important sustainable livelihood options for adapting to the impacts of climate change and for reducing the gap between the amount of fish recommended for good nutrition and sustainable harvests from coastal fisheries in the Asia-Pacific region where this gap is being exacerbated by rapid population growth and inadequate management of coastal fish habitats (Bell *et al*., 2016).

Shifting from coral reef fishing to pelagic fishing

One of the key recommendations in the climate and fisheries literature with a focus on the Asia-Pacific region is to shift from coral reef fishing to pelagic fishing. This is considered to be a way to adapt to the continued degradation of coral reefs caused by more frequent mass bleaching and ocean acidification. Materializing such a shift requires building new skills among small-scale coastal fishers and providing new resources and methods (such as fish aggregating devices (FADs) that may be anchored within a few kilometres of the coast). Although the outlook for harvesting small pelagic fish in the longer term is uncertain and likely to be site specific, small pelagic fish (mackerel, anchovies, pilchards, sardines, scads and fusiliers) have relatively high resilience to fishing and provide a potential way to increase the catch of small-scale fishers in the near term.

Large pelagic fish, including yellowfin tuna, skipjack tuna, wahoo and mahi mahi, have been identified in models as remaining abundant enough in a climate change environment to support local fisheries in most PICT until 2050, thus opening an opportunity to fill the gap between the fish needed for good nutrition and sustainable harvests of demersal fish. However, energy efficiency programmes will be needed to assist domestic fleets to cope with increasing fuel costs and the possible need to fish further from port (Hoegh-Guldberg *et al*., 2014). Another mechanism to address the potential shortage will be to re-allocate some of the catch of large and small pelagic fish taken by industrial fleets to small-scale fishers, and/or arrange for industrial fleets to land more of their catch in local ports.

Sources: Bell *et al*. (2017) and Bell *et al*. (2016)

Optimize post-production processing and supply chain

Improvements in post-harvest methods and technology, and supply chains from beginning to end, can increase the amount of fish product available for food and reduce wastage. Improving fish handling by providing better access to ice, for example, will increase the time that catches remain viable for human consumption (Bell *et al*., 2016). The availability of mobile phone networks have also improved efficiency in assessing market conditions to optimize income and time the transport of catches to markets (Bell *et al*., 2016).

Mitigation

Improve energy efficiency

Fisheries and aquaculture are considered relatively energy-efficient ways to produce animal-source foods, more so than most terrestrial animal production systems. Expanding carbon- and energy-efficient fisheries and aquaculture, and increasing energy efficiency in capture fisheries (including the reduction of fishing overcapacity) are beneficial for fishery management, marine conservation, sectoral economic efficiency, healthy human diets, and terrestrial land and water issues (Allison and Bassett, 2015). Increasing the fuel efficiency of fishing vessels and methods, and reforming operational patterns of fisheries and post production processes have been emphasized in the literature (Komatsu, 2013) and often recommended by the APFIC member countries as a part of climate change mitigation. Several countries have suggested replacing old fishing vessels and outdated fisheries production and post-production technologies that are fuel inefficient or energy inefficient. However, realizing this option would require new investment and technical resources.

Combine adaptation and mitigation, while ensuring food security

Ecosystem-based management and adaptation options that can mitigate climate change impact and at the same time increase food security and generate jobs and business opportunities, are of major importance (PaCFA, 2011). Mitigation and emission reduction should be seen as an investment, and not as a cost. According to PaCFA (2011):

> Improved integrated management of the coastal and marine environments, including protection and restoration of ocean's blue carbon sinks, provides one of the strongest win-win mitigation efforts known today, as it may provide value-added benefits well in excess of its costs, but has not yet been recognized in the global protocols and carbon trading systems. (p. 8)

During the FAO/APFIC Consultative Workshop 2017, the fishery working group from the Bay of Bengal recommended creating seagrass beds and culturing seaweeds to serve the double purpose of carbon sequestration and alternative livelihood activity.

Campbell *et al*. (2016) suggested that closing the emissions intensity gap by both increasing production and decreasing emissions should be a goal of sustainable food systems, and that future food production should be assessed by measuring emission efficiency in relation to food yields or emission intensity. According to Campbell *et al*.:

> The most promising outcomes compatible with future food security will arise from sequestering carbon through increased agro-forestry or soil carbon and avoiding future emissions through increased productivity, improved efficiency of inputs, reduced food loss or waste, diets based on lower emissions foods, and avoiding conversion of high carbon trees and forests. (2016, p. 40)

Develop a regional roadmap for mitigation

Many countries at the Consultation Workshop in Bangkok 2017 recommended: 1) that the APFIC member countries should develop a regional climate mitigation roadmap; 2) that they should agree on a definite

time line for the reduction in GHG emissions from the fisheries subsector at the regional level; and 3) that financial mechanisms need to be created to support adaptation and mitigation. The Blue Carbon Fund is an example of such a fund.[9] Creating a fund of this type could potentially engage private, public and civil society interests and aims, and operate at a range of levels – from supporting regional or national level investment in oceanic/aquatic management strategies, to supporting strategic and specific research on systems, processes and impacts, creating income flows for specific communities, building capacity at a range of levels, and promoting localized investment in ecosystem protection and enhancement (PaCFA, 2011). Several actions have been proposed by PaCFA for a Blue Carbon Fund:

- within international instruments on climate change, create mechanisms to allow the future use of carbon credits for marine and coastal ecosystem carbon capture and effective storage as acceptable metrics become available;
- establish baselines and metrics for future environmentally sound aquatic carbon capture and sequestration;
- consider establishing enhanced coordination and funding mechanisms; and
- upscale and prioritize sustainable, integrated and ecosystem-based coastal/aquatic zone planning and management, especially in hotspots within the vicinity of blue carbon sinks, to increase the resilience of these natural systems and maintain food and livelihood security from the oceans.

Table 6 provides examples of regional strategies and supporting national actions from fisheries working group discussions at the FAO/APFIC Consultative Workshop 2017.

Table 6. Regional strategies and supporting national actions related to fisheries

Regional strategies	National actions
Promote holistic approaches in building climate resilience in countries in the Asia-Pacific region	Mainstream disaster risk reduction plan in the development plan of the country
International agreement for adaptation	Increase cooperation among relevant countries
Develop regional mechanism on sharing early-warning information for disaster events and possible coping mechanisms Site linkages to disaster risk reduction framework and strategies	Develop early-warning systems and distributing of information, e.g. among fisherfolk
Establish and promote region-wide research and development on climate change solutions focusing on innovations through public-private partnership	Promote research and development on climate change and adaptation of fisheries Engage private sector
Strengthen knowledge, technology, and scientific research on climate change impacts and adaptation at national and regional levels	Seek financial support for regional capacity building on relevant topics Mandate national fisheries research institutions to undertake climate change impact related research and provide them with necessary funding
Improve database and information on climate change impacts	Conduct climate change impacts and vulnerability assessments
Promote knowledge, information and technology at regional and national levels Exchange these among countries, sharing platforms	Organize conventions to share lessons on failure and success regarding climate change

[9] https://www.oceanfdn.org/sites/default/files/A%20Blue%20Carbon%20Fund%20Flyer-.pdf

Table 6. *(continued)*

Regional strategies	National actions
Promote regional capacity building and research and development cooperation	Build capacity of climate change researchers Build institutional capacity Establish regional fisheries management forum and organization on climate change issues
Promote Responsible Fishing	Documentation of traceability and catch per unit effort Replace old wooden vessels with fibreglass boats Extend liquefied natural gas fishing vessels Standardization of fishing vessels and fishing gear Stringent action on mangrove cutting and juvenile fish catch
Promote EAFM	Implement EAFM at national level by developing and implementing localized EAFM plans Enforce laws for fishing Improve management framework to mitigate effect of climate change on fisheries Develop management areas through EAFM Promote habitat management and restoration Improve governance through appropriate legislative support
Stock enhancement	Identify fish stocks under stress and efforts to restore them Implement conservation measures, such as uniform fishing ban at national level Develop rules on closed fishing seasons Improve fishing harvesting strategies Create fish ways connecting tributaries and main streams
Protect, conserve and restore habitats and ecosystems for both inland and marine fisheries	Maintain and create protected areas and sanctuaries to conserve fisheries resources Restore fisheries habitats (mangroves, coral reefs, wetlands, marshlands, lagoons and estuaries) Restore water resources through desiltation and flow regulation
Reduce GHG emissions from fisheries subsector at regional level	Provide fuel-efficient and emission-compliant engines to replace those that do not meet these standards in the fishing sector Promote use of renewable energy in fisheries Create seagrass beds for carbon sequestration and culture seaweeds as alternative livelihood activity

Monitoring and evaluation

To be able to track the effectiveness of the above actions and assess how well the strategies are being implemented and whether modifications are required, national and regional programmes should have clear goals and objectives with logical outputs, indicators, and means of verification. Table 7 provides an example of a programme logframe.

Table 7. Example of a programme logframe for fisheries, aquaculture and climate change

Programme level	Indicators	Means of verification	Risks and assumptions
Goal			
People, communities and states meet their social and development goals effectively, while taking into account and responding to the additional challenges imposed by climate change [CC] on fisheries and aquaculture	Government performance, strategies, process, monitoring, resilience parameters, future provisioning	Actions, accords, structures, data (ecosystem, social, economic), future analyses, investment priorities	
Purpose (*expected result*)			
Member states and partners supported to adapt effectively to and mitigate the impacts of CC for fisheries, aquaculture and aquatic ecosystems, through policy development, knowledge development and exchange, normative outputs, practical demonstration, and capacity building	Functional partnerships, well-developed strategies, and implementation actions, outputs, ecosystem quality, food security and social benefits maintained	Partnership agreements, reports and actions, output, value, food supply, income and other statistics	CC impacts too indeterminate, social and political stresses, and investment demands in other sectors too great
Outputs			
1 Global, regional and local CC action partnerships, across public, private community and NGO sectors, promoted and supported, with management and implementation structures as required	Joint actions and projects among agencies, Global Partnership for Climate Change, Fisheries and Aquaculture (PaCFA) meetings	Agency documents, partnership agreements, memoranda of understanding (MoUs), work plans	National and local government capacity and implementation aims, consistency of agency aims, strategic objectives, funds, timing
2 Strategic context, awareness-raising, policy development and knowledge base for CC and fisheries subsector established, interlinking with other sectors, defining spatial scale other impact/response features	Strong, accessible body of subsector knowledge linking with CC science, policy, actions, clear influencing themes and messages into key arenas	Documents, engagement in strategy processes – reviews with coherent, well-founded content, clear CC links, at local to global levels	Incoherence, complex messages, trade-off issues, other lobbies, CC indeterminacy, data and standards inadequacy, inconsistency
3 Fishery subsector CC mitigation-related issues/ actions identified and developed, and implementation supported within and across the subsector	Analyses of GHG interactions and range of mitigation measures identified, reduction in GHG emissions	Documentation of emissions and GHG reduction/capture methods from subsectors, guidelines on emissions reductions	Inadequate interest, research, action, funding, poorly measurable effects, policy deficits
4 Adaptation strategies identified and promoted for implementation within mainstream subsector development frameworks	Guidelines and pilot cases promoting adaptation in fisheries and aquaculture, more-resilient communities	Documentation of local, national, global actions, analyses of results	Insufficient attention, funding, data, pressure of wider influences, policy deficits

Table 7. *(continued)*

Programme level	Indicators	Means of verification	Risks and assumptions
5 Lesson-learning and capacity building process established with partners to build CC and sectoral knowledge and response through specific tools, e.g. strategies, best practices	Documentation on CC links, mitigation and adaptation available, assistance in strategy and plan development	Assessments, studies, documentation, guidelines, strategies	Disorganized/unfocused approach, funding, unclear messages
6 Communication strategy for CC mitigation and adaptation, for a range of audiences defined and implemented	Clear messages about subsector, CC and development widely accessible	Materials, websites, documents; target and usage records	Effective connection across agencies, mixed messages

Source: FAO (2012a)

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Background Paper 2

Enhancing adaptive capacity and building resilience in the aquaculture sector with respect to the impacts of climate change

Evelyn Grace De Jesus-Ayson

Introduction

The current world population of more than 7.4 billion is projected to reach 8.5 billion in 2030 and 9.7 billion in 2050, with most of the increase occurring in developing regions. Poverty and concomitant hunger and malnutrition remain among the top challenges facing the world today. Fish is an important source of food and nutrition for 3 billion people, many from low-income families in rural areas. Fish comprise at least 50 percent of animal protein and essential minerals for 400 million people mainly from the least developed countries of the world. Hence, the fisheries and aquaculture subsector play important roles in global food and nutrition security.

The fisheries and aquaculture sectors also provide employment, livelihoods and income to millions of people engaged in fish capture, culture, processing and trade contributing to economic growth and development (FAO, 2016a). The global trade in fisheries products increased from USD 8 billion in 1976 to USD 148 billion in 2014. The increased demand for fish and fisheries products is fueled by a growing global population coupled with a stronger purchasing power and an increased awareness of the health benefits of fish in the diet.

Although total production from capture fisheries has leveled off at 90 million to 95 million tonnes since the mid-1990s, the increasing demand for fish and fishery products will be met mainly through increased production from aquaculture, which is currently providing a higher proportion of fish for human consumption. In 2014, farmed fish surpassed wild fish as the source of food fish for the first time. The average fish consumption per capita worldwide increased to 19.7 kg in 2014 from 9.9 kg in 1960 and 14.4 kg in the 1990s. Concomitantly, the share of farmed fish to fish consumption has increased to 33 percent in 2014 from 7 percent in 1974 and 26 percent in 1994 (FAO, 2016a).

Although it has stabilized somewhat recently, growth in employment in the aquaculture sector was the fastest among the food production industries. Fish farming employs 18 million people directly worldwide. 94 percent are in Asia, 1.9 percent in Latin America and the Caribbean and 1.4 percent in Africa (FAO, 2016a). An FAO study in 2010 estimated that 117 million people were dependent on aquaculture through its multiplier effects of generating indirect employment and support to household members (Valderama, Hishamunda and Zhou, 2010). However, the continued expansion of the aquaculture industry hinges on the absence of disasters resulting from severe climate disturbances and major fish disease outbreaks and longer-term productivity trends as well as the absence of major perturbations in the markets.

Climate change, especially extreme weather events, threaten the sustainability of capture fisheries and aquaculture development in marine, coastal and freshwater environments (Bueno and Soto, 2017). Climate change impacts occur as a result of gradual atmospheric warming and associated physical (sea surface temperature, ocean circulation, waves and storm systems) and chemical (salinity, oxygen concentration, acidification) changes in the aquatic environment. Atmospheric warming could lead to warmer water temperature, changing ocean currents, sea level rise, changes in rainfall, river flows, water levels and thermal structure in lakes and other waterbodies. These changes affect fish distribution, quantity and composition of catch, as well as production of farmed fish and other aquatic organisms because of their impacts on reproduction, breeding success, development, growth and survival of farmed stocks. Moreover, extreme weather events and sea level rise associated with climate change will affect fisheries and

aquaculture-related infrastructure. Climate change impacts on aquaculture will consequently impact food, nutrition and livelihood security, efforts at poverty alleviation, and economic development. The effects could be higher in the largely developing countries of the Asia-Pacific region where about 90 percent of the world's aquaculture production comes from and where more than 80 percent of the fish farmers are small-scale farmers and many are resource-poor, have a high per capita intake of fish and therefore a high dependence on fish for food security and nutrition (Bueno and Soto, 2017).These possible events could take place in the context of other global social and economic pressures on natural resources and ecosystems including environmental degradation and increasing land and water scarcity.

Overview of aquaculture in the Asia-Pacific region

Global aquaculture production has increased rapidly, reaching about 74 million tonnes in 2014, making aquaculture the fastest growing animal food production sector. In contrast, the total production from capture fisheries has leveled off at 90 million to 95 million tonnes since the mid-1990s. The total world fisheries production from capture and aquaculture is projected to be higher by 17 percent in 2025 compared to the 2013–2015 level (see Table 8). All being equal, the absolute growth will be about 29 million tonnes by 2025. Most of the increase in production will come from developing countries comprising 85 percent of the total output, a little bit higher than their annual average share in total production of 83 percent during the period 2013–2015 (FAO, 2016a).

Table 8. Comparison of average 2013–2015 production and projected production in 2025 based on fish model (1 000 tonnes)

	Total production			Aquaculture		
Region/Country	2013–2015 average	2025 (projection)	Growth (%)	2013–2015 average	2025 (projection)	Growth (%)
World	166 889	195 911	17.4	73 305	101 768	38.8
Developed countries	29 018	29 305	1.0	4 393	5 521	25.7
Developing Countries	137 871	166 606	20.8	68 911	96 247	39.7
Africa	9 699	11 208	15.6	1 696	2 287	34.8
Latin America and the Carribean	14 424	16 245	12.6	2 702	3 780	39.9
Asia and Oceania	113 748	139 154	22.3	64 513	90 180	39.8
China	62 094	78 717	26.8	45 263	62 962	39.1
India	9 434	11 570	22.6	4 830	6 880	42.4
Indonesia	10 543	12 411	17.7	4 211	5 761	36.8
Philippines	3 142	3 429	9.1	795	982	23.5
Republic of Korea	2 039	1 980	-2.9	470	536	14.1
Thailand	2 719	2 965	9.0	942	1 191	26.4
Viet Nam	6 257	7 816	24.9	3 361	4 802	42.9

Source: FAO, 2016a

The increasing demand for fish and fishery products will mainly be met through increased production from aquaculture, which is expected to reach 102 million tonnes in 2025, 39 percent higher than the production level in 2013–2015. The aquaculture industry will continue to expand, although the annual growth rate is estimated to decline from 5.4 percent in the previous decade to 3 percent in the projection period. A number of factors contribute to the slowdown in the expansion of the aquaculture industry including: constraints related to availability of and accessibility to good quality water resources; competition from alternative uses for optimal production locations; availability of high quality seeds, feeds

and feed ingredients; insufficient investments in infrastructure for aquaculture production; capital constraints; and challenges in governance and regulatory frameworks.

The contribution of aquaculture to the total fishery production will reach 52 percent in 2025, higher than the average contribution of 44 percent during the period 2013–2015. Aquaculture production is projected to surpass production from capture fisheries in 2021 (FAO, 2016a). Most (95 percent) of the production from aquaculture will come from developing countries. Countries in Asia will contribute 89 percent to the total production in 2025, with China alone accounting for 62 percent of the world output. Aquaculture production in developed countries and in all continents will also continue to increase, with variation across countries and regions in terms of species and products. Freshwater species such as carp, catfish (including pangasius) and tilapia will account for an estimated 60 percent of the increase in aquaculture production in 2025. Production of higher value species such as shrimp, salmon and trout is also projected to continue to grow in the next decade.

The projections are based on specific assumptions regarding the future macro-economic environment, absence of major perturbations in the markets, absence of severe climate disturbances and major fish disease outbreaks and longer-term productivity trends. However, climate change impacts, especially extreme weather events, threaten the sustainability of capture fisheries and aquaculture development in both marine and freshwater environments.

Among the countries in the Asia-Pacific region, the contribution of aquaculture to overall national, regional and global fisheries production cannot be over-emphasized. Aquaculture production in Asia continued to increase between 1995 and 2014 from approximately 21.7 million tonnes in 1995 to 65.6 million tonnes in 2014 (Table 9). Production from the region remained close to 90 percent of the total world production during the same period.

Table 9. Aquaculture production in Asia from 1995 to 2014 (1 000 tonnes)

Year	1995	2000	2005	2010	2014
Production	21 667.50	28 422.50	39 188.20	52 439.20	65 601.90
% of World Production	88.91	87.68	88.47	88.92	88.91

Source: FAO, 2016a

China remains the world's top aquaculture-producing country with a total aquaculture production of about 58.8 million tonnes in 2014. In descending order, Indonesia, India, Viet Nam, the Philippines, Bangladesh, the Republic of Korea, Myanmar, Thailand and Malaysia also made it to the world's top 25 aquaculture-producers in the same period (Table 10). Aquaculture production in China has increased dramatically from the 1950s and currently accounts for 75 percent of the country's total fisheries production. In Indonesia, aquaculture production constitutes the bulk (approximately 68 percent) of total fisheries production. A similar scenario is true in Bangladesh. In contrast, marine capture fisheries constitute 74.4 percent of Malaysia's fish production with coastal fisheries contributing 82 percent to capture fisheries production. The same is true for Myanmar where about 80 percent of total fisheries production comes from capture fisheries. Thailand's aquaculture production contributes 35 percent to total fisheries production. Aquaculture production in India, the Philippines, the Republic of Korea and Viet Nam constitutes about 50 percent of total fisheries production. Aquaculture production in the Republic of Korea is expected to increase as a result of the government's aquaculture promotion policy and fleet reduction programme.

A diversity of species is farmed in countries in the Asia-Pacific region. These include freshwater fish and crustaceans, marine fish, shrimp and other marine crustaceans such as lobsters and crabs, mollusks, seaweeds and other commodities. The bulk of the production from inland aquaculture consists of finfishes (40.3 million tonnes) whereas mollusks comprise the bulk of the production from coastal/marine

Table 10. Aquaculture production of countries in the region that are among the top 25 producers in the world (1 000 tonnes)

Country	Aquaculture production	Rank
China	58 795.3	1
Indonesia	14 330.9	2
India	4 884.0	3
Viet Nam	3 411.4	4
Philippines	2 337.6	5
Bangladesh	1 956.9	6
Republic of Korea	1 569.4	7
Myanmar	964.3	12
Thailand	934.8	13
Malaysia	321.0	15

Source: FAO, 2016a

aquaculture (14.5 million tonnes). Production of crustaceans from coastal/marine aquaculture (3.5 million tonnes) is a little higher than production of freshwater crustaceans from inland aquaculture (2.7 million tonnes). Aquaculture production in Cambodia is mostly (90 percent) from inland aquaculture. Overall, production from inland aquaculture (43.8 million tonnes) is about twice the production from coastal/marine production systems (21.8 million tonnes) (see Table 11).

Table 11. Production of major species groups in inland and coastal/marine aquaculture production systems in Asia (1 000 tonnes)

Commodity/ Culture Area	Inland	Coastal/Marine	Total
Finfish	40 319 666	3 388 124	43 707 790
Mollusks	277 744	14 545 398	14 823 142
Crustaceans	2 673 159	3 507 019	6 180 178
Others	530 244	370 538	890 782

Source: FAO, 2016a

In Bangladesh, the major cultured species are Indian major carps, exotic carps, tilapia, pangasius, Thai koi, (climbing perch), indigenous high value species, freshwater prawn (*M. rosenbergii*) and shrimp (*P. monodon*). The production systems include monoculture of tilapia, pangasius, shing, koi and others, as well as polyculture of Indian major carps, exotic carps with other fish species. Shrimp culture is done in brackishwater areas. Crabs and mud eels are also cultured but on a limited scale in selected areas.

Aquaculture farms in Cambodia vary from small-scale farms using onfarm/domestic wastes as inputs to large-scale farms using feeds to produce fish. The main culture systems are cages (50 percent) and ponds, mostly in freshwater. Aquaculture production is mainly for domestic consumption. The three main species that are cultured are *Channa micropeltes*, *Pangasianodon hypopthalmus* and hybrid catfish. Most of the seedstocks are sourced from the wild except for pangasius, *Barbonymus gonionotus, Leptobarbus hoeveni, Trichogaster pectoralis and Barborymus altus* that are produced in hatcheries. Exotic species that are also cultured include hatchery-produced tilapia, carps (silver carp, common carp, bighead carp, grass carp, Mrigal, and hybrid catfish in ponds. Pond production systems are mostly extensive or semi-intensive (75 percent) and intensive (25 percent). Pangasius, snakehead and hybrid catfish are the three species

cultured intensively in ponds. Extensive and semi-intensive pond culture in areas away from wild fish population sites is promoted for family consumption. The promotion of family fish ponds started in 1986 through the UNICEF's Family Food Programme. Ponds are 80 m^2 to 300 m^2. The main species are Pangasius, silver barb, carps and tilapia. Stocks are fed farm wastes such as rice bran, duckweed, termites, morning glory and rice-wine waste. Rice-fish culture started in 1997. The main species are silver bard, carps and tilapia. Public hatcheries have been established to serve the seedstock needs of the aquaculture industry. Village hatcheries have also been established in different provinces. Shrimp farming was introduced in the 1990s. Seedstocks are either collected from the wild or are imported. For marine cage farming, the main species are grouper, sea bass, and cobia. The problems with mariculture include unavailability of hatchery-produced seed and reliance on wild and imported seeds.

Aquaculture in China covers a diversity of species groups including finfishes, crustaceans, mollusk, seaweeds and other species. Mollusks comprise 72 percent of mariculture production whereas finfish from freshwater production systems comprise 85 percent of total finfish production. Production systems include culture in ponds, cages and tanks, as well in rice cum fish, integrated systems, IMTA and RAS.

In India, the major aquaculture systems include pond, cages, pen and tank culture, polyculture, integrated fish farming and RAS. The cultured commodities include carps, Pangasius, tilapia, native catfishes, freshwater prawn and ornamental fish, shrimp, marine fish and others.

Malaysia's major aquaculture products are seaweeds (*E. cottonii*), mollusks (cockle, mussel and oyster), shrimp (white shrimp, black tiger) and freshwater finfish (catfish, red tilapia, black tilapia, riverine catfish) and marine finfish (sea bass, grouper, snapper).

Myanmar's major aquaculture commodities include 15 species of freshwater fish, freshwater prawn, marine fish (grouper, snapper, sea bass), marine shrimp, seaweeds and mud crab. Rohu is the main cultured commodity in intensive culture systems. Culture is mainly done in ponds. Extensive and semi-intensive farming of shrimp is done in coastal areas. Groupers and sea bass are grown in cage culture systems. Soft shell crab production is a booming industry whereas seaweeds farming is expanding.

Altogether 12 exotic fish species have been introduced for culture in Nepal. Major aquaculture systems adopted are carp polyculture in ponds, lakes and enclosures. Cage culture of herbivorous carp species and common carp in rice-fish culture are common practices in the subtropical hill region. In addition, the technology of rainbow trout (*Oncorhynchus mykiss*) farming is being scaled up in the temperate region of the country.

Although Pakistan has a coastal belt of about 1 100 km, there is no coastal aquaculture in Pakistan. The commonly cultured species include indigenous species (rohu, *Labeo rohita*; Mori, *Cirrhinus mrigala*; and Thaila, *Catla catla*), exotic species (silver carp, grass carp, bighead carp, common carp, tilapia), and cold water species (rainbow trout and brown trout). Most farms are extensive with a few semi-intensive ones. However, with the introduction of all male tilapia culture and catfish culture, intensification and use of artificial feeds may be inevitable.

Philippine aquaculture involves the farming of many species of fish, crustacean, mollusk and seaweeds in different farming systems in freshwater, brackishwater and marine waters. The predominantly farmed species are seaweeds, milkfish, tilapia and shrimp/prawn. Other species include mussel, oyster, carp, mud crab, catfish, grouper, siganids and others. Culture techniques for abalone, sea urchin and sea cucumber are being developed. The majority of aquaculture operations in the Philippines are small-scale to medium-scale level.

Culture based fisheries in perennial reservoirs is considered as the main provider of fish protein to rural village people in Sri Lanka. Shrimp culture is mainly in earthen ponds. Ornamental fish culture is also a major activity that brings foreign exchange. Over 200 species belonging to 40 families of marine ornamental fish collected from the wild are also being exported. One of the emerging aquaculture systems

is sea cucumber fattening. The existing culture systems include: culture-based fisheries in reservoirs (tilapia, carps), shrimp farming (tiger prawn, extensive), ornamental fish farming (collect seeds from the wild), cage culture and pen culture (sea cucumber, marine fish), pond culture (fish), seaweeds culture.

Aquaculture in Thailand consists of coastal aquaculture and inland aquaculture. The main species cultured in brackishwater ponds are the black tiger prawn and the Pacific white shrimp. The major cultured finfish species are sea bass and grouper in cages or in ponds. Green mussel, blood cockle, and oyster are cultured along the coast. Coastal aquaculture usually produces high-value products; white shrimp and black tiger prawn are mainly for export whereas marine fish and shellfish are mainly for domestic consumption. Freshwater fish species (Nile tilapia, catfish, silver barb, giant river prawn and snakeskin gourami) are cultured in ponds, cage, paddy field and ditches. Inland aquaculture production is also mainly for domestic consumption.

In Timor-Leste, the cultured species include tilapia, catfish, common carp, white shrimp, seaweed, mud crab, milkfish and grouper.

Viet Nam's top aquaculture products are catfish, shrimp and mollusks (oysters, clam). Production in the Mekong Delta accounts for 70 percent of total production and export. Brackishwater shrimp (white leg shrimp and tiger shrimp) are cultured in intensive and semi-intensive culture systems. Pangasius farms are 100 percent intensive culture systems.

Global climate change and possible impacts on aquaculture

Global climate change poses three broad types of hazards to aquaculture systems: physical, chemical and biological. Most of the chemical and all of the biological hazards are offshoots of the physical hazards. There is, however, limited information on the interactions and combined effects of the different types of hazards. Moreover, because of the scarcity of long time-series data, the uncertainty of biological responses to change, and the cumulative impact of climate and anthropogenic effects, predictions of climate change impacts at the regional and subregional level are difficult to make with certainty (FAO, 2016b).

The impacts of global climate change on aquaculture can also be categorized into short-term and long-term impacts that arise from either extreme meteorological events (such as temperature anomalies, precipitation anomalies, cyclones or storms, floods or droughts) or long-term global climate trends. The short-term impacts include production losses from loss or mortality of stocks and damage to infrastructure because of extreme weather events, and production losses because of outbreaks of diseases, parasitic infestation, or harmful algal blooms. Long-term impacts include: scarcity of wild seed because of degradation of habitats and breeding or nursery areas; reproductive or recruitment failure because of increased water temperature that is beyond the optimum range for reproduction or development, growth and survival or ocean acidification that hinders normal development in shellfishes; limited access to water for farming; limited access to feed sources or supply of feed ingredients; and decreased productivity because of sub-optimal farming conditions.

Hence, at a global level, climate change impacts on aquaculture will likewise impact food and nutrition security, poverty alleviation efforts and livelihood security, and economic development. The effects could be higher in the largely developing countries of the Asia-Pacific region where about 90 percent of the world's aquaculture production come from and where more than 80 percent of the fish farmers are small-scale farmers and many are resource poor, have a high per capita intake of fish and therefore a high dependence on fish for food security and nutrition (Bueno and Soto, 2017). Likewise, freshwater fish production is threatened by climate change impacts on the one hand and scarcity and pollution of freshwater (which can also be exacerbated by climate change) for fish farming on the other hand. This will threaten the food security of 3 billion people who rely on freshwater fish as food fish and the livelihoods of the millions of farmers producing freshwater species.

Box 1. Hazards to aquaculture related to global climate change

Physical hazards

Temperature anomalies – higher air temperature and increased frequency of hot days and nights, heat waves and abnormally cold events are more likely and will affect stock performance and productivity. The effect of increased temperature could be positive for some aquaculture species. In contrast, instances of extreme cold can cause mortalities in fish stocks and damage to facilities (FAO, 2013).

Sea surface temperature changes (SST) – each species is adapted to a particular temperature range. A change in SST may put some production systems at risk if the increase or decrease in temperature exceeds the optimal range for growth or survival. Increased sea surface temperature can also cause widespread coral bleaching and will affect habitats and breeding grounds of reef fish.

Precipitation anomalies – likely increases in the frequency and intensity of heavy rainfall events on the one hand and a prolonged absence of precipitation (drought) on the other hand, adversely affects aquaculture production; productivity is also affected by erratic precipitation patterns.

Rising sea levels – sea levels are expected to increase and the intrusion of saline waters inland could render some freshwater production systems unsuitable for the culture of freshwater species. Wave surges and inundation can also alter habitats of cultured species, eroding or submerging coastal areas.

Floods – flooding triggered by abnormally heavy rainfall may become more severe rendering aquaculture systems, sources of inputs such as wild seeds and feed ingredients more vulnerable.

Droughts – probably more intense or of longer duration, or both. The occurrence of droughts can be partly attributed to deficient or erratic rainfall and climate variability (UNISDR, 2011).

Cyclones – the growing intensity of tropical cyclones can cause the widespread destruction of infrastructure and the disruption of farming activities and services that affect aquaculture production and other segments of the value chain (seed and feed production and supply, post-harvest, transport, marketing). Cyclones also cause siltation that affects mollusk growing areas.

Chemical hazards

Acidification – a number of studies have shown that ocean acidification affects the development of certain farmed species especially mollusks and crustaceans; acidification also affects corals.

Salinity changes – may increase or decrease depending on changes in precipitation or evaporation; heavy influx of floodwaters from rivers and estuaries into coastal waters or by the intrusion of seawater in rivers.

Low oxygen levels in culture waters – an increased impact of upwelling of anoxic water; plankton respiration intensified as a result of higher temperature; eutrophication.

Biological hazards

Eutrophication – rising temperature levels are likely to cause wide fluctuations in the thermal dynamics of freshwater bodies, increasing stratification and nutrient circulation, and affecting primary production and hence higher trophic levels. More intense eutrophication and algal blooms will have implications for local aquatic ecosystems and for aquaculture, especially in static waterbodies such as lakes and reservoirs.

Harmful algal blooms – increasing temperature is correlated with increasing frequency and extent of algal blooms as well as changes in the diversity of zooplankton.

Pathogens and parasites – there is an increase in prevalence as well as a shift in the distribution of pathogens and parasites, and enhanced growth and reproduction of microbes.

Pollution – increase in pollution toxicity, including dilution of microplastics because of increasing water temperature.

Source: Bueno and Soto, 2017.

Table 12. Climate change-related hazards increasingly experienced by countries in the Asia-Pacific region in recent years

Type of hazard	Impact on aquaculture operations
Temperature anomalies	• disruption of reproduction and spawning • low larval survival, decreased seed production in hatcheries, low supply of quality seeds for grow-out • slow growth and lower survival in the grow-out stage • higher incidence of disease outbreaks • decrease in production
Changing sea surface temperature	• slow growth and lower survival in mariculture • higher incidence of disease outbreaks • decrease in production
Precipitation anomalies	• slow growth and lower survival • higher incidence of disease outbreaks • decrease in production
Floods	• damage to farm infrastructure and other facilities • loss of stocks (escapes and/or mortalities) • production losses • additional cost for repairs • may also provide opportunities for short-term culture (e.g. nursery of fish in areas where water pools persist for some time
Drought	• disruption of reproduction and spawning • low larval survival, decreased seed production in hatcheries, low supply of quality seeds for grow-out • decrease in suitable farming areas because of recession of waterbodies/lack of water • shorter duration for culture, reduces the number of crops in a year • slow growth and lower survival in the grow-out stage • higher incidence of disease outbreaks • decrease in production
Cyclones	• damage to farm infrastructure and other facilities • loss of stocks (if floods occur) • production losses • additional costs for repair
Sea level rise	• loss of production areas for strictly freshwater species • provides opportunities for farming species that can tolerate low salinity

Mitigation and adaptation strategies

Mitigation of and adaptation to climate change impacts involves actions that reduce emission of carbon dioxide and other greenhouse gases into the atmosphere as well as preparing society for the impacts associated with climate change (Shelton, 2014). Countries in the Asia-Pacific region have made wide-ranging efforts for climate change mitigation and adaptation.

The Bangladesh Climate Change Strategy and Action Plan (BCCSAP) 2009 is mainstreamed with relevant sectors under the government's Sixth Five-Year Plan. Programmes under the Plan focus on six areas: food security, social protection and health; comprehensive disaster management; infrastructure; research and knowledge management; mitigation and low carbon development; and capacity building and institutional strengthening. The Bangladesh Country Investment Plan (CIP) 2011 was established with the task of

ensuring food security in the face of climate change. The CIP has 12 priority investment programmes including development of fisheries and aquaculture (Government of the People's Republic of Bangladesh, 2011). Recognizing that climate change mitigation and adaptation require considerable financial investment, the government created two endowments to channel funds for climate change-related programmes: the Climate Change Trust Fund (CCTF) for domestic funds and the Bangladesh Climate Change Resilience Fund (BCCRF) for funds from external sources.

Bangladesh' National Adaptation Plans of Action identified 15 priority adaptation measures focused on reduction of climate change hazards through coastal afforestation with community participation, adaptation to agriculture systems in areas prone to increased flash flooding, exploring options for insurance and other emergency preparedness measures to cope with increasing climate change disasters. The country's mitigation strategy focuses on low carbon development and the government's energy policy is geared towards raising efficiency in production and consumption of energy as well as development of renewable energy sectors especially solar and biogas; enhancing carbon sequestration and improving ecosystem services through partnership with civil society to implement a nationwide social forestry programme to afforest the coastal belts; adopting state of the art technologies to ensure low carbon development pathways (improve farming and waste management practices); afforestation projects and preparing for the United Nations Collaborative Programme on Reducing Emissions from Deforestation and Forest Degradation in Developing Countries (REDD); Clean Development Mechanism (CDM) projects and carbon trading; conversion of 2-stroke to 4-stroke engines and petrol cars to compressed natural gas-driven vehicles; biomethanation from landfills; and Collaborative REDD and Improved Forest Management Sundarbans Project (CRISP) aimed at reducing emissions and enhancing livelihoods and at the same time exploring carbon-financing opportunities. Some adaptation initiatives that have been implemented include flood management schemes to protect low-lying areas agricultural and urban areas; coastal embankment projects; construction of cyclone shelters; promotion of irrigation schemes; R&D to develop climate change-tolerant varieties of rice; and coastal greenbelt projects. These have resulted in increased agricultural production, reduced fatalities during disasters and improved the ability to deal with natural disasters.

The Cambodia Climate Change Strategy Plan (CCCSP) 2014–2023 was approved in 2013 and is the country's first comprehensive national policy document responding to climate change issues. The CCCSP is mainstreamed with Cambodia's National Strategic Development Plan (NSDP) 2014–2019 as well as with the different sector development plans formulated by the relevant ministries, the Rectangular Strategy, and the National Strategic Plan on Green Growth. The Plan focuses on adaptation, GHG mitigation and low carbon development. The priority sectors are agriculture, forestry, human health, coastal zone and water resources with 39 priority activities in coastal areas (4), malaria (6), water resources and agriculture (20) and cross-sectoral activities (5). Priority activities related to aquaculture include: development and improvement of small-scale aquaculture ponds; promotion of household integrated farming; and introduction of short culture period rice varieties in areas affected by seawater intrusion (also applicable to introduction of saline-tolerant fish) and droughts.

The CO_2 emissions of China are greater than the combined GHG emissions of all other countries hence it will play a vital role in global efforts on greenhouse mitigation and addressing climate change issues. China has made significant investments in policies aimed at reducing greenhouse gas emissions focused on improving energy efficiency and energy supply. In the mid-1990s, China's Five Year Plan set to reduce energy intensity (energy consumption per unit GDP) and supported the use of renewable energy as embodied in the Renewable Energy Law of 2005 and 2009 which set national renewable energy targets and required grid companies to connect to renewable energy sources. China's Eleventh Five Year Plan (2006–2010) acknowledged that economic growth cannot continue at the expense of environmental degradation and set the first quantitative and binding energy targets to reduce energy intensity by 20 percent, increase the use of non-fossil (renewable and nuclear) energy to 10 percent of primary energy, and reduce major pollutants by 10 percent. At the Copenhagen Climate Change Conference in 2009, China committed to cut its emissions per unit GDP by 40 to 45 percent in 2020 from the levels in 2005 and

increase the contribution of non-fossil energy to 15 percent of the supply in 2020. The Twelfth Five-Year Plan 2011–2015 set to reduce carbon intensity (CO_2 emission/unit GDP) by 17 percent, reduce energy intensity by 10 percent and increase the use of non-fossil energy from 8.6 percent to 11.4 percent from 2010 levels in 2015. Measures that were identified to help meet the commitments include pilot emissions trading schemes, energy and coal consumption caps, carbon capture and storage projects, support for improving the efficiency of coal-fired generators, renewable energy projects, residential energy use caps and support for smart grids and electric vehicles. China has made significant steps in reducing GHG emissions. It has developed a renewable energy industry, the country's energy intensity has declined rapidly and the average energy efficiency of its coal power plants has increased from 31 percent in 2000 to 37 percent in 2010, its pilot emissions trading scheme has expanded and covered 700 million tonnes of CO_2 emissions. The Thirteenth Five-Year Plan calls for an "Ecological Civilization" and among others provides a sound policy platform for the protection of marine ecosystems and the restoration of capture fisheries within China's EEZ (Williams, 2014; Cao *et al*., 2017).

Although India's GHG intensity is 20 percent lower than the world average, the government's policy aims to: improve energy efficiency; increase use of renewables (wind, solar, biomass/biofuels, hydropower) and nuclear power; promote the use of compressed natural gas-powered vehicles and an expanded public mass transport system; and reform energy pricing to encourage investments in the renewable energy industry (Anonymous, 2008). India is a party to the UNFCCC and the Kyoto protocol, although it has no binding emission limits. However, it is an active party to the CDM that grants marketable emission credits for verified reductions in developing countries with 345 CDM projects, mostly on biomass and wind power. The first National Action Plan on Climate Change focused on energy (renewable energy), energy efficiency and conservation, transportation, biofuels and forestry.

Indonesia committed to voluntarily reduce its GHG emissions by 26 percent and up to 41 percent with international support by 2020 compared to business as usual emissions levels (Anonymous, 2008; Morizane *et al*, 2016). To achieve this commitment, Presidential Regulation No. 61/Year 2011 or the National Action Plan on GHG emission reduction (RAN-GRK) was issued. Presidential Regulation No. 71/Year 2011 or the National GHG Inventory was issued to provide information on the status and trends of GHG emissions and removals. These initiatives are linked with international efforts including reporting to the UNFCCC. The GHG inventory focused on five areas: energy; industrial processes and products; agriculture; land use, land use change and forestry (LULUCF); and waste. National Appropriate Mitigation Actions (NAMAs) were identified to achieve the targets: sustainable peatland management; reduction in deforestation and land degradation; development of carbon sequestration targets in forestry and agriculture; promotion of energy efficiency; development of alternative and renewable energy sources; reduction of waste; and shifting to low-emission transportation modes (Murniningtyas, 2013). Under the Indonesia Climate Change Sectoral Road Map 2009, the targets for the agriculture sector included the introduction of low-emission paddy varieties, irrigation, water efficiency and organic fertilizer use. The National Development Planning Agency was designated as the Lead Coordinating Agency for Climate Change. The Agency formulated Indonesia's Medium-term (5 years) and Long-term (25 years) Plans. The country's climate change mitigation and adaptation initiatives are mainstreamed with the Medium-term Plan 2015–2019. The Agency also developed the Guidelines for Monitoring, Evaluation and Reporting of Mitigation Actions 2013. Funding for the initiatives for reduction of GHG emissions is taken from the Indonesia Climate Change Trust Fund (ICCTF) which is sourced from the state and regional budgets and other sources or the FREDDI (Funding for $REDD^+$ Indonesia) which is a trust fund for the $REDD^+$ Programme. Presidential Regulation No. 19/Year 2010 established the $REDD^+$ Task Force and Presidential Regulation No. 62/Year 2013 launched the $REDD^+$ Agency. Indonesia entered into a partnership agreement with the Kingdom of Norway, which will provide USD 1 billion for Indonesia's $REDD^+$ efforts with actual funds disbursed based on verified emissions reductions.

The Republic of Korea formulated its Comprehensive Plan on Climate Change Adaptation in the late 90s. The first (1999–2001) and second comprehensive plan (2002–2005) only covered climate change mitigation, but the third comprehensive plan (2005–2007) began to include climate change adaptation.

The current National Comprehensive Plan on Climate Change Adaptation 2009–2030 was formulated through the joint efforts of 13 government ministries. The National Strategy for Green Growth and Five-Year Plan included "reinforced climate change adaptation capacity" as one of the ten major national policy tasks, and established the Korean Adaptation Center for Climate Change (KACCC) to carry out strategic research, and provide policy support regarding national climate change adaptation. In terms of international cooperation, it organized an international symposium to help countries share outstanding adaptation policies and tools and provided climate change adaptation training for developing ASEAN countries.

The Framework Act on Low Carbon, Green Growth prescribed government responsibilities to formulate a national adaptation plan, and accordingly, the National Climate Change Adaptation Plan 2011–2015 was established as the Republic of Korea's first legally prescribed adaptation policy through the joint efforts of 13 associated government ministries under the supervision of the Ministry of Environment. Detailed implementation plans will be formulated for each government ministry and local governments based on the master plan that will be formulated in a five-year rolling plan format in order to ensure flexible responses to variations in climate change phenomena and to reflect advancements in climate change monitoring and prediction technologies. The plan covers the ten priority areas – health, disasters, agriculture, forestry, marine and fishing industries, water management, ecosystems, climate change monitoring and prediction, adaptation industries and energy, education and promotion, and international cooperation. The basic direction of this adaptation plan is to carry out impact analyses and vulnerability assessments in each sector according to the new scenario, formulate measures to give priority to vulnerable populations and regions that will be most directly damaged by climate change, and focus on identifying cooperative projects among sectors instead of measures for each sector. It involves monitoring the climate environment on a yearly basis, carrying out implementation evaluations, and reflecting the results in the plan for the following year.

An integrated information system on climate change adaptation is being built to formulate integrated policies and help private businesses to make use of climate change information. Accordingly, government ministries and institutions will mutually leverage each other's expertise. Long-term climate change adaptation R&D will be carried out to help formulate highly effective adaptation measures. In addition to enhancing the adaptive capacity of the public sector, measures will also be implemented to do the same for industries and other parts of the private sector such as by developing a climate change risk assessment system and preparing methods to introduce a public institution (public enterprise) adaptive capacity reporting system. The Ministry of Environment is developing a geostationary environment monitoring satellite to be launched in 2018 to reinforce climate change monitoring and prediction. This satellite will constantly monitor climate change in East Asia and the emission of air pollutants. The Ministry of Environment is building a "climate change adaptation information delivery hub" to provide experts and the public with information in an efficient manner.

The National Strategy on Climate Change (NSCC) of Lao People's Democratic Republic which was approved in 2010 identified seven priority areas for adaptation and mitigation, as follows: agriculture and food security; forestry and land use change; water resources; energy and transport; industry; urban development; and public health. The NSCC is streamlined into the country's Seventh National Socio-Economic Development Plan 2011–2015. National adaptation projects are focused on water, agriculture and disaster risk management (Government of Lao People's Democratic Republic, 2009 and 2014) and have funding from external sources including the Asian Development Bank (ADB), Global Environment Facility (GEF), Least Developed Countries Fund (LCDF), Nordic Development Fund and United Nations Development Programme (UNDP).

Malaysia launched its National Policy on Climate Change in 2010. It is the first document with major focus on adaptation since the government has been advocating a balanced approach between mitigation and adaptation (Government of Malaysia, 2009). Priority sectors identified are water resources, agriculture, forest resources, coastal and marine management, energy and human health. Adaptation measures in the

agriculture sector focus on improving agricultural practices for both crops and livestock. Malaysia has a relatively low participation in regional adaptation projects relative to other developing countries in East and Southeast Asia including projects focused on adaptation in agriculture, nature, coastal zones, marine resources, natural resources management, water and policy formulation.

The Priority Adaptation Projects of Myanmar are categorized into eight sectors or themes and consist of 32 priority activities (Government of Myanmar, 2012). Agriculture, early-warning systems and forests; public health and water resources; coastal zone; and energy and industry as well as biodiversity are considered as first, second, third and fourth priority sectors/themes, respectively. Priority activities under the agriculture sector are: 1) reducing climate change vulnerability of rural and subsistence farmers through locally-relevant technologies, using climate-resilient rice varieties and *ex situ* and *in situ* conservation of plant genetic resources; 2) increasing climate change resilience of rural and subsistence farmers in the dry and hilly areas through legume crop diversification and use of climate-resilient varieties; 3) increasing the climate resilience of dry zone communities by diversifying and intensifying home gardens through the use of solar power technology, higher income fruit crops, and climate-smart aquaculture practices; and 4) reducing the vulnerability of livelihoods in agro-ecological zones to climate change through the transfer of a wide range of high yielding and climate-resilient rice varieties. Priority activities under the coastal zone sector include: 1) implementing integrated coastal zone management; 2) implementing community-based mangrove reforestation to build climate change-resilient rural livelihoods in degraded coastal areas in Rakhine State; 3) introducing community-based eco-friendly aquaculture systems (mud crab, clam, shrimp and tilapia) for enhancing the climate change resilience of rural livelihoods and supporting the recovery of mangrove forest ecosystems; and 4) introducing small-scale aquaculture in mangrove buffer demonstration sites for transferring adaptation technologies to Mon and Tanintharyi coastal communities.

Nepal is largely an agrarian economy highly sensitive to climate change impacts and the availability of natural resources. The country's policies integrate strategies for low carbon development and adaptation to climate change impacts around six thematic areas: agriculture and food security; forests and biodiversity; water resources and energy; climate-induced disasters; public health; and urban settlements and infrastructure (Government of Nepal, 2010). The policies are set within the context of the country's development goals. Considerable focus is given to providing information, knowledge, skills and technologies to the most vulnerable households living in fragile, climate-vulnerable areas/districts. These are targeted to enhance the adaptive capacities of communities through livelihood support, improved governance, collective responses, improved services delivery mechanisms and access to technology and financing.

Pakistan's Committee on Climate Change was established in 2005. In the same year, the Planning Commission that prepared the country's national plans established the Task Force on Climate Change to lay down the country's policies on climate change. The identified sectors for adaptation action include water, disaster risk reduction, policy formulation, agriculture, energy, forestry, coastal zone and natural resources.

The Philippines' climate change mitigation and adaptation strategies are embodied in the National Framework Strategy on Climate Change. Mitigation strategies focus on improving energy efficiency and conservation; harnessing renewable energy, development and establishment of environmentally-sustainable mass transport systems; sustainable infrastructure, enhancing the national REDD^{+} strategy; and water resources management. The country is heavily reliant on thermal electric power generators (gas-fired, oil-fired, or coal-fired power plants) for its energy needs. The government is targeting the harnessing of geothermal and hydropower resources, and the doubling of their outputs in the next 20 years to partly replace energy generated from thermal electric power generators. Furthermore, adaptation strategies will focus on enhanced vulnerability and adaptation assessment; integrated ecosystems-based management (including river basin, coastal and marine resources and biodiversity); climate-responsive agriculture (including expanded investment in aquaculture and other food production sectors); water governance and management; a climate-responsive health sector; and disaster risk reduction and management.

The National Climate Change Policy of Sri Lanka was adopted in 2012 Government of Sri Lanka, 2015. The country's National Climate Change Adaptation Strategy (2011–2016) and the National Adaptation Plan for Climate Change Impacts are mainstreamed with the National Climate Change Policy. The identified vulnerable and hence priority sectors are: food security (including agriculture, livestock and fisheries), water, coastal sector, health, human settlements, biodiversity, tourism and recreation, export development, and industry-energy-transportation.

Thailand's strategies for mitigation and adaptation to climate change are consonant with its current Eleventh National Economic and Social Development Plan which envisions the shift in development paradigm and consumption behaviour towards an environment-friendly and low carbon economy (Uppanunchai *et al*, 2016). The national plans on environment and climate change are formulated under the Ministry of Natural Resources and the Environment and include the National Strategic Plans on Climate Change 2008–2012 and the draft National Master Plan on Climate Change 2011–2050. Aside from these, National Sectoral Plans are formulated by concerned ministries hence the Ministry of Agriculture and Cooperatives formulated the draft Strategic Plans on Climate Change in the Agriculture Sector. The National Strategic Plans on Climate Change aim to reduce GHG emissions based on sustainable development through the Clean Development Mechanism, increase forest area by afforestation, and increase activities that promote clean and low carbon technology. Under this, the Renewable Energy Development Plan and the Energy Efficiency Plan have also been formulated. The National Master Plan on Climate Change identifies the following climate change management strategies: adaptations for coping with the negative effects of climate change; mitigation of GHG emissions and increase GHG sinks; and strengthening the capacity of human resources and institutions to manage the risks from climate change effects. The priority areas for mitigation are in transport, power production, urban management, buildings, biodiversity and water management, whereas the priority areas for adaptation are on agriculture, public health, water resources management, settlements, natural resources management and tourism. Thailand's Nationally Appropriate Mitigation Actions focus on countermeasures for carbon dioxide emissions including renewable energy, energy efficiency, biofuels and other alternative energy sources and an environmentally-sustainable transport system with the goal of reducing CO_2 emissions in the range of 7 percent to 20 percent in 2020 in relation to current or "business as usual" levels.

The vulnerability of Timor-Leste to the impacts of climate change is exacerbated by the country's high dependence on its natural resource base, inadequate infrastructure and need for institutional capacity strengthening. The formulation of the country's NAPAs was spearheaded by the Ministry of Economy and Development through the State Secretariat for Environment. The priority sectors are food security (agriculture), water, health, disasters, biodiversity (in forests and coastal ecosystems) and infrastructure (Government of Timor-Leste, 2010).

Climate change issues are considered in Viet Nam's Socio-Economic Development Plan 2010–present, hence the National Climate Change Strategy, the National Action Plan on Climate Change and the National Target Programmes to respond to climate change are in line with the National Socio-Economic Development Plan. The key climate change-related objectives include: increasing resilience and reducing vulnerability to climate change impacts; responding proactively to disaster and improving climate monitoring, weather forecasting, early-warning systems and communications to local communities; and responding to sea level rise and urban inundation. Agriculture is considered a high priority sector and the vulnerabilities of the sector as well as impacts on climate change on the sector have been identified.

The need for adaptation in the fisheries and aquaculture subsector and the associated challenges are expected to increase with climate change (IPCC AR5). There is an increasing number and variety of adaptation options that can either be applied reliably to specific impacts — there are those that might broadly apply to a variety of impacts, those that are easy and inexpensive, as well as those that are complex and need a significant amount of resources to implement.

Aside from laying down the policy frameworks and strategic action plans for adaptation to climate change impacts, countries in the Asia-Pacific region have also implemented and are currently implementing initiatives aimed at enhancing adaptive capacity to climate change impacts. Some of the activities undertaken by countries in the region that are geared towards building climate change resilience in the aquaculture subsector include: interventions in terms of adoption of improved or adaptive technologies; R&D for development of climate change-resilient technologies or practices; capacity building and mechanisms to support farmers; and legislative frameworks that facilitate response, mitigation and adaptation measures to the impacts of climate change-related extreme weather events.

Adoption of climate-adaptive technologies or practices includes:

- improvement of aquaculture management practices;
- diversification of culture systems (culture in pens and cages, coastal or offshore culture), adoption of new technologies (e.g. RAS, use of temperature control system in breeding and hatchery facilities);
- use of fast growing species or advanced or larger-sized fingerlings that are suitable for short-term culture (e.g. in seasonal ponds);
- farm species that can thrive with little water (e.g. catfish);
- adoption and promotion of saline-tolerant strains (e.g. tilapia) in coastal areas and sites vulnerable to saltwater intrusion or cold-tolerant species (e.g. blue tilapia that can be farmed in cold places);
- development, adoption, promotion of adaptive culture systems such as RAS, rice–fish culture, integrated culture or IMTA; and
- improvement of infrastructure (e.g. building big and deep water reservoirs or fish ponds that can hold more water during periods of drought); drill ground water for additional source of water.

R&D for development of climate change-resilient technologies or practices includes:

- selective breeding or strain/genetic improvement programmes to ensure continuous supply of quality seeds (including marine plants) that are climate change-tolerant (e.g. temperature-tolerant, saline-tolerant, disease-resistant; developing strains that are adapted to higher temperatures);
- innovation in farm system management (e.g. environment-friendly aquaculture such as zero waste aquaculture, water recirculation and closed systems, offshore farming of green mussel to remove organic matter in seawater), refinement of RAS and IMTA;
- monitoring of climate change-related impacts and threats including fish health monitoring, health certification for imported seeds and broodstock, toxicity tests for biotoxins, e.g. for PSP and compliance to good aquaculture practices in farms and certification schemes;
- analysis of the relationship between atmospheric data and water parameters and impact of primary production and yield, establishment of baseline for monitoring of several climate change-related parameters in the nearshore ecosystem of Timor-Leste funded by NOAA, 2017;
- development of a GIS-based Vulnerability and Suitability Analysis (VSA) system for capture fisheries and aquaculture that will rank areas based on their vulnerability to physical and climate hazards that will help in investment planning, implementation and mitigation of the effect of or preventing potential losses caused by climate change;
- finding suitable sites (e.g. shrimp farming in the desert, a collaborative project between the Republic of Korea and the National Institute for R&D for Fisheries and Aquaculture of Algeria to pilot shrimp farming with little water, high temperature and unstable salinity), delineation of appropriate aquaculture zones, diversification of species/development of techniques for farming of suitable new species or varieties;
- climate change-resilient designs of aquaculture facilities and infrastructure (e.g. ponds reconstruction); and
- research on carbon sequestration and aquaculture as carbon sinks (e.g. culture of mollusks and seaweeds) or culture of low carbon footprint species.

Awareness and capacity building and mechanisms to support farmers and vulnerable groups include:

- campaigns to create awareness regarding climate change, climate change-related extreme weather events and their impacts/threats and risks to aquaculture, livelihoods and others;
- programme/projects to increase adaptation management skills in response to climate change impacts and increase institutional capacity to handle climate change-related issues (e.g. the project "Building capacity for integrating climate change adaptation in the fisheries subsector in Cambodia" implemented by the FiA in collaboration with WorldFish with funding from the Cambodia Climate Change Alliance, the FishAdapt project in Myanmar funded by FAO which aims to strength the adaptive capacity and resilience of fisheries and aquaculture dependent livelihoods, and the project Building Capacities for Climate Resilient Tilapia Farming in the Philippines (funded by FAO, to increase the resiliency of the pond-based tilapia producing subsector from the negative externalities imposed by climate-weather risks, primarily their impact on farm productivity) which has been expanded to include other major aquaculture commodities); and
- early-warning system developed from web and mobile-based information and communications technology (ICT) applications that will assist farmers in mitigating climate hazards and risks through provision of relevant climate information and farm advisories at the local level and strengthen the adaptive capacity of the community against climate uncertainty.

Major gaps and constraints in building climate-resilient aquaculture

A comparison of the gaps/constraints/issues in building climate-resilient aquaculture identified during the workshops in 2011 and 2017 show several commonalities. Although the countries in the region have made significant headway in addressing these issues, efforts need to be intensified especially in implementing or adapting policies and strategies at the local level (Table 13).

Table 13. Comparison of gaps/constraints/issues in building climate-resilient aquaculture 2011 and 2017

Gaps identified during the 2011 Workshop	Gaps identified during the 2017 Workshop
• Information/data/technology gaps in climate change adaptation and mitigation related to aquaculture (lack of information on impacts of climate change on ecosystems that impact aquaculture activities; lack of methodologies for vulnerability assessment; lack of R&D on climate change adaptation and mitigation; no guidelines on adaptation to climate change; need to develop training courses/capacity-building programmes) • Lack of sufficient capacity on aquaculture-related adaptation and mitigation (e.g. lack of capacity to predict changes in climate, lack of expertise, low adaptive capacity of the people) • Lack of financial capacity to cope with climate change (e.g. lack of resources to support studies of the impact of climate change on aquaculture; difficult to anticipate and evaluate the extent of actions taken by each country, lack of financial resources to assist communities to adapt to climate change) • Lack of awareness on the impacts of climate change on aquaculture (lack of awareness on climate	• Limited information on climate change and its impacts on aquaculture – knowledge gaps on climate change and its projected impact are still apparent especially to those not directly involved in climate change discussions; massive information dissemination must be conducted both at the national and local level to improve people's understanding of the issues • In most cases, basic data on the vulnerability and risk assessment of aquaculture to climate change, as well as mitigation and adaptation capacity are lacking and mapping of aquaculture zones is also needed • Impact of climate change on the biology of fish such as reproduction and early development (e.g. maturity, spawning, hatching, survival of larvae, etc.) is largely unknown • Need to enhance capacity for innovations to improve the existing adaptability of fish farmers/ entrepreneurs and resilience of the aquaculture subsector in general

Table 13. *(continued)*

Gaps identified during the 2011 Workshop	Gaps identified during the 2017 Workshop
change impacts on aquaculture among the different stakeholders particularly the policymakers and the most vulnerable groups, difficulty in making coordinated regional actions in addressing aquaculture-related climate change issues because of differences in perception of climate change impacts among the different countries, lack of awareness of the potential contribution of aquaculture to climate change mitigation) • Lack of institutional development (lack of coordination between line agencies, lack of laws/ policies and strategic action plans covering aquaculture, no linkage/lack of coordination among government agencies/ministries and between government, NGOs and INGOs, gap between policymakers and practitioners, lack of collaboration between communities and ministries, lack of implementing bodies, conflict of interests between aquaculture and other water users)	• Lack of alternative or supplemental (seasonal) livelihoods for vulnerable groups • Lack of resources and funds or programmes for climate-resilient aquaculture including investments in infrastructure to cope with disasters brought about by climate change-related extreme weather events, lack of funds for rehabilitation of damaged facilities, human resources and institutional capacity building programmes and R&D programmes • Lack or low adoption of aquaculture insurance schemes that could provide immediate financial assistance to farmers for speedy rehabilitation, resumption of operations and recovery • Identified strategies and action plans are not specifically designed for aquaculture

Integrating climate change adaptation and disaster risk management in national development plans and programmes

Incidents of disasters from natural occurrences including climate change-related events have been on the rise in recent years. Along with this, there has been a paradigm shift in disaster management from a reactive response and relief to a proactive and more comprehensive risk reduction culture. There is considerable overlap in disaster risk management and climate change adaptation in as much as both address impacts from calamities resulting from extreme natural phenomena (cyclones, storms, flooding, drought, soil erosion/landslides, etc.). Considering this, countries have pushed for the integration of disaster risk management and climate change adaptation plans of action. Several of the strategies for disaster risk reduction and management can also be adopted for climate change adaptation to achieve resilience.

(a) Increasing awareness and enhancing resilience through capacity building on mitigation of and adaptation to climate change impacts

In spite of efforts to enhance awareness and capacity building programmes on mitigation of and adaptation to climate change impacts, these remain a challenge in the aquaculture subsector. Although there have been a number of dialogues, workshops, seminars and other information sharing events on climate change and its impact in general or in the food production sectors including the aquaculture subsector in particular, information may not have trickled down to the local or farmers' level. Hence there is an urgent need for dissemination of information on climate change and its effects on the aquaculture industry from production and the whole value chain including the different stakeholders, policymakers, producers and others that are dependent on the industry.

With the increasing frequency and severity of disasters from natural occurrences in recent years, many nations including countries in the Asia-Pacific region joined together at the World Conference on Disaster Reduction in Kobe, Japan and committed to implement the Hyogo Framework for Action (HFA), which is the global framework for building resilience of nations and communities to disasters and reducing vulnerabilities to risks and hazards. There is also the ASEAN Agreement for Disaster Management and Emergency Response (AADMER) of 2009, the regional framework which has been translated into concrete work programmes (2010–2015) (ASEAN Secretariat, 2013). The AADMER supports and reinforces the

implementation of the HFA in the region. Most countries have put in place a disaster risk reduction and management system and in most cases this is aligned with its climate change adaptation strategies. Disaster risk reduction and management plans (DRRMPs) usually include disaster prevention and mitigation, disaster preparedness, disaster response and disaster rehabilitation and recovery. An important component of the DRRMP is information dissemination to enhance awareness about hazards, threats and impacts, and strengthen the capacities of communities to anticipate, cope and recover from the negative impacts of emergency occurrences and disasters. For example, the Philippines, which is in the typhoon belt and is battered by several typhoons annually, has disaster risk reduction and management councils (DRRMC) at the national (NDRRMC), regional, provincial, city or municipal and barangay (village) levels (Government of the Philippines, 2011). Each level of government has its DRRMP which integrates the information dissemination, awareness and capacity building components and its implementation down to the grassroots level. A similar framework is being adopted by other countries. In addition, the different government agencies are also required to formulate DRRMPs for the sectors they represent (e.g. Lao People's Democratic Republic's DRRMP for its agriculture sector that integrates DRRM and CCA in agricultural development planning and programming). The AADMER Work Programme 2010–2015 calls for the integration of DRRM in the school curriculum as a strategy towards prevention and mitigation of disasters. This can also be adopted as a part of the strategies for climate change adaptation.

(b) Assessment of hazards, risks as well as sectoral vulnerability and adaptive capacity to climate change impacts and disasters

Under conditions of continued development, changing environment and climate, risks are likewise evolving and manifesting in new areas and affecting more communities. Hence, understanding hazards and risks, vulnerabilities and disaster management/climate change adaptation capacities are critical for effective planning, response and recovery as well as building overall resilience to climate change impacts or disasters. Most countries have undertaken and are currently undertaking risk and vulnerability assessments, and have come up with maps of areas that are vulnerable to particular hazards (e.g. storms, cyclones, extreme rainfall, storm surges, flooding, droughts, soil erosion, landslides, salinity intrusion). Changing conditions also call for continuous assessment of risks, vulnerabilities and coping capacities in order to refine management and adaptation strategies. However, the assessments are undertaken using different methodologies and at different scales, hence data contents also differ, making comparisons unrealistic. AADMER pushes for a regional risk assessment programme that employs the best established protocols and best practices to compliment exiting member states' initiatives. This will be linked with the UNISDR Regional Risk Assessment of Asia initiative. There is also a need for specific risk and vulnerability assessments for the different sectors (e.g. agriculture, fisheries, aquaculture) and countries have undertaken this initiative with varying levels of implementation.

(c) Monitoring and implementation of early-warning systems

Climate/weather monitoring Climate monitoring and early-warning systems are fundamental components of disaster risk management. Currently, there is global coordination in hazard detection and forecasting to support multi-hazard early-warning systems under the auspices of the World Meteorological Organization (WMO). Meteorological data from global observation systems are directed to global data processing and forecasting systems. Forecasts and climate information are sent to national meteorological and hydrological services for national level dissemination of warnings and alerts through various means and media (radio or TV broadcasts, text blasting in collaboration with mobile phone service providers). AADMER also has among its work programmes improving capacities in the ASEAN for regional risk assessment, continuous monitoring and development of effective and efficient multi-hazard early-warning systems to support disaster mitigation efforts. Moreover, under the Southeast Asia (PDR-SEA) project, there are community-based initiatives on hazards, vulnerability and capacity mapping as well as community-based early-warning systems (Partnership for Disaster Reduction, 2018a and 2018b). PDR-SEA was initiated in 2001 to promote community-based disaster risk management in Cambodia, Indonesia, Lao People's Democratic Republic, Philippines, Thailand, Timor-Leste and Viet Nam. Bangladesh also has a community-

based flood information system and a community-based flood warning system in place. Joint monitoring and establishment of an early-warning system at a regional or subregional level or covering a large ecosystem shared by a number of countries have been suggested. A workshop aimed at developing/strengthening environmental monitoring and early-warning systems to enhance resilience of the fisheries and aquaculture sectors in the Lower Mekong Basin was organized by FAO and NACA in 2015. In as much as the countries have their own monitoring system, the initiative advocates for sharing of information among the countries as well as with China, which has an established network for environmental monitoring at the national and provincial level. The combined data would be valuable in establishing an efficient early-warning system and long-term monitoring of climate change and its impacts (Verapat, Wilkinson and Soto, 2017). Channeling communications and early warnings through farmer clusters or collectives in order to reach a larger number of small-scale farmers was also seen as a potentially effective information dissemination strategy.

Although the general disaster risk management strategies focus on monitoring of meteorological and hydrological observations, sector-specific disaster risk management plans can focus on risks that are specific for the sector. For example, Lao People's Democratic Republic's disaster risk reduction and management plans for its agriculture sector (including fisheries) address transboundary diseases and other biological issues.

Disease surveillance An increase in the incidence of disease outbreaks in aquaculture has been noted in recent years. The World Organization for Animal Health (OIE), being an intergovernmental organization and a reference organization of the World Trade Organization (WTO), coordinates, supports and promotes the control of the spread of animal diseases (including aquatic animal diseases). It maintains a list of notifiable diseases and requires member countries to submit reports on the presence and status of these diseases in their territories. The Network of Aquaculture Centres in Asia-Pacific (NACA) also has a list of reportable diseases and NACA member countries submit reports to its Quarterly Aquatic Animal Health Disease Reporting System. OIE's Fish Disease Commission (OIE/FDC) and the Asia Advisory Group on Aquatic Animal Health (AG) under NACA decide on the diseases that are included in the list. Countries on the other hand have active aquatic animal diseases surveillance and monitoring schemes largely anchored on the Asia Regional Technical Guidelines on Health Management for Responsible Movement of Live aquatic Animals[10] and the Beijing Consensus and Implementation Strategy.[11] To enhance cooperation in addressing aquatic animal health issues between and among countries, international and regional organizations organize seminars, workshops or consultations to formulate plans of action. For example, FAO organized an international technical seminar/workshop on acute hepatopancreatic necrosis disease (AHPND) in Panama in 2015 and in Bangkok in 2016. The ASEAN Regional Technical Consultation on EMS/AHPND and other Transboundary Diseases for Improved Aquatic Animal Health in Southeast Asia was likewise organized in the Philippines in 2016. Among the policy recommendations from the consultation was the establishment of a regional emergency preparedness and response system, including a regional early-warning system for transboundary diseases (Pakingking, de Jesus-Ayson and Acosta, 2016). Towards this end, an ASEAN Regional Technical Consultation on EPRS is being organized in Bangkok in 2018.

Monitoring of harmful algal blooms (HABs) Algal blooms are natural phenomena. Some species bloom and produce basically harmless discolouration of the water, other species bloom and reach densities that can cause mass mortalities of fish and other aquatic organisms in the area because of oxygen depletion or by damaging and clogging the gills of fish and other invertebrates, especially in intensive aquaculture systems, and another group produce toxins that can bioaccumulate in organisms that feed on them (e.g. shellfish, other invertebrates and fish) and cause poisoning (Hallgraeff, 1993). In recent years, many countries in the region have experienced an increasing trend in the incidence of massive blooms of harmful and toxic algae called harmful algal blooms or HABs. The occurrence of HABs is a big concern for aquaculture because it can cause production losses as a result of mass mortalities of the cultured stocks

[10] www.fao.or/docrep/005/X8485E/x8485eo5.htm
[11] www.fao.or/docrep/005/X8485E/x8485x06.htm

as well food safety issues in aquaculture products that are potentially contaminated with toxins from HABs. These considerations make HABs monitoring important not only for the aquaculture subsector but for the fisheries subsector as well. Timely detection is a critical component of fish and shellfish safety management plans and can provide early warning to aquaculture operators. The ASEAN Regional Technical Consultation on Harmful Algal Blooms was organized in Singapore in 2015 to have a clear understanding of the occurrence of HABs in the region, assess the capacities of ASEAN Member States to detection, monitoring and management of HABs and facilitate information exchange towards a harmonized regional monitoring system. Although many countries in the region have an ongoing HABs monitoring programmes, some countries need to either strengthen their monitoring programmes or start building their HABs detection and monitoring capabilities. To address this constraint, the Southeast Asian Fisheries Development Center/ Marine Fisheries Resources Department (SEAFDEC/MFRD) in collaboration with the Intergovernmental Oceanographic Commission – Sub-Committee for the Western Pacific (IOC-WESPAC) organized a regional training programme on identification of HABs species commonly found in the region in 2016. Follow-up capacity building programmes include training on specimen preservation and its application in HABs monitoring and research and training on culture techniques for HABs species, identification and characterization of toxins. In collaboration with the ASEAN Member States, SEAFDEC/MFRD is also conducting a regional biotoxin monitoring programme (since 2015) that will run until 2019 (Yeap and Sulit, 2017).

Need for intensified research, technology development and dissemination of technological innovations to farmers to enhance resilience of the aquaculture sector to climate change impacts

Aside from research that allows prediction and modeling of climate change related scenarios, there is a pervasive perception of a general lack of R&D on climate change impact on aquaculture and technological developments that would ensure sustainable aquaculture production, enhance adaptive capacity and develop the resilience of the aquaculture subsector to climate change impacts. Furthermore, research outputs and technologies developed so far can be harnessed for climate change adaptation. Sustainable aquaculture production is constrained by reliable supply of quality seeds, feeds, control of diseases, production systems that optimize yield while preserving environmental integrity. The impacts of climate change likewise pose an additional challenge to the sustainability of the aquaculture subsector.

(a) Supply of quality seeds for aquaculture: Success in commercial production of any aquaculture species relies heavily on whether the technologies for captive breeding, hatchery production, nursery and grow-out culture are well established (Romana-Eguia and de Jesus-Ayson, 2011). Although production can be realized using seed stocks from the wild, the scale and sustainability of production can be constrained by the diminishing supply of wild seeds. Captive breeding and seed production of a variety of freshwater fish (e.g. tilapia, carps, catfish), marine fish (e.g. groupers, sea bass, milkfish, snapper, rabbitfishes, pompano and others), crustaceans (e.g. penaeid shrimps, freshwater prawn, mud crab, swimming crab), mollusks (e.g. oyster, abalone, giant clam) have been achieved and adopted with varying levels of success. Efforts to develop captive breeding and seed production technologies of other popular species with potential for commercial production continue in the face of diminishing supply in the wild (e.g. tuna, eel, scat and others). Moreover, closer attention should be given to impacts of climate change, especially increased temperature and increased duration of extremely hot days as well as abrupt changes in the weather which have been observed to disrupt spawning and subsequently recruitment in a variety of stocks bred in captivity. For example, rabbitfish (*Siganus guttatus*) breeders conditioned in a diurnal temperature regime of 31°C to 33°C had lower incidence of spawning, with most of the female breeders having atretic eggs, embryonic development was aborted resulting in very low or no hatching of spawned eggs (Ayson, pers. comm.). Efforts on mass production of seaweeds plantlets from tissue culture have also been undertaken to ensure supply of plantlets to farms that traditionally rely on cuttings from the current crop to use as planting materials for the next crop (Luhan and Sollesta, 2010), as

this farming system is highly vulnerable to increased sea surface temperatures and prolonged hot spells, as well as typhoons and cyclones resulting in total loss of the crop and no material to start the next crop. When Typhoon Haiyan hit the Philippines in 2013, many of the major seaweeds production areas were washed out and had no planting materials to re-start production. Plantlets from tissue culture are currently being field-tested in the different major seaweeds farming areas in the Philippines in collaboration with farmers' associations, local government units and non-government organizations and results indicate better growth performance of crops using plantlets from tissue culture than those that used cuttings from several cropping cycles (Luhan, pers. comm.). Stock improvement programmes similar to the ones undertaken for tilapia and carps in the past and ongoing efforts to develop pathogen-tolerant or pathogen-resistant shrimp as well as saline-tolerant tilapia need to be expanded to include development of stocks with a wider and higher thermal tolerance range and freshwater species that can tolerate saline conditions so that production can continue in traditional culture areas affected by saltwater intrusion/sea level rise. Meanwhile, farming of euryhaline species that can tolerate freshwater, brackishwater and marine culture environments (e.g. sea bass, mullet, milkfish) may be considered.

(b) Quality feeds using alternative ingredients: Aquaculture is the fastest growing food production subsector with the increase in production largely fueled by intensification in production and increasing dependence on feeding of stocks. The rapid growth in the production of fed species has resulted in increased demand for aquafeed which in turn has resulted in increased use of fisheries resources and products for fish meal and fish oils used in aquafeed production. In recognition of this potential threat to the wild fisheries resources and considering the rising cost and possible shortage of fish meal based ingredients, a large proportion of research on feed development for aquaculture has focused on development and use of alternative feed ingredients or fish meal substitutes in aquafeed formulations (Catacutan, Coloso and Acosta, 2015). During the 2011 ASEAN-SEAFDEC Conference on Sustainable Fisheries and Food Security Towards 2020, the ASEAN Ministers and Senior Officials endorsed the Resolution and Plan of Action that enjoins Member States to "improve the efficient use of aquatic feeds by strictly regulating the quality of manufactured feed and feed ingredients, and support continued research for developing alternative protein sources that will reduce the dependence on fish meal and other fish-based products". An ASEAN Regional Technical Consultation on Development and Use of Alternative Dietary Ingredients or Fish Meal Substitutes in Aquaculture Feed Formulation was convened in Nay Pyi Taw, Myanmar in 2014 to assess the availability and use of alternative ingredients in aquafeeds in Member States as well as identify constraints in the wider use of these resources for aquaculture. Although some good practices in the development and use of alternative ingredients in aquaculture feed have been achieved by some Member States, especially those that are among the top aquaculture producers (Thailand, Indonesia, Viet Nam and Philippines), these practices are still in the process of development in other countries in the region. Some of the key constraints identified include: inadequate knowledge of alternative sources of protein to replace fish meal and fish oil in feed formulation as well as the technology needed for processing of some alternative ingredients to improve their quality; supply and traceability of fish meal and feed ingredients (should not be from IUU fishing); lack of regulations and policies (e.g. considering availability and access to land and water resources and use conflict); and lack of cooperation to manage development of aquafeeds. Among the recommendations to address the identified constraints include: continue R&D for the production of aquafeeds with minimal fish meal content; develop/improve formulations using alternative dietary ingredients; develop techniques and create programmes in Member States for mass production of locally-available high quality fish meal and fish oil substitutes and establish a centralized supply and suppliers' network; share information and best practices; assess the production capacity of feed mill plants including the volume of raw materials for feed ingredients needed; establish and apply a traceability system of all raw materials used as feed ingredients; establish national aquafeed quality control policies; establish or designate a focal agency for regional programmes on development and use of alternative dietary ingredients

in aquaculture feed development to work closely with Member States, research institutions, academe, industry and inter-regional organization; create an ASEAN forum or network on development and use of alternative dietary ingredients in aquaculture feed development; formulate national action plans on development and use of alternative dietary ingredients in aquaculture feed formulations; and enhance awareness on the importance of reducing dependence of aquaculture on feed and ingredients of marine animal origin (Catacutan *et al*., 2015). To facilitate information-sharing, a regional database with information on alternative ingredients that have been tested in feed formulations for various cultured species in the region including their proximate composition, inclusion levels, presence of antinutritional factors (if any), processing methods required to improve quality, availability in the region and other pertinent information is being established by SEAFDEC/AQD in collaboration with Member States and with funding from the Government of Japan Trust Fund (GOJ-TF).

(c) Health management in aquaculture: With intensification of aquaculture, climate change and introduction of new species either for culture, as source of broodstock or for the ornamental fish trade, the incidence of disease problems has also increased. The dynamism of aquaculture has also inadvertently led to the transboundary movement and exchange of pathogens. Hence, health management continues to be an active area of research in the field of aquaculture. An important component of disease prevention and control is the development of diagnostic techniques that would allow timely disease diagnosis and identification of the pathogen. In order for diagnostic procedures to be effective tools in health management, these have to be harmonized and farmer-friendly applications should be made available. This would facilitate monitoring and surveillance as well as timely reporting of disease incidence to competent authorities. Research on prevention and control of diseases continues to be actively pursued targeting persistent and emerging diseases. For example, research on prevention and control of white-spot disease (WSD) caused by the white-spot syndrome virus (WSSV) continues to this day and research on the prevention and control of Tilapia Lake Virus (TiLV), the most recent disease reported in tilapia, that has spread through continents is being intensively pursued (Leano and Liang, 2018).

(d) Production systems for increased adaptive capacity and resilience to climate change impacts: aquaculture production systems such as polyculture, aquasilviculture, IMTA, cage culture, recirculating systems, aquaponics, rice-fish farming (RFF), and culture-based fisheries are being promoted to enhance the adaptive capacity and resilience of fish farmers to climate change impacts. These technologies have been developed, tested and adopted in different places, at different scales and using different species or species combinations, hence refinements are necessary for specific sites and the species used. In the case of RFF that combines growing rice and fish in the same production area either at the same time or on a rotation basis and has evolved into a "rice-aquaculture" system where other aquatic species such as freshwater (FW) shrimps/prawns, FW crabs, turtles and other FW aquatic species are grown together with rice in rice paddies using appropriate species or fish stocking densities, the yield can be substantially higher than in traditional RFF (e.g. an average yield of 0.97 tonne/hectare (ha) in intensive rice–carp farming compared to 0.33 tonne/ha in traditional rice–carp combination; 0.39 tonne/ha for rice–crab, 1.44 tonnes/ha for rice–crayfish, 1.10 tonnes/ha for rice–loach, and 2.0 tonnes/ha for rice–turtle) (Hu *et al*., 2016). Furthermore, the rice yield is similar or even better in RFF than in RM systems when the area devoted for fish culture is about 10 percent of the total arable area (Hu *et al*., 2016). RFF maximizes the use of both land and water resources, hence it is appropriate for areas where availability of both water and land resources for food production is limited. It has been practiced in China for centuries and is now practiced by farmers from countries in Asia, Africa, South America and Europe (FAO, 2012). Similar factors – site, species/species combinations, stocking density for each species and others need to be considered in adopting IMTA in a particular farming area. Culture-based fisheries need to consider the resources in the site and the appropriate species that can be introduced e.g. mud crab in mangrove areas or abalone in coral reef areas (Lebata *et al*., 2009). Given these considerations, the provision of technical assistance is

crucial and the important role of extension workers cannot be over-emphasized in the dissemination and subsequent adoption of any technologies.

(e) Institutional capacity development: Successful dissemination and adoption of aquaculture technologies that would help enhance farmers' adaptive capacity and resilience to climate change impacts through institutional capacity development approaches require promotion of the appropriate technology, technology extension through learning-by-doing exercises, the establishment of relevant and appropriate governance support systems, the facilitation of links between farmers and financial institutions and the development of entrepreneurial capacities among farmers. This strategy was adopted in the management of the Panabo City Mariculture Park in Southern Philippines (Ayson, Ventura and de Jesus-Ayson, 2016). SEAFDEC/AQD espouses a similar strategy in implementing projects under its institutional capacity development for sustainable aquaculture (ICDSA) programmes for dissemination of technologies for community-based projects or people's organization's initiatives. Community-based approaches are used for disaster risk management. The Partnership for Disaster Reduction-Southeast Asia (PDR-SEA) was initiated in 2001 to promote community-based disaster risk management in Southeast Asia and implemented in Cambodia, Indonesia, Lao People's Democratic Republic, Philippines, Thailand, Timor-Leste and Viet Nam. A similar project for small-scale shrimp farmers was also implemented in Bangladesh (Islam *et al*, 2018).

Lack or low adoption of an aquaculture insurance system to provide immediate financial assistance to farmers for speedy rehabilitation, resumption of operations and recovery

More than 80 percent of aquaculture farmers in Asia are small-scale farmers and are highly vulnerable to impacts of climate change-related extreme weather events. Aquaculture insurance is being promoted as a risk management or risk-sharing scheme to facilitate recovery from financial losses because of climate change-related impacts and enhance overall resilience of the aquaculture subsector to climate change (Roberts, 2007). Insurance coverage could likewise improve farmers' access to credit that would increase their financial capacity to restart operations in the aftermath of calamities. It encourages the adoption of good aquaculture practices since a requirement set by insurance companies is that the insured farmers take measures to prevent, increase preparedness for, and mitigate disasters. This will reduce the burden on insurance companies for compensation and at the same time will also contribute to sustainable aquaculture development. However, aquaculture insurance is constrained by the high-risk profile of the aquaculture subsector and the cost of providing the service to small-scale farmers. Thus, aquaculture insurance is accessible mostly to large-scale farms. Some countries in the region have started implementing an aquaculture insurance system.

China started implementing an insurance system focused on shrimp aquaculture in the early 1980s (Yuan *et al*, 2017). The programme was however hampered by problems with shrimp diseases. From 2004 to 2012 some local governments started providing premium subsidies to farmers. Coverage was expanded in 2013 as a result of a fiscal subsidy policy, but was constrained by difficulty in matching the farmers' ability to pay a premium given the high risk nature of aquaculture, especially shrimp farming. The China Insurance Regulatory Commission in 2015 defined the legal status of mutual insurance organizations, which guaranteed their legal license to operate. However, mutual insurance lacks the capacity for compensation in cases of catastrophic events hence other schemes have to be considered. Premium subsidies from the central, provincial and local government were also important in encouraging more farmers to avail of aquaculture insurance in as much as awareness of insurance as a risk management measure and farmers' capacity to purchase insurance are still low.

Viet Nam's agricultural insurance is a social policy to assist farmers to overcome and compensate financial losses from natural disasters and diseases. An aquaculture insurance system was piloted in shrimp and pangasius farms in five provinces in the period 2011–2013 with financing from the central and local governments. Different rates of support for premium subsidy were given to farmers. The scheme was not

successful largely because a high loss ratio was incurred by the aquaculture insurance company from failed crops resulting from shrimp disease outbreaks. Although aquaculture insurance covered 2 percent of households, it accounted for 95 percent of total compensation. In spite of the early failure, it was recommended that the aquaculture insurance programme continued but on a voluntary basis. It was also recommended that partial premium support for small-scale farmers should be retained but they should pay for part of the premium themselves to develop their sense of ownership and enhance their responsibility to follow technical guidelines and insurance contract conditions (Nguyen and Phongthannapanich, 2016).

In the case of the Philippines, fisheries and aquaculture insurance is mandated under the Fisheries Code of 1998, which provides for the inclusion of fisheries and aquaculture in agriculture insurance. The Philippine Crop Insurance Corporation (PCIC) is mandated to include provision of insurance coverage to fish pens, fish cages, seaweeds farms and other culture systems and assets. The government provides full premium subsidy for subsistence farmers and fisherfolks listed in the Registry System for Basic Sectors in Agriculture (from 2014). In Thailand, provision of financial support or compensation to farmers affected by disasters or disease outbreak is linked with the farm registration scheme; only registered farms receive financial support or compensation.

The insurance business in India consists of public sector, state-owned enterprises. All general insurance issues in the country, except for life insurance, are handled by the General Insurance Corporation of India (GIC), which is at the same time the overall policymaking body for general insurance. At the field level, insurance coverage is provided by subsidiaries of the GIC. Two insurance schemes were designed in the 1990s to assist the aquaculture subsector: the Brackish Water Shrimp Insurance Scheme and the Inland Fish Insurance Scheme. In 2003, the Agriculture Insurance Company of India Limited (AIC) was established by the Government of India and took over the implementation of the National Agricultural Insurance Scheme (NAIS) (including aquaculture) from GIC. In Bangladesh, the Sadharan Bima Corporation introduced a specific insurance programme for shrimp culture projects called Technology-based Fisheries Insurance (although it does not include insurance coverage for fish culture), along with a livestock and crop insurance programmes. Bangladesh is a disaster-prone country, making both pond culture in inland areas and shrimp culture in the coastal areas rather risky ventures.

In Japan, aquaculture insurance is offered under the Fishery Damage Indemnification System which is both a mutual aid system and an important part of the national government's fishery damage assistance policy. The system was originally designed to rationally insure fisherfolk against damages caused by contingencies, and to spread the risks among them. The government currently provides the following assistance to fisherfolk and aquaculturists: government subsidies for those participating in the Fishery Mutual Insurance Scheme to cover a part of their premium payments (subsidy is available to those whose scale of fishing or aquaculture operations is below a certain level); in case of damages resulting from catastrophic disasters considered to be beyond the coverage of the mutual aid schemes, the government insurance scheme may cover such damages by a retrocession contract with the National Federation of Fishery Mutual Insurance Associations (excluding Fishing Gear Insurance); assistance to fishery mutual insurance institutions by providing subsidies to cover a part of their administration expenses, including the wages of employees needed for managing the scheme; subsidies of up to two-thirds of the premium of special insurance contracts against damages by red tide, which are included in the Aquaculture Insurance Scheme; support in guaranteeing capital to the Credit Fund for Agriculture, Forestry and Fisheries, which extends loans to the fisheries mutual insurance institutions for running their insurance operations in support of the subsector. Aquaculture insurance in Japan is "named perils" insurance. There are two types of aquaculture insurance policies: for partial and total loss by death or escape of the cultured products during the culture cycle; and for damage, losses and sinking of aquaculture facilities while in operation. Insurable damages means that when the insured facility is partially damaged and in cases when the cost of full recovery of the facility is expected to be higher than a half of its insurable value, the total loss is covered by the insurance. Damages that are not covered by the insurance include damages caused by war or similar disturbance; loss by theft; contamination of water because of the discharge or leakage

of sewages, waste fluids and other substances harmful to the cultured products; negligence of the policyholder or by third parties; excessive red tides (excluding those under a special contract for red tides). A specific Aquaculture Insurance Scheme was initiated to cover losses and damages to cultured seaweeds, such as laver, undaria and kelp including financial losses resulting from the sudden declines in market prices for these products.

In general, implementation of aquaculture insurance needs policy and technical support. Cooperation between the insurance company and the government is necessary. In the major aquaculture producer countries in Asia, the aquaculture insurance cover is not limited to finfish species, but also includes molluscs, crustaceans and seaweeds. Most aquaculture insurance companies insure offshore cage culture and onshore culture in ponds, raceway systems and recirculation systems. Most intensive and semi-intensive culture systems will be considered for insurance whereas extensive or improved extensive systems are less likely to be insured, although some improved–extensive pond production is insured, but only in Viet Nam. Hatchery and nursery production are only insured on a very limited scale. Not many insurance companies are eager to step into shrimp hatchery production insurance. Offshore submersible and semi-submersible cages are considered culture systems that might be covered in the near future. Aquaculture insurance policies in force are "named perils", which means that the policies cover only for the risks named in the policy documents. Named perils commonly included in standard policies:

For onshore systems:

- pollution from external sources;
- aircraft and other aerial devices or articles dropped from the sky;
- malicious acts;
- predation;
- floods, inundations and tidal waves;
- storm damage (including hurricanes, cyclones and typhoons);
- landslides, earthquakes and volcanic eruptions;
- structural failures (e.g. of dykes), breakage or blockage of any part of the water supply system;
- drought, fire, lightning, explosion;
- freezing, frost damage, frazil ice;
- mechanical breakdown or accidental damage to machinery and other installations;
- electrical breakdown, failure or interruption of the electricity supply, and electrocution; and
- de-oxygenation and other changes in the concentration of the normal chemical constituents of the water that cause damage.

For offshore systems:

- pollution from external sources;
- aircraft and other aerial devices or articles dropped from the sky;
- malicious acts;
- predation or physical damage by predators or other aquatic organisms (excluding by sea lice or other ectoparasites);
- storm, lightning, tidal waves and collision;
- sudden and unforeseen structural failure of equipment;
- freezing, super-cooling, ice damage;
- de-oxygenation as a result of competing biological activity or changes in the physical or chemical conditions of the water, including upwelling and high water temperatures; and
- other changes in the concentration of the normal chemical constituents of the water, including pH or salinity.

Insurance policies with additional cover for diseases (e.g. shell disease, vibriosis, parasitic diseases) and for damage caused by red tides can often be arranged. Theft, riots, strike, war and similar disturbances are generally not covered, nor is damage caused by negligence of the policyholder.

The lack of adoption of aquaculture insurance notwithstanding, there is a general sentiment regarding the lack of financing for climate change adaptation and mitigation. There is little investment in climate change adaptation especially in remote areas where the rural economy does not have a high value. Some countries have already established national climate change funds. It would be advantageous if a similar strategy is adopted as in disaster risk reduction and management wherein local government units are provided disaster risk reduction and management allocations to fund their programmes, including establishment of protective structures, procurement of equipment as well as for financial assistance/relief for those affected by calamities.

Furthermore, there are a number of multilateral and bilateral funding mechanisms for financing of initiatives that address climate change issues (Table 14). The projects focus on mitigation, adaptation or disaster risk reduction and recovery. Priority sectors for mitigation include renewable energy, clean, energy efficiency, reduction of greenhouse gas emissions, sustainable transportation system, management of land use/land use change forestry, low carbon development, REDD, enhancing participation in mitigation efforts such as CDM as well as access to carbon markets, infrastructure and urban development. Priority sectors for climate change adaptation include food security, agriculture, water resources management, coastal resources management, forestry, management of fragile ecosystems, biodiversity conservation, public health and education. Priority projects for disaster risk reduction and recovery include risk management, climate information and early-warning systems, infrastructure. The Asia-Pacific Disaster Response Fund prioritizes the restoration of life-saving services after a disaster. Most funding programmes give priority to human/community capacity building and institutional strengthening programmes. The ADB Climate Change Fund (although currently inactive) funds projects related to the development of climate change-related knowledge products and services and knowledge management activities including regional conferences and workshops.

Table 14. Examples of fund sources for climate change-related initiatives

	Focus	Fund type	Eligibility	Type of support
Adaptation Fund	Adaptation	Multilateral	All developing countries that are parties to the Kyoto Protocol	Grants
Least Developed Countries Fund (LDCF)	Adaptation	Multilateral	All Least Developed Countries	Grants
Special Climate Change Fund (SCCF)	Adaptation, mitigation	Multilateral	All developing countries that are parties to the UNFCCC	Grants
CIF Strategic Climate Fund: Pilot Programme for Climate Resilience (PPCR)	Adaptation	Multilateral	Countries that are eligible for ODA according to OECD with active in-country multilateral development bank programme; priority is given to vulnerable Least Developed Countries	Co-funding, concessional loans grants, ODA, technical assistance
Global Climate Change Alliance (GCCA)	Adaptation, mitigation, REDD^{+}	Multilateral	Least Developed Countries and Small Island States that are recipients of ODA	Grants, technical assistance
Nordic Development Fund (NDF)	Adaptation, mitigation	Multilateral	27 low income and lower middle income countries in Africa, Asia and Latin America. Eligible countries in Asia include Bangladesh, Cambodia, Kyrgyzstan, the Lao People's Democratic Republic, Maldives, Mongolia, Nepal, Pakistan, Sri Lanka, Viet Nam	Grants

Table 14. *(continued)*

	Focus	Fund type	Eligibility	Type of support
Nordic Climate Facility (NCF)	Adaptation, mitigation	Multilateral	21 low income countries in Africa, Asia and Latin America. Eligible countries in Asia include Bangladesh, Cambodia, Lao People's Democratic Republic, Nepal, Sri Lanka, Viet Nam	Grants
International Climate Initiative (ICI)	Adaptation, mitigation, biodiversity, REDD+	Bilateral	Broad eligibility including developing, newly-industrializing and transitioning countries	Concessional loans, grants
International Climate Fund (ICF)	Adaptation, mitigation, REDD+	Bilateral	Broad eligibility; funding for adaptation is for poor and vulnerable countries including Least Developed Countries, Small Island States and Africa; funding for mitigation may include some middle income countries	Grants
Green Climate Fund (GCF)	Adaptation, mitigation	Multilateral	All developing countries that are parties to the UNFCCC	Concessional loans, grants
GEF Trust Fund	Largely mitigation	Multilateral	Developing countries that are parties to the UNFCCC	Grants
ADB Climate Change Fund	*inactive since 2012	Multilateral	ADB Developing Member countries	Grants, loans, ODA
Global Facility for Disaster Reduction and Recovery	Disasters	Multilateral	Pacific Island Countries	Grants, technical assistance, co-Financing
CIF Strategic Climate Fund: Forest Investment Programme	Mitigation	Multilateral	Developing countries but piloted in only a few countries in Africa, South America and Asia	Grants, concessional loans, guarantees, equity
CIF SCF: Scaling up Renewable Energy Projects	Mitigation	Multilateral	Low income countries	Grants, concessional financing
CIF Clean Technology Fund	Mitigation	Multilateral	Low income countries	Grants, concessional loans, guarantees
World Bank Catastrophic Risk Management	Disaster recovery	Multilateral	All Pacific Islands Countries except Nauru and Niue	Risk management, co-Financing
Asia Pacific Disaster Response Fund (APDRF)	Disaster recovery	Multilateral	All ADB Developing Member Countries	Grants
Forest Carbon Partnership Facility	Mitigation	Multilateral	Developing countries in the tropics and subtropics	Grants
UNREDD Programme	Mitigation	Multilateral	Developing countries	Grants

Table 14. *(continued)*

	Focus	Fund type	Eligibility	Type of support
IFAD Adaptation for Smallholder Agricultural Farmers	Adaptation	Multilateral	Smallholder farmers in developing countries	Grants (co-financing IFAD loans and grants)
Global Energy Efficiency and Renewable Energy Programme	Mitigation	Multilateral	Projects in developing markets that qualify for ODA. Priority is given to projects in countries with appropriate policies and regulatory frameworks on energy efficiency and renewable energy	Private equity, grants, technical assistance
OPEC Fund for International Development	Adaptation, mitigation	Multilateral	Developing countries (OPEC members)	Public sector loans, direct support to private enterprise, trade financing, grants
Asian Development Fund	Adaptation, mitigation	Multilateral	Developing countries that are members of ADB	Grants, loans
ADB Canadian Climate Fund for Private Sector	Adaptation, mitigation	Multilateral	Eligible ADB Developing Member Countries	Grants, concessional loans
International Climate Initiative (Germany)	Adaptation, mitigation	Bilateral	All countries	Grants, loans, ODA
International Climate Fund (UK)	Adaptation, mitigation	Bilateral	Poor and vulnerable countries including Least Developed Countries, Small Island Developing States and Africa	Grants, loans, ODA, loan guarantees
BMZ/GIZ (Germany)	Adaptation, mitigation	Bilateral	All countries but currently operational only in Timor-Leste	Grants, loans, technical assistance
Australian Department of Foreign Affairs and Trade	Adaptation, mitigation	Bilateral	Developing Countries	Grants
KfW Development and Climate Finance (Germany)	Adaptation, mitigation	Bilateral	All countries	Grants, loans, ODA, structural financing
Climate and Development Knowledge Network (CDKN)	Adaptation, mitigation	Bilateral	All countries	Co-financing, grants, technical assistance
Japan International Cooperation Agency	Adaptation	Bilateral	Least Developed Countries and Small Island Developing States	Loans, grants, technical assistance
Agence Française de Développement	Adaptation	Bilateral	Pilot in Fiji, Vanuatu, New Caledonia and French Polynesia	Grants, loans, technical assistance

Table 14. *(continued)*

	Focus	Fund type	Eligibility	Type of support
USAID	Adaptation	Bilateral	Pacific Island Countries	Grants, technical assistance
New Zealand Ministry of Foreign Affairs and Trade	Sustainable development	Bilateral	Strong focus on Pacific Island Countries	Grants, technical assistance
Norway International Climate Forest Initiative	Mitigation	Bilateral	Developing countries	Primarily grants
Australia International Forest Carbon Initiative	Mitigation	Bilateral	Developing countries	Grants
Abu Dhabi Fund for Development	Mitigation, adaptation	Bilateral	Developing countries	Grants, loans, investments

Source: Pacific Forum Secretariat and Secretariat of the Pacific Regional Environment Program, 2015)

Recommendations on regional strategies and actions to support the national efforts to build climate-resilient aquaculture

The impacts of climate change in the Asia-Pacific region will affect food security not only in the region, but globally. Even without climate change, competition for land and water resources is already high in many countries in region. Climate change will intensify the struggle for these resources, exacerbating the challenges for management and increasing the risk of resource use-related conflicts. All countries in the region will be hotter and drier, increasing the likelihood of droughts. Moreover, rainfall will tend to be heavier during the rainy season, increasing the frequency of floods. The region will also be exposed to increasing frequency of extreme weather events of increasing intensity. Bangladesh, China, India, Indonesia and Viet Nam will be the countries most affected by sea level rise and seawater intrusion. Given the limited understanding of the nature and extent of the impact of climate change on agriculture in general and aquaculture in particular, planning for appropriate mitigation and adaptation measures will be done with a measure of uncertainty. Table 8 shows that the recommendations from the 2017 workshop mirror the recommendations of a similar workshop in 2011.

Mainstreaming climate change issues in policies related to agriculture, including aquaculture, is important but will not be enough in order to adapt or build resilience to climate change impacts. Innovations for enhanced adaptive capacity would include improvement of farming practices, efficient use of land and water resources, diversification of crops, continued R&D and technological development, establishment of advisory/information and warning systems, risk management and crop insurance. Developing countries usually underinvest in science, technology and innovation. However, selective breeding for stocks with increased tolerance to stressors related to climate change (heat, drought, salinity, diseases/pathogens) will be essential. Cooperation among governments in the region will be necessary in order to ensure effective implementation of adaptation and mitigation strategies as well as to explore financial resources to address climate change issues. Regional cooperation can enhance adaptation to climate change impacts. Climate action plans including NAPA need to be integrated into national development plans. Concerted action at all levels (national, provincial and local) is needed in order to realize adaptation and resilience to climate change impacts, hence the need for the involvement and capacity development of all stakeholders, especially government officials and the community. Adaptation and mitigation strategies should also be incorporated in ongoing climate change negotiations to ensure creation of appropriate incentive mechanisms (ADB, 2009).

Table 15. Recommendations from the 2011 and 2017 workshop on building resilience of the aquaculture subsector to the impacts of climate change

Recommendations from the 2011 workshop	Recommendations from the 2017 workshop
Advocate for increased policy emphasis and financial resourcing for climate change adaptation and mitigation in the subsector Strengthen governance and integrate climate change adaptation in decision making Improving monitoring, tracking and assessment Strengthen management of fisheries and aquaculture to improve adaptation and resilience to climate change Involve communities and local institutions in climate change adaptation as this is critical for success Recognize the different gender-related impacts of climate change Develop accessible information for decision makers (in other sectors) Building capacity Conduct targeted research and development, knowledge development Take note of recommendations for regional organizations to support member countries Take note of specific recommendations for FAO, APFIC and regional organizations to support improved integration of the subsector in climate change planning	Provide a regional platform for increasing the knowledge base and information-sharing on climate change events, impacts, mitigation and adaptation strategies in order to build resilience for aquaculture through capacity building programmes (regional training, workshops, study tours/field visits/exchange programmes), active dissemination, promotion and adoption of innovative adaptive technologies and practices that contribute to a climate change-resilient aquaculture subsector Develop an early-warning system for climate change or weather-related events and impacts (e.g. disease outbreaks, harmful algal blooms, upwelling, etc.) at the local, national and if possible, regional level Promote regional research cooperation programmes or research networks focused on climate change R&D, as well as foster collaboration among research institutions, industry and communities to jointly address the impacts of climate change Integrate climate change issues (impacts, risks, threats, vulnerability, adaptation and mitigation) in national fisheries and aquaculture policies, strategies and programmes, as well as in regional frameworks including allocation funds (e.g. under the Green Climate Fund and programmes dealing with global commons) Promote the use of EAA restoration in coastal areas (particularly mangroves)

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Extended summaries of country/regional partner/project/private sector presentations: Fisheries[12]

Bangladesh

Shah Md. Enamul Hoque

Introduction

Bangladesh is one of the largest deltas in the world and is located at the confluence of three large river systems: the Ganges, the Brahmaputra and the Meghna. The country has a land area of 147 570 sq. km and a population of 163 million.[13] The country is highly vulnerable to natural disasters because of its geographic location, its flat and low-lying landscape and its high population density (more than 1 100 persons per sq. km). The economy of Bangladesh is mostly agriculture driven. As a sector of agriculture, fisheries plays a substantial role in the socio-economic development of the country through ensuring food security, alleviating poverty and earning highly precious foreign currency. According to DoF, the fisheries sector provides 60 percent of the daily animal protein intake by the nation, creates direct or indirect employments for almost 11 percent of the total population, and contributes 3.65 percent to GDP and 24.41 percent to agricultural production. Also, the export of fish and fish products accounts for 1.87 percent of the country's total export earnings. Despite remarkable progress in fish production, the sector has frequently encountered adverse climate effects because of global warming in recent years. Therefore, Bangladesh needs to frame policies and institutional arrangements to build climate-resilient fisheries and aquaculture to adapt its fisheries production to changing climatic conditions. This paper highlights the current trend of fisheries production systems, the impacts of climate change on the fisheries sector, and also focuses on the national strategies to support climate resiliency in the fisheries sector.

Fisheries production systems

Bangladesh has been blessed with diversified fisheries resources. The country's fisheries production systems can be categorized into: inland capture, inland culture and marine capture.

A total of 57 transboundary rivers and their tributaries, as well as estuaries, the Sundarbans mangrove forst (one of the largest in the world), beels, Captai lake and seasonally flooded wetlands comprise 3.9 million hectares of inland open waters, which are enriched with 260 fish species and 24 species of freshwater prawns. Total capture from inland fisheries in 2015-2016 was 1.05 million tonnes.

To the south of the country is an enormous area of marine waters that abound with 475 species of fishes, 36 species of shrimp and other exploitable fisheries resources. Marine capture from trawl and artisanal fishing was 0.63 million tonnes in 2015-2016.

Climatic impacts on fisheries sector

Climate change is a change in the statistical distribution of weather patterns when that change lasts for an extended period of time (Wikipedia).[14] Emission of greenhouse gas (GHG) is primary responsible for causing global warming and climatic impacts. Bangladesh emits only 0.3 percent of the emissions producing climate changes but is one of the worst victims of climate change in the world. Major consequences of global warming as well as climate change that Bangladesh experiences are:

[12] The full text of the original presentations may be available from the authors.
[13] https://data.worldbank.org/indicator/SP.POP.TOTL
[14] https://en.wikipedia.org/wiki/Climate_change_in_Bangladesh

(a) Flash floods: almost 80 percent of total land is prone to flooding.
(b) Cyclones and storm surges: south and southeastern parts of the country were frequently hit by tropical cyclones during the past few years.
(c) Salinity intrusions: the whole coastal belt along the Bay of Bengal is facing salinity problems.
(d) Extreme temperature and drought: north and northwestern parts of the country are suffering from extreme temperature and drought conditions.
(e) Sea-level rise: according to the Intergovernmental Panel on Climate Change (IPCC) findings, a 45 cm sea level rise will inundate almost 10.9 percent of territory of Bangladesh and will displace 5.5 million people living in coastal regions.

Those impacts of climate change have adverse effects in fisheries resources of Bangladesh. The major risks are as follows:

(a) Effects on inland fisheries: drought and siltation in the dry season reduces river flow and also causes isolation of open waters from main channels. These changes in water dynamics of inland waters hamper growth, breeding and migration of fishes, thus causing fish kills and loss of aquatic biodiversity. Also, rapid fluctuations in temperature, intensity, time and volume of rainfall etc. cause changes in physico-chemical and biological qualities of inland waters and thereby hamper gonadal development and reproduction and reduce spatial abundance and production of fishes. Moreover, reduction in surface waters because of evapotranspiration and extreme temperature causes conflicts between fisheries and agriculture over surface waters.

(b) Effects on coastal fisheries: the main impact of climate change on coastal areas in Bangladesh are sea level rise, reduction of freshwater availability by salinity intrusion and increasing cyclone frequency. The salinity intrusion, as well as the sea level rising, creates harmful effects on the existing fish stock. Salinity intrusion threatens brackishwater fish production. Frequent and intense cyclones resulting from global warming can cause a temporary decline in the abundance of some fishes because of the loss of critical habitats of certain species or their sources of food. Cyclones Sidr and Aila, for example, affected the coastal fishery and fishing grounds.

National efforts in addressing climate change and building climate resilience in fisheries

Bangladesh has established the Bangladesh Climate Change Trust Fund (BCCTF) and the Bangladesh Climate Change Resilient Fund (BCCRF) to address the challenges emerging from climate changes. There also exists plans such as the National Action Programme on Adaptation (NAPA) of 2005 and the Bangladesh Climate Change Strategy and Action Plan (BCCSAP) of 2009.

The Ministry of Fisheries and Livestock, Bangladesh has made some efforts to integrate capacity building and adaptation policies to build climate-resilient fisheries and aquaculture. The key approaches are: (i) formulation and implementation of a strategic plan to enhance natural breeding and conserve biodiversity in inland fisheries; (ii) rehabilitation of aquatic habitats for enhancing water flow and retention capacity; (iii) establishment and management of fish sanctuaries to support biodiversity; (iv) fish stocking and establishment of a beel nursery to enhance natural stock; (v) training and expansion of adaptive culture in open water systems, viz. community-based floodplain aquaculture, cage culture, pen culture etc.; (vi) inclusion of vulnerable fishers' communities in the social safety networks to achieve enforcement measures; (vii) determining a strategy for conserving coastal fisheries resources; (viii) campaign to create awareness regarding impacts/risks of climate change in fisheries; (ix) programme to increase adaptation and management skills among affected communities in response to climate change effects; (x) all development plans include CC resilient fisheries; (xi) strengthen inter-ministerial cooperation and collaboration to address CC issues; and (xii) HRD to increase institutional capacity to handle CC related issues.

Constraints in building climate resilient fisheries

Greater climate variability and uncertainty complicate the task of adaptating to the impacts of climate change on fisheries. Information on impacts of climate change on fisheries is limited. Moreover, there remain knowledge gaps that hinder efforts to find innovative means to improve the existing adaptability of fishers and aquaculturists. More importantly, the government lacks adequate resources and funds to support national programmes pertaining to climate-resilient fisheries.

Recommendations

The impacts of climate change on the fisheries sector is long-lasting. The unfolding calamity that Bangladesh is encountering from climate change demands a response and cooperation from the international community to support the national efforts of the Government of Bangladesh such as:

- integrating CC issues (impacts, risk, vulnerability, adaptation and mitigation) in fisheries policy, strategy and programmes;
- improving knowledge generation, technology, scientific research, R&D and information dissemination structure;
- improving capacity for planning and implementation of adaptive and mitigation projects in fisheries and aquaculture systems;
- developing and implementing adaptation and mitigation programmes with the vulnerable fishers communities living in climate hotspots;
- accessing international funding and technology supports under the UNFCCC and multilateral funding mechanisms; and
- increasing investment in research and actions on climate resilient and sustainable fisheries and food security

Cambodia

Tob Chann Aun

Since ancient times, rice and fish have been integral staple foods in the daily diet of the Cambodian people. Because Cambodia's geography is dominated by the Mekong River, which is more than 500 kilometres in length, with the Tonle Sap (Great Lake) as its heart, the country is rich in natural resources of all kinds, especially fisheries. Cambodia's fisheries play a very important role in contributing to employment opportunities to about 6 million people (total Cambodian population 15 million) working full time and part time in fisheries and fisheries-related activities, providing people's livelihoods, national food security and adding approximately USD 1.5 billion per year to the economy, corresponding to about 12.9 percent of total gross domestic product (GDP).

Today, about 500 inland fish species and 520 marine fish species are known in Cambodia, and the total annual freshwater and marine capture fisheries production is estimated at about 700 000 tonnes to 800 000 tonnes, of which the annual yield of inland fish amounts to 50 000 tonnes to 6 000 000 tonnes, ranking fourth worldwide in inland fish production after China, India and Bangladesh. The annual marine capture fish production is estimated at 100 000 tonnes to 150 000 tonnes, and the annual aquaculture production adds some 90 000 tonnes to 100 000 tonnes. Cambodian annual fish consumption is 63 kg/person and fish provides 81.5 percent of Cambodian people's animal protein intake. At present, multiple factors, including population growth, climate change, overfishing etc. are likely to have potential impacts on fisheries resources. Recently, the Royal Government of Cambodia reformed the fisheries subsector by abolishing all fishing lots and transferring the management to communities to conserve and use in a sustainable manner to contribute to poverty reduction.

Since the fisheries policy reform from 2000 to 2015 was adopted 15 years ago, the Fisheries Administration has worked tirelessly on the in-depth implementation of the policy reforms to achieve success, including aquaculture development, fishery management and community fisheries development, conservation of fishery resources, improving fisheries conservation and protected areas, protection of flooded and mangrove forests, development of community fish refuges, processing and quality control of fishery products, planning, and research and extension services.

The vision for the fisheries sector emphasizes the management, conservation and sustainable use of fisheries resources aimed at ensuring people's food security and socio-economic development in order to enhance people's livelihoods and the nation's prosperity.

Mission of the fisheries sector

- conservation of fishery resources and biodiversity to contribute to ensuring food security to improve living conditions of people and to enhance socio-economic development;
- sustainable utilization and management of the fishery resources;
- aquaculture development to contribute to food security and poverty alleviation;
- quality and safety assurance of fish and fishery products; and
- development and management of post-harvest technologies in fisheries.

Mandate of fisheries sector

- administration tasks such as administrative management, organizing all fishery activities, and community fishery development;
- technical tasks such as scientific research, conservation, development of the fisheries economy and technology, and technology relevant to fisheries, along with the promotion of aquaculture; and
- law enforcement such as inspection, monitoring, control and surveillance of all fishery activities.

For Cambodia, the Rectangular Strategy (RS) phase III (2014–2018) sets out the priorities of the current government for growth, employment, equity and efficiency, which are further elaborated in the National Strategic Development Plan (NSDP) 2014–2018. The NSDP is the policy document to which all sector policies and plans are aligned. The Strategic Planning Framework for Fisheries (SPF), the public policy of the fisheries subsector, was consequently updated after the adoption of the NSDP for the period 2015–2024.

The Royal Government of Cambodia allows the operation of dai net fishing, which uses a type of bag net and catches an abundance of small fish migrating down river from the Tonle Sap, for processing into fish paste and fermented fish to supply the remote rural people from various provinces. During the last 15 years, the total fish production has been increasing and the inland fish production has been higher than marine fish catches, but the trend of capture fisheries has only slightly changed as compared to the continued increase in the development of aquaculture. Per capita, the average Cambodian fish consumption is 63 kg/year, of which inland fish comprises 44.2 kg, marine fish 17.3 kg, and aquaculture 1.3 kg, which provides 81.5 percent of animal protein intake. Cambodians' consumption of fish paste is 5.2 kg/year, fermented fish 4.8 kg/year, smoked fish 8.3 kg/year, salt-dried fish 9.3 kg/year, and fish sauce 4.5 litres/year.

Cambodian people are currently aware of the declining resources and have changed their attitude from depending on natural fish to engaging in fish culture. Thus fish culture activities have increased remarkably, as have the quantity of fingerlings produced, the number of hatcheries, and the number of community fish refuges being established from year to year.

A community fish refuge (CFR) is a type of protection or conservation area generally established in a rice paddy field flooded during the wet season and far away from natural waterbodies that hold water all year round. CFRs are important for providing a huge contribution to increased fisheries resources and rice field

fisheries production. To date, 820 CFRs have been established, with the aim of creating 1 CFR for every commune throughout the country.

Recently, it has been reported that there were 63 000 households participating in aquaculture activities and trained by FiA, among which 154 persons are model fish farmers and local aquaculture extensions.

Fish species cultured so far are sea bass, grouper, blood cockle, silver barb, pangasius, climbing perch, walking catfish, giant gorami, tilapia, silver carp, freshwater eel, and freshwater prawn. The current production of aquaculture is now up to 90 000 tonnes (or 12 percent of the total fish production), of which 90 percent is from inland aquaculture and 10 percent from mariculture.

The Royal Government of Cambodia considers aquaculture to be one of the most important fish replenishment strategies for daily food consumption in Cambodia. In particular, for the smallholder aquaculture farmer as it is a low cost input farming strategy, and to help mitigate the predicted adverse impacts of global climate change.

Donor coordination

With a budget of EUR 10.3 million (70 percent from the European Union (EU)), the fisheries component of the EU-funded programme Promotion of Inclusive and Sustainable Growth in the Agricultural Sector: Fisheries and Livestock, which ends in June 2018 and is implemented through programme estimates and grants under indirect management, has contributed, among others, to actions aiming at improving surveillance, strengthening community fisheries, supporting the dialogue with the Directorate-General for Maritime Affairs and Fisheries of the European Commission on the fight against illegal, unreported and unregistered fishing, developing official controls on quality of fish and fishery products, improving skills and monitoring and evaluation capacities. It will also coordinate with important EU initiatives in the sector or in relation to the sector:

- Cambodia Programme for Sustainable and Inclusive Growth in the Fisheries Sector: Aquaculture component (CaPFish Aquaculture) managed by Agence Française de Développement and to be implemented over the period 2018–2023, with a total cost of EUR 31 million, including provision of credit lines to the financial sector;
- a EUR 5 million contribution to Mekong River Commission (MRC)'s basket fund, to support the implementation of MRC Strategic Plan 2016–2020 and enhanced cooperation in the Lower Mekong Basin; and
- a possible contribution from the Asia Investment Facility (currently under instruction) to support investment from AFD in the irrigation sector, which in its current design would include a specific component to strengthen the Ministry of Water Resources and Meteorology's capacities to implement integrated water resources management (IWRM) approaches in Cambodia.

Beside the EU, the main sources of overseas development aid to the capture fisheries sector aim at strengthening community management capacities in the northeastern region of Cambodia and include:

- the World Bank-funded Mekong Integrated Water Resources Management Project, phase III, 2016–2021 (USD 16.5 million), through its Fisheries and Aquatic Resources Management in Northern Cambodia component, which intends to support 70 community fisheries and the livelihood diversification of their members, and its Water Resources Management component, which aims at supporting transboundary water resources monitoring and management in the Sekong-Sesan-Srepok sub-basin, in northeastern Cambodia;
- the Cambodian component of the KfW-funded Lower Mekong Basin Wetland Management and Conservation Project, 2016–2020 (EUR 4 million), which will focus on wetland protection in Cambodian Ramsar sites (Boeung Tonle Chmar, Stung Treng) and provide livelihood support to neighbouring communities;

- the Partners programme to support forestry and fisheries communities in northeastern Cambodia, 2017–2020 (USD 6.1 million, of which 49 percent is funded by the Swiss Agency for Development and Cooperation).
- the USAID-funded Feed the Future Cambodia Rice Field Fisheries Project, phase II, 2016–2021, implemented by WorldFish, focuses on improving the productivity and availability of rice field fisheries, with the intention to scale the results of the first phase to 100 to 120 new community fish refuges (CFR) locations. The FAO and United Nations Industrial Development Organization have also provided intermittent support to the sector, pending the availability of funding. In addition, there are numerous international and local NGOs that contribute to the development of the sector, with a focus on conservation, community management and livelihoods.

China

Xiujuan Shan

The fish capture industry is an important part of the overall fishing industry in China, and has greatly developed since the reform and opening-up of the traditional fishing industry. The fish capture industry now plays a major role in ensuring food safety, moving toward an "ecological civilization", promoting sustainable socio-economic development, and safeguarding the country's maritime rights. The marine capture industry is an important part of the fish capture industry in China, with the largest production, the highest output value, the most fishing vessels, and the largest fishing labour force of the overall fish capture industry. For example, in 2016, the capture production was 17.59 million tonnes, made up of the freshwater capture production 2.32 million tonnes and the marine capture production 15.27 million tonnes. Marine fisheries (including mariculture) comprised about 16 percent of direct ocean GDP in China.

At present, the effects of climate change on fisheries have been assessed by analyzing data concerning the relationships between environmental factors and fishery species and further confirmed by the impact of climate change-related hazards on fisheries. The research results mainly focused on various economic fishery species, for example small yellow croaker, largehead hairtail and so on. Long-term changes in the dynamics of Pacific herring in the Yellow Sea for several hundred years have been analyzed by looking at the correlation between the marine hydrological conditions and periodic variations in herring numbers. In addition, ENSO and La Niña events also greatly affected the biomass of fish species. In recent years, a computer model was used to predict the redistribution of fishery species, habitat changes and fishing grounds migration in China coastal waters under various climate change scenarios.

Several projects on sustainable utilization of capture fisheries have been launched in China, some of them already completed: coastal ecosystem succession under climate change (2010–2014); sustainable utilization and adaptive management in China coastal waters under multi-stressors (2011–2015); and the key process and ecological effects of jellyfish bloom in China coastal waters (2011–2015). Some projects are ongoing: regulating environmental changes that influence the recruitment process of fishery stocks and their effects on fishery resources in China's coastal waters (2015–2019); and vulnerability and sensitivity of coastal ecosystems under climate change (2017–2021). In addition, there is a national plan for scientific and technological innovation related to climate change during the Thirteenth five-year plan period in China issued by the Ministry of Science and Technology, Ministry of Environmental Protection and China Meteorological Administration in 2017. In the Fourth National Assessment Report on Climate Change in China launched in 2017, the assessment report involved three parts: 1) the history and future trends of climate change; 2) the effects of climate change; 3) actions to address climate change. The effects of climate change on fisheries were also addressed in the Report.

To respond proactively to the affects of climate change on fisheries, the important thing is to adopt a scientific perspective on fisheries. The following matters are of prime importance: (1) studying fish species distribution, population dynamics, food webs, and habitat changes in the coastal waters, particularly for

rare and endangered species; (2) improving marine biodiversity and marine habitats through the establishment of marine protected areas and the formation of regional and international marine protected area networks; (3) improving fisheries monitoring, reduction of fishing intensity, the construction of the deep processing industry of aquatic products and marine infant industry, and promotion of job-transfer capacities and opportunities for fishers; (4) enhancing fishery resource conservation, with the promotion of studies on ecological stock enhancement programmes, artificial reefs, and sea ranching practices, the building of a sea ranching zone with the conservation of living resources and rational marine capture. (Since the "Action outline for conservation of aquatic resources in China" was issued in 2006, a total of 300 billion individuals have been released, incurring a cost of RMB 8 billion. In addition, 492 National Aquatic Germplasm Reserves have been established in China, as well as 23 Aquatic Conservation Areas. At present, 42 national level sea ranching zones have been established, and the number will reach 120 in the future); (5) creating a "fish releasing festival" to enhance societal awareness of fishery resources and environment protection; and (6) relieving the fishing intensity by reducing the number of fishing vessels – a total of 35 thousand fishing vessels (1.8 million kW) was taken out of the fishing industry during the twelfth five-year plan period, and 20 thousand fishing vessels (1.5 million kW) will be the subject of a buy-back programme in 2020.

India

A. Antony Xavier

Climate change is one of the most important global environmental challenges of the twenty-first century. India has reasons to be concerned about climate change as nearly 700 million rural people (57.85 percent of the total population) directly depend on climate-sensitive sectors (agriculture, forests and fisheries) and natural resources (such as freshwater, mangroves, coastal zones, grasslands and biodiversity) for their subsistence and livelihoods. The impacts are already being felt in India. During the period 2014-2015 the food production in the country declined to a four-year low of 251.12 million tonnes because of droughts, flood, hailstorms and unseasonal rains. The impacts of climate change on Indian fisheries were evident through scientific studies carried out by leading national institutes. Habitat change was induced because of variability in climatic as well as oceanographic parameters. A rise in sea surface temperature was observed (0.5ºC–1.3ºC) along India's coasts as well as precipitation changes and changes in wind patterns. These climatic parameters impacted the fisheries sector of the nation creating challenges to food and nutritional security. Changes in phenology and trophodynamics of fish species were also revealed by research. The spawning season shift, changes in maturity, mean length reduction and distributional shift of fish species were identified, all of which have implications for stock availability, catch, livelihoods and the national economy. Technologies to adapt to climate change are to be developed and demonstrated directly to fishers communities. Integrated farming methods need to be popularized across the nation with support from the government. A large number of fisher communities and other stakeholders are to be empowered to cope with climate change through training, workshops, awareness programmes, etc.

1. Specific threats/risks of CC and CC-related extreme meteorological events to fisheries

Sea level rise (SLR)

A mean sea level rise (SLR) of 15 cm–38 cm is projected along India's coast by the middle of the twenty-first century and of 49 cm–59 cm by 2100. Sea level rise estimates for the Indian coast are between 1.06 mm and 1.75 mm per year, with a regional average of 1.29 mm per year, when corrected for GIA using model data. These estimates are consistent with the 1 mm to 2 mm per year global sea level rise estimates reported by the IPCC.

Increase in intensity of tropical storms

Projected increase in intensity of tropical cyclones poses a threat to the heavily populated coastal zones in the country. Increase in tropical cyclones is authenticated by the recent cyclones such as Nisha (2008), Neelam (2012), Nada (2016), Vardah (2016) and associated torrential rains in Mumbai, Chennai and other coastal areas of India during 2015 and 2017 that resulted in huge damage to fishing assets and livelihood losses to fishers.

Sea surface temperature (SST) increase

The variation of sea surface temperature (SST) of Indian seas during the 40 years from 1976 to 2015 revealed that SST increased by 0.602°C along the coast of northeast India (NEI), by 0.597°C along along the coast of northwest India (NWI), by 0.690°C along along the coast of southeast India (SEI) and by 0.819°C along along the coast of southwest India (SWI). However, the rate of change in SST was highest in northwest India (0.0156°C/annum) followed by southwest India (0.0132°C/annum), southeast India (0.005°C/annum) and northeast India (0.001°C/annum) respectively. The rate of change in SST over Indian seas revealed that the west coast has been more impacted than the east coast of India. The northern Indian Ocean has been identified as one of the 17 climate change hotspots among the world's oceans. These areas will warm faster than 90 percent of the world oceans.

Ocean acidification

Studies indicate an increasing trend in the annual number of instances when the pH of surface waters off Kochi, Kerala was less than 6. Analysis of the instances of low pH values of surface waters in three depth zones *viz*., 10 m, 20 m and 30 m during the period 2005 to 2012 has indicated that in the year 2012, the pH of surface water at 10 m depth zone was low for a considerably longer period than in the previous years.

Coral bleaching

On the Saurashtra coast in Gujarat, studies carried out on the distribution and community structure of Zoanthids indicated higher adaptive capacity to changes in environmental and abiotic conditions in comparison to their counterparts.

Impact on fish stock

A metabolic increase of 10 percent corresponds to a 1°C increase in temperature, implying that a temperature increase of as little as 1°C in seawater could affect the distribution and life processes of fish. Shifts in spawning periods of fishes have already been observed in a number of commercially important fish stocks, such as threadfin bream. Changes in distribution patterns of two key species in Indian fisheries have already been established – migration patterns of the Indian oil sardine and Indian mackerel have changed greatly over the past 50 years shifting from the Kerala coast to Tamil Nadu.

Impact on fish stock availability

Until the mid-1980s, the restricted distribution of oil sardine ensured that the entire catch of oil sardine was obtained from the southwestern coast of India. North of 14°N, little to no oil sardine was caught previously. In the last two decades, however, the oil sardine catch from 14°N to 20°N has gradually and consistently increased, contributing 15 percent to the all-India oil sardine catch by 2006. Since the catch in the southwestern regions has not decreased in overall terms, this represents an extension of the distributional boundaries of the oil sardine.

Impact on the harvesting sector

Climatic changes that affect distribution also affect the fishing methods used to harvest affected fish stocks. In the Bay of Bengal, rising sea surface temperatures have caused fisher folk to increase the depth at which nets are cast. Studies have shown an increase in recruitment and catch of oil sardine and Indian mackerel after the southwest monsoon season as a result of increased temperatures.

Studies confirm that the impact of fishing pressure is very high and widespread as compared to that of sea surface temperature on fish abundance. However, as 14 percent of species are also vulnerable to changes in SST, measures to control fishing need to be increased in parallel with conservation management measures, which can increase the resilience of vulnerable species to climate variability.

Life cycle assessments (LCA) performed on the fishing industry have shown the majority of emissions originating from the fishing subsector are generated during the actual harvesting phase, followed by the processing phase.

Impact on fishing communities

Erosion resulting from sea level rise and abnormal weather events presents a significant risk for vulnerable coastal communities. The east coast of India is considered more vulnerable because of its flat terrain and the numerous deltas. Estimates show that the inundation area will be about 4.2 sq km for a 1.0 m rise in sea level in the region surrounding Nagapattinam in Tamil Nadu. The most vulnerable group likely to be affected by the effects of climate change on fisheries is the small-scale fisheries sector, comprising artisanal and subsistence fishers.

2. Adaptations

Adaptation of fisheries habitats

Habitat mapping and modelling: In the context of climate change, research on fish habitats is of great significance. Regional or zone wise (SW, NW, NE, SE) mapping and spatial representation of Indian aquatic habitats and their linkage with ecosystem services is identified as a prospective adaptation option. Habitat mapping could be extended specifically for commercial as well as vulnerable species for better conservation, management and sustainable utilization of aquatic resources.

The Indian satellites IRS – 1C, 1D, P4 and P6 with their improved spatial resolution (PAN – 5.8 m, LISS III – 23.6 m, LISS IV – 5.8 m, WiFS – 188 m and AWiFS – 56 m), have extended the spectral range (inclusion of middle infrared band in LISS III), increased repeatability (fve days for WiFS data) and have opened up new applications in the coastal zone.

Mangrove mapping, conservation and restoration: India accounts for nearly 3 percent of the world's mangrove vegetation and the carbon sequestration potential of mangroves and their sediments has become more significant in the context of climate change. Mangrove reforestation, carbon stock assessment in mangrove sediments, assessment and mapping of mangrove ecosystems are important areas of mangrove research being carried out in India. The status and trends of mangrove areas in India including the causes of losses and their restoration and traditional conservation have been assessed. Some NGOs in Southern India are playing a vital role in afforestation/rejuvenation of mangrove forests.

Adaptation of fishery stocks

Stock modelling: To enhance the resiliency of stocks and their ability to recover from population collapses stock modelling can be done. Several research institutions in India are capable of carrying this out.

Vulnerability assessment along Indian coastal zones and conservation: Scientific criteria developed by CMFRI for long-term vulnerability assessment of Indian marine fishes could be used to assess the species level

adaptability to climate change. Species identified as highly vulnerable could be prioritized for conservation and management strategies. Conservation and fishing protocols based on species stock vulnerability could also be developed so as to enhance sustainability.

Adaptation of fish stock availability

Potential fishing zones (PFZ) could be identified for reducing scouting time and increasing fishing profitability. Activities in fishing zones could be monitored for sustainable exploitation of fisheries resources.

Adaptation of the harvesting sector

Implementation of minimum legal size (MLS): Catch is of serious concern in the harvesting sector and can be directly attributed to climate change and stock distribution. However, this increases the fishing pressure on vulnerable populations. Hence to bring about sustainability, minimum legal size could be implemented. The Central Marine Fisheries Research Institute (CMFRI) on the basis of scientific studies recommends departments of fisheries and state governments to implement the suggested MLS for 58 commercial species and to carry out inspections and studies to determine the violations.

Green fishing protocols for carbon footprint reduction: Alternative energy usage in fishing operations could be considered. However, owing to the direct contribution of the fisheries sector directly to the food and nutritional security of millions of people, implementation of a shift in operational techniques to reduce the carbon footprint needs to be done with considerable caution.

Adaptation of fishing communities

Climate change preparedness of vulnerable coastal populations: Several climate preparedness activities (CPAs) could be implemented effectively to enhance the preparedness levels of coastal populations. Improved climate change awareness, adaptation and preparations of the fisher folks could be done through suitable scientific meetings and training. In India, Community Based Disaster Risk Reduction Programmes (CBDRRM) are being carried out at village level periodically to enhance the preparedness.

3. Efforts taken to mitigate the impact of climate change and build the climate resilience of fisheries

These include the following:

- The Department of Animal Husbandry, Dairying and Fisheries (DADF, Government of India) has called for a revolution in the fishing industry, with identified and defined objectives for the period 2015/16–2019/20 promoting non-destructive fishing practices such as gillnetting and longline fishing;
- mitigation measures for carbon release related to fishing activities lie in the fuel use and efficiency of boats and vessels, thus measures to reduce the carbon footprint include setting emission norms for marine engines and the development of fuel-efficient engines; fishers in Tamil Nadu have developed fishing boats powered by solar energy;
- scope of the Marine Fishing Regulation Acts (MFRAs) of maritime states/UTs to include registration of boat building yards for continuous monitoring and control of boat construction so as to produce fuel-efficient engines and boats for marine fisheries subsector;
- the Marine Fishing Regulation Acts (MFRAs) of maritime states/UT provide regulations on minimum legal size of fish to be caught;
- the Uniform Seasonal Fishing Ban is being enforced all along the coast of India;
- the Coastal Regulation Zone notification was issued in February 1991 and the Environment Protection Act 1986 of India, to regulate activities in the coastal areas along the coast of India;

- Coastal Aquaculture Authority Act 2005 has been enacted and implemented to regulate the activities connected with coastal aquaculture in the coastal areas; and
- artificial reefs are being deployed to restore the marine habitats for the organisms which were lost because of human activity and the effects of climate change.

4. Major gaps and constraints in building climate-resilient fisheries

Several key areas exist in which to improve the response to the pervasive effects of global warming.

Common knowledge databases

- Common, shared knowledge databases must be made available to researchers across the country. This will streamline research and study in the field of climate change, as significant time is lost on bureaucratic efforts between research organizations during collaborative efforts.

Continuous evaluation and fish stock monitoring and dynamic regulation

- Constant monitoring of potential vulnerable species, accompanied by dynamic regulation of the utilization of fish stocks could lead to shifting the fishery status of certain fish stocks away from threatened or vulnerable.

Historical data records for important fish stocks

- Data records for important species could be compiled and made publically available to increase transparency and allow for greater insight into population and exploitation trends being displayed by commonly harvested species.

Inclusion of scientific committees in policy determination

- Greater involvement of scientific committees comprised of expert panels during the process of policy determination would allow for quicker policy responses to changes resulting from climate change.
- Increased awareness amongst policymakers and consumers about the importance of aquaculture in the national economy and the extent of damage to the sector is required.

5. Recommendations on regional strategy and actions to support the national effort to build climate-resilient fisheries

- Technologies to adapt to climate change are to be developed and demonstrated directly to fisher communities.
- Large number of fisher communities and other stakeholders are to be empowered to cope with climate change through training, workshops, awareness programmes, etc.
- There is a need to forecast the likely effects of climate change on the fisheries sector and to develop strategies to assist fisher communities to adapt to the upcoming changes.
- More research is needed to look at the adaptation strategies that could help the fishers to improve fish catch and income in the context of changing climate and extreme events.
- Cooperation among research institutes, industry and communities needs to be fostered in order to form a framework through which the effects of climate change can be mitigated.
- Existing management plans for the fisheries sectors and coastal zones need to be reviewed and, if needed, further developed to ensure they cover potential climate change impacts, mitigation and adaptation responses.
- Fisheries need to be adequately addressed in climate change policies including allocation of funds under the Green Climate Fund and programmes dealing with the global commons, food security and trade and also in the decisions related to climate change in the other major sectors.

Indonesia

Renny Puspasari Ramli

Indonesia is a large maritime country with a 99 000 km coastline and 16 056 islands. As a maritime country, fisheries are a very important economic sector in Indonesia. In 2016, total fisheries production was 23 506 301 tonnes, produced from aquaculture industries and capture fisheries. Aquaculture industries share 71 percent (16.7 million tonnes), marine capture fisheries share 27 percent (6.4 million tonnes) and inland capture fisheries share only 2 percent (0.48 million tonnes). A total of 2.8 million fishers and 2.4 million aquaculturists contribute to fisheries production, ensuring national food security.

There are 11 fisheries management areas (FMAs) in Indonesian territorial waters, and each has different characteristics. The dominant fishes in every FMA are different, but mostly large pelagic fishes and small pelagic fishes dominate most of them. More than 96 percent of the fishing fleet in Indonesian waters are less than 10 GT, indicating that Indonesian fisheries is dominated by small-scale fisheries. Marine fishes contribute 85.4 percent to total fisheries production, and this is dominated by large and small pelagic fishes, whereas inland fishes contribute only 8 percent. Skip jack, neritic tuna, yellowfin tuna, king mackerel and albacore are the dominant species of the large pelagic group. Scad, short mackerel, yellowstrip scad, anchovy and goldstrip sardinella dominate the small pelagic group. Demersal fishes are dominated by red snapper, trevally, catfish, snapper and yellowfin tuna. Crustacea is also one of the commercial fisheries products that have high economic value. Production of crustaceans in Indonesia mostly comes from aquaculture industries. Capture fisheries of crustaceans share 6.6 percent of total fisheries production. The dominant species of crustaceans are banana shrimp, endeavour prawn, tiger prawn, tiger cat shrimp and blue swimming crab.

Indonesia lies between two oceans, namely the Pacific Ocean and the Indian Ocean, and in between the two continents of Asia and Australia. The climate conditions in Indonesia are affected by the regional climate in those areas. Regional climate such as El Niño-Southern Oscillation (ENSO) in the Pacific Ocean affect the sea surface temperature anomaly (SSTA) in eastern Indonesian waters, whereas the Indian Ocean Dipole, affects the SSTA in western Indonesian waters. Extreme temperatures occur as an impact of regional climate change phenomena. There have been several periods of extreme temperatures which have affected the ecosystem, such as in 2010-2011 and 2015-2016. The extreme temperatures that occurred in those periods, significantly affected the high SSTA in Indonesian waters and caused disruption in fish production and coral bleaching. The increasing frequencies of extreme temperature periods, result in an unstable environment for fish resources and the entire marine and terrestrial ecosystem.

Indonesia has a National Action Plan for Climate Change Adaptation (RAN-API) which was developed by the Ministry of National Development Planning (BAPPENAS). The action plan for mitigating climate change impacts to fisheries activities, consists of: (1) ensuring the stability of coastal communities and small island communities; (2) improving environmental quality; (3) implementing an management structure for adaptation in coastal areas and small islands; (4) adjusting the layout of urban areas against the threat of climate change; and (5) developing and optimizing the research and information system on climate change in coastal areas and small islands. The Ministry of Marine Affairs and Fisheries has developed a strategic plan for climate change adaptation and mitigation for the period 2015–2019. The strategic plan for fisheries focuses on: (1) implementing mitigation and adaptation measures, including coastal habitat rehabilitation, the increase of ecofriendly fisheries, fish health management and the development of specific local commodities; (2) improving community resilience, including a smart fishers programme, cold chain system, education programme on climate adaptation and mitigation, and developing facilities and infrastructure; (3) reducing IUU fishing; (4) empowering communities in the outer islands; and (5) developing human resource capacity.

Some research and technology development has been carried out related to climate change, such as: (1) research on the impact of climate variability on pelagic fish resources; (2) research on the carbon

footprint of the tuna fishery; (3) research on habitat rehabilitation and restoration: application of artificial reefs and fish shelters; (4) development of guidelines on the adaptation to climate changes for tuna fisheries; (5) observations on the impact of increasing SST to the coral reef ecosystem; and (6) research on the application of RAS to cage net aquaculture in the reservoir system.

There are several programmes in fisheries activities addressing climate change in fisheries, covering both adaptation and mitigation: (1) combating IUU fishing; (2) addressing climate change issues in fisheries management and planning; (3) implementing the Ecosystem Approach to Fisheries Management (EAFM) for sustainable fisheries management; (4) developing a harvest strategy for tuna fisheries in Indonesian territorial waters; (5) establishing a climate school for fishers by the Meteorological, Climatological and Geophysical Agency; (6) increasing the number of climate smart fishers; (7) carrying out mangrove rehabilitation; (8) creating seaweed based alternative livelihoods; (9) developing 20 ha of MPAs in 2018; and (10) developing climate resilience in coastal areas.

A habitat rehabilitation programme already benefits the environment and fisher communities, for example the coral reef rehabilitation programme which has been implemented by Indonesia Nature Foundation, an NGO, together with the local community in Les Village, Buleleng District, Bali province. They installed some artificial reefs in Buleleng waters beginning in 2004, and now the coral reef ecosystem in that area has recovered leading to an increase in the production of ornamental fish, which is the main livelihood of fishers in Les Village.

However there are gaps and constraints in building climate-resilient fisheries in Indonesia. The major gaps are that climate change has not been a priority issue at the national and ministerial level resulting in minimum attention and effort. Moreover, the available fisheries data could not be related to the climate change phenomenon resulting in poor understanding of the impact of climate change on fisheries. The recommendations on regional strategy and actions to support the national effort to build climate-resilient fisheries are: (1) include the marine and fisheries subsector in Nationally Determined Contributions; (2) develop a national action plan on climate change mitigation for fisheries sector; and (3) develop a "blue carbon" road map.

Lao People's Democratic Republic

Thongkhoun Khonglaliane and Akhane Phomsouvanh

1. Introduction

Lao People's Democratic Republic is located in the Indochina Peninsular (Mekong region), bordered by China to the north, Viet Nam to the east, Cambodia to the south, and Thailand and Myanmar (Burma) to the west and northwest respectively. Lao People's Democratic Republic has a total land area of approximately 236 800 km^2, of which 87.7 percent of the land (or catchment areas) (207 674 sq km) drains into the Mekong River and contributes about 35 percent of the Mekong River Basin flow. Another 12.3 percent of the northeastern area produces a discharge to the north of Viet Nam before draining into the South China Sea. Mountains are found in the northern region, the Annamite Chain (forming most of the eastern border of the country), and in the south, posing a significant natural buffer to storms that occur in the region. However, the remaining 20 percent of the country comprises mostly flat floodplains along the Mekong River. The lowest altitude of Lao People's Democratic Republic is 2 metres and highest is over 200 metres. Almost all Lao territory is of enormous importance both for fishery resources and for its rich aquatic biodiversity.

Lao People's Democratic Republic has a tropical climate that is influenced by the southeast monsoon, which causes significant rainfall and high humidity. The climate is divided into two distinct seasons: rainy season, or monsoon, from May to mid-October, followed by a dry season from mid-October to April. The annual rainfall ranges from 1 300 mm to 3 000 mm. Average temperatures in the northern and eastern

mountainous areas and the plateaus are 20ºC, and in the plains 25ºC–27ºC. In 2006, the average temperature for the country was 26.5ºC. On the basis of its altitude, Lao People's Democratic Republic is divided into three different climatic zones, as follows: (1) the northern mountainous areas above 1 000 m have a montane temperate and hilly sub-tropical climate; they are relatively dry, with an average rainfall between 1 500 mm and 2 000 mm; temperature ranges are lower there than in the rest of the country; (2) the central mountainous areas in the Annamite Chain range in altitude from 500 m to 1 000 m (with some mountain peaks >2 000 m); they have a tropical monsoonal climate with a higher temperature and higher average rainfall than elsewhere which ranges from 2 500 mm to 3 500 mm; and (3) the tropical lowland plain and floodplains along the Mekong River and its main tributaries include the plains of Vientiane, Borikhamxay, Khammouan, Savannakhet, Champasack, Saravane, and Attapeu Provinces; more than 50 percent of the population of Lao People's Democratic Republic lives in these areas, which have an average rainfall of 1 500 mm to 2 000 mm.

2. National policy and action plan addressing climate change adaptation and mitigation

Lao People's Democratic Republic ratified the United Nations Framework Convention on Climate Change (UNFCCC) in 1995 and the Kyoto Protocol in 2003. The Water Resources and Environment Administration (WREA), which is under the Prime Minister's Office, was established as the UNFCCC National Focal Point. The National Steering Committee on Climate Change (NSCCC) and the Technical Working Groups (TWG) were established in 2008. The TWG comprise seven concerned sectors as follows: (1) agriculture, forestry and land use; (2) energy; (3) water resources; (4) urban infrastructure; (5) public health; (6) economic development; and (7) financial instruments. The National Climate Change Office (NCCO) was established in October 2008 under the Department of Environment (Water Resources and Environment Administration).

The National Strategy on Climate Change of Lao People's Democratic Republic was officially endorsed by the Prime Minister's Decree on 12 March 2010 which identified seven priority areas for adaptation and mitigation as follows: (1) agriculture and food security; (2) forestry and land use; (3) water resources; (4) energy and transport; (5) industry; (6) urban development; and (7) public health.

3. Review of previous activities on climate change adaptation and mitigation in the context of fisheries and aquaculture

On 21 May 2009, the Water Resource and Environment Administration (WREA) and United Nations Development Programme (UNDP) launched the National Adaptation Programme of Action to Climate Change (NAPA) and the National Capacity Needs Self-Assessment (NCSA) for Global Environment Management. These two projects have been implemented by WREA, supported by UNDP, and have received funding from the Global Environment Facility and the Least Developed Country Fund. They have enabled the government to identify key priorities for adapting to climate change and prioritize capacity needs to strengthen implementation of the United Nations Framework Convention on Climate Change, the United Nations Convention on Biological Diversity, and the United Nations Convention to Combat Desertification. The NAPA reviews the predicted impacts of climate change on the country, and also assesses and prioritizes possible adaptation options. It has identified 45 project proposals that are key to adapting to climate change, with a focus on the four sectors of agriculture, forestry, water and water resources, and public health. The projects, developed for flood and drought prone areas, include strengthening the capacity of the National Disaster Management Committees, community participation in the development of improved systems for the sustainable use of drinking water, reforestation, and further development of early-warning systems, amongst others. The National Capacity Needs Self-Assessment for Global Environment Management plan has enabled the government to identify and characterize the nature of critical capacity constraints and priority capacity needs at national, institutional and individual levels related to global environmental management, with a focus on the implementation of the various United Nations Conventions in the country.

More than 80 percent of Lao people depend on natural resources for their livelihoods and the Lao economy relies heavily on the country's natural resource base. This means they are highly susceptible to the impacts of climate change. For example, based on a 2007 countrywide national risk and vulnerability assessment conducted by the Word Food Programme, it is estimated that up to 46 percent of the country's rural population – about 188 000 households most of whom live in the lowlands – are vulnerable to the long dry season. This is in addition to the 2 percent of people who are already chronically food insecure.

UNDP is continuing to support efforts to improve the capacity of the Lao agriculture sector to deal with the impacts of climate change. A project document on Improving the Agriculture Sector to Climate Change Impacts was signed on the 10 May 2010 by the National Agriculture and Forestry Research Institute (NAFRI) and UNDP at the Ministry of Agriculture and Forestry in Vientiane. The cooperation project, which is valued at USD 12.1 million, was implemented in Savannakhet's Champhone and Outhoumphone districts and Xayaboury's Paklai and Phieng districts from 2011 to December 2014. The project aimed at combating food insecurity resulting from climate change and minimizing the vulnerability of farmers to extreme flooding and drought. Expected project outcomes included strengthening of the national knowledge and information base on climate change impacts, and enhancement of the capacity of sector planners and agricultural producers. Demonstration and promotion of diversified and adaptive agriculture practices at the community level, and communication and dissemination of information and adaptive lessons learnt were also anticipated project results.

Improving the resilience of the agriculture sector to climate change impacts is a National Adaptation Programme of Action (NAPA) follow-up project and forms part of a larger goal of formulating urgently needed action plans for adaptation to climate change in the country, focusing on four sectors: agriculture, forestry, water resources, and public health. The adaptation options include mainstreaming of climate change matters in agriculture policies, productivity enhancement through conservation agriculture, water resources management improvement and monitoring, strengthening small- and medium-size farming and support for community-based adaptation, country-specific research at macro and village level, information dissemination enhancement and extension, and improvement of cooperation at the national and regional level.

4. Status of fisheries and aquaculture sector

In 2007, for the purpose of statistical information and economic valuation of capture fisheries and aquaculture, the Department of Livestock and Fisheries and the Ministry of Agriculture and Fisheries restructured the types of inland water resources and re-estimated fish production. According to this study, the Mekong River and its 14 main tributaries, and five northeastern rivers cover an area of 304 704 ha of Lao People's Democratic Republic. The area of large hydropower reservoirs is estimated at 96 030 ha, and shallow lakes, natural pools, peat swamps, swamps and other wetlands occupy 114 800 ha. Irrigation reservoirs and weirs are estimated at covering 60 000 ha, whereas wet season rice fields total 632 850 ha. Seasonal flooding areas in the Mekong Plain are believed to cover more than 30 000 ha. Overall, this adds up to a total water resource of 1 238 394 ha for capture fisheries. In contrast, it is estimated water resources used for aquaculture total about 42 000 ha. Of this total, fish ponds take up 22 000 ha, man-made oxbow lakes and irrigation weirs use 15 000 ha and rice-fish culture occupies about 5 000 ha. The total wetland (water surface) area for both capture and culture fisheries has now been re-estimated at 1 280 384 ha, in comparison with the MRC GIS database broad categories of wetlands (1992–1998) which recorded it at about 1 019 600 ha.

Lao People's Democratic Republic has a total population of about six million of which 75 to 80 percent still live a rural lifestyle. In 2005 it was estimated that 32.7 percent of these people lived below the poverty line. The people of Lao People's Democratic Republic, especially in the rural communities, still rely heavily on aquatic resources, i.e. fishes and other aquatic animals, as the most reliable sources of animal protein intake. In Lao People's Democratic Republic, the most current estimated yield of inland fish amounts to 167 922 tonnes per year, whereas the yield of other aquatic animals comprises 40 581 tonnes per year.

These figures have been based on consumption studies and expressed as fresh whole animal equivalent weights (FWAEs). The estimate of the annual fish consumption per capita of inland fish was 24.5 kg, whereas the figures for other aquatic animals were about 4.1 kg and marine products contributed 0.4 kg to make a total of 29 kg. These figures were almost consistent with the Lao Expenditure and Consumption Survey 3 (LECS3) conducted by the National Statistic Center in 2002/2003.

Because of the diversity of aquatic ecosystems, the structure of inland fisheries as well as their production can be characterized by various sub-types of capture and culture. Capture fisheries can be categorized by the use of various water resources such the Mekong and its tributaries; large hydropower reservoirs; natural pools, lakes and small specific wetlands; irrigation reservoirs, weirs and the large areas of wet season rice fields and seasonal Mekong flood plains. The majority of the catches of fish and other aquatic animals in the various water resources are still at the level of subsistence and semi-subsistence fishing or artisanal fisheries, except in large reservoirs where the catches have been organized and formalized. The general accessibility of aquatic resources to most local communities, and the high participation in exploitation and utilization of these resources are linked intimately. This type of catch is an integral part of the livelihood of entire communities, as most fishing effort is part time and seasonal in nature. In contrast, aquaculture development in Lao People's Democratic Republic is progressing well, but is still encountering many difficulties that need to be overcome. The forms of production used for aquaculture include fish pond culture, community fish culture in oxbow lakes and in irrigation weirs, rice-fish culture and cage fish culture.

Inland capture fisheries and aquaculture in Lao People's Democratic Republic are based mainly on water resource ecosystems consisting of rivers and their basins, hydropower and irrigation reservoirs, temporary or permanent diversion weirs, gates and dykes, small waterbodies, flood plains and wet season rice fields. The total water resources for capture fisheries are believed to be more than 1.2 million ha. The estimated yield of inland fish in Lao People's Democratic Republic is approximately 167 922 tonnes per year whereas consumption of other aquatic animals is estimated at 40 581 tonnes per year. These estimated yields are conservatively valued at almost USD 150 million per year.

More than 481 fish species have been identified in Lao People's Democratic Republic, including 22 fish species identified as exotic species. Only about 37 amphibians, 7 species of crabs and 10 species of shrimps have been recorded, but these records would cover only about 15 percent of the estimated total.

In order to understand the ecosystem diversity and species diversity, it is very important to understand the migration patterns of Mekong fish species. And to justify or demonstrate the migration patterns, it is essential to examine studies based on local ecological knowledge, landing site surveys, logbook migration monitoring and larvae sampling of important fish species. These will reveal the distribution, the population structure, feeding habits, critical habitats, life cycles and the fisheries for these fish species. Inland capture, mostly qualified as subsistence and semi-subsistence fisheries, is complex in nature and involves a wide variety of activities undertaken by people from a wide spectrum of socio-economic backgrounds. The development of aquatic resources deserves to be given a higher priority by the Government of Lao People's Democratic Republic, as it is a key component in improving food security. To confront the problems and challenges in the fisheries subsector, two interlinked strategic frameworks or issues of resource assessment and management of capture fisheries should be developed in concert with the promotion of sustainability of culture fisheries.

5. Conclusions and recommendations

As a least developed country, Lao People's Democratic Republic is one of many countries vulnerable to the impacts of climate change. In recent years, the country has witnessed more frequent and severe floods and droughts. Temperature is continuously increasing and the rainfall is erratic, resulting in a number of adverse impacts to the economic system, environment and the livelihoods of people of all ethnic groups. Thus, climate change poses a great challenge for the Lao People's Democratic Republic to tackle and we

must adapt to climate conditions and control the emission of greenhouse gases. Lao People's Democratic Republic lacks data, adaptation strategies, funds, human resources, experience, an appropriate approach and the mechanisms to develop immediate and long-term solutions.

The Government of the Lao People's Democratic Republic endeavours to find practical solutions to the challenges posed by climate change at a national level by formulating policies, approving proper rules and regulations and making solid decisions to participate with the international community by ratifying the United Nations Framework Convention on Climate Change (UNFCCC) in 1995 and the Kyoto Protocol in 2003. Thus, Lao People's Democratic Republic is fully committed to its obligations involving the management and protection of the environment. The country is making significant strides to reduce slash and burn activities, pay close attention to the management and sustainable use of our forests, support the renewable use of energy, develop biogas, increase climate change awareness, and at the same time, manage and control pollution growth, and minimize waste from social and economic development activities. All in all, these activities directly contribute to developing carbon sinks, facilitating adaptation to climate change and mitigating greenhouse gas emissions to the atmosphere. The main goal of the National Adaptation Programme of Action to Climate Change (NAPA) is to formulate urgently needed action plans for adaptation to climate change in the Lao People's Democratic Republic. A focus has been placed on four sectors, namely, agriculture, forestry, water resources and public health. In this regard, 45 priority projects have been identified to implement urgent plans to adapt to climate change. This NAPA is in line with the objectives of the Socio-Economic Development Strategy, National Growth and Poverty Eradication Strategy, National Environment Strategy, Agriculture Strategy, Policies on Irrigation Extension, Draft Strategy for Water Resources Management, and Natural Disaster Prevention. In addition, the NAPA contributes to the achievement of the Millennium Development Goals. Lao People's Democratic Republic cooperates with other nation states throughout the world to meet its commitments towards the UNFCCC, Kyoto Protocol and the Paris Agreement. However, even though efforts in the past have achieved considerable success on many fronts, the challenges continuously increase. In order to deal with these, there is a growing need to improve strategies that counteract the disasters caused by climate change and strengthen the capacities of the National Disaster Management Committee to deal with the adverse impacts which are likely to occur in the future. It is necessary to strengthen the recently established Climate Change Office, install an early-warning system, realize in-depth studies of the impacts of climate change especially concerning droughts and floods in Lao People's Democratic Republic, formulate a strategy on climate change, mobilize reforestation, and other necessary activities. Consequently, the country's future mission is one of cooperation, formulation of cooperation mechanisms, fund mobilization, technical assistance, coordination and monitoring amongst relevant sectors to implement the NAPA. In addition, the NAPA must be widely disseminated to attract the participation and involvement of every sector in the society, including the public sector and the donor organizations which are of primary importance for the effective and successful implementation of this cross-sectoral programme.

With over 80 percent of Lao people depending on natural resources for their livelihoods and a national economy that heavily relies on the country's natural resource base, the people of Lao People's Democratic Republic are highly susceptible to the impacts of climate change. For example, based on a 2007 countrywide National Risk and Vulnerability Assessment conducted by WFP, it is estimated that up to 46 percent of the rural population in Lao People's Democratic Republic – approximately 188 000 households most of whom are living in lowlands – are vulnerable to drought. Furthermore, no detailed studies have been yet conducted for the fisheries sector (including aquaculture). There has been no study on the vulnerability of the fishery sector to climate change in the country. Such a study is necessary in anticipation of likely impacts, so that appropriate adaptation measures can be designed to minimize any negative consequence.

The fisheries sector, especially aquaculture, must be considered when developing national strategic programmes for adaptation and mitigation to climate changes. Therefore, it is essential that concerned fisheries agencies are fully involved in the development process of "National Adaptation Programme of Action" (NAPA) in the future. There is also an urgent need for information dissemination on climate change effects and their implication for the fishery sector in a form that is understandable to policymakers.

The following issues need to considered when developing adaptation and mitigation measures to climate change in regard to fisheries and aquaculture:

- stakeholder involvement is critical when developing and implementing adaptation and mitigation strategies;
- fisheries must be an essential part of Integrated Water Resources Management (IWRM);
- the use of an Ecosystem Approach to Fisheries (EAF) needs to be heavily promoted; and
- participatory fisheries management approaches (e.g. co-management, community-based management, CBF, etc.).

Malaysia

Abdul Razak bin Abdul Rahman

Introduction

In Malaysia, it is well understood that the capture fisheries sector relies on the capture of wild fishes both in the ocean and the inland rivers. The capture fisheries sector in Malaysia makes a significant contribution to fish production, although the overall production figure has been declining at an average of 3.8 percent each year. On average, the capture fisheries sector makes up 74 percent of total fish production each year with the value reaching RM 9.3 billion in 2015. The major contribution is from coastal fisheries at 82 percent. Overall there are about 53 002 licenced vessels recorded in 2011 with 51 892 units of fishing gear equipment. The fishing gears were classified as commercial gears (such as trawl nets, purse seine nets) and conventional gears which refer to fish rod, trap and drift nets. Of the 134 110 registered fishers in 2011, about 53 564 (39.9 percent) were involved in commercial vessels especially in trawlers and used purse seine fish gear.

Major fisheries production system (marine and inland) and commodities in the country

The two major fisheries production systems for capture fisheries in Malaysia are marine capture fisheries and inland capture fisheries:

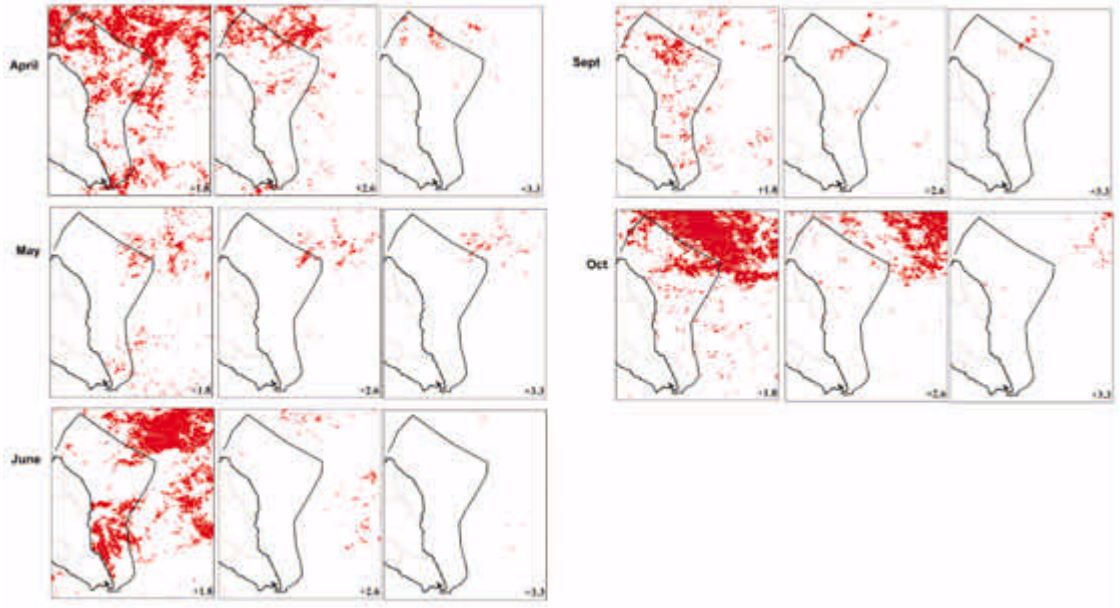
a) The marine capture fisheries are divided into coastal fisheries (onshore) which operate within 30 nautical miles and deep sea fisheries (offshore) which operate beyond 30 nautical miles. Each type uses a different class of vessel and fishing gear. The main target species in onshore fishing are finfish, shrimp, squid, small fishes, whereas oceanic tuna is the main species targeted in offshore fishing.
b) The inland capture fisheries involve river and lake fishing. The total production landing was recorded at 5 964 million tonnes with a value of RM 55 million in 2011. The fish landed sell as fresh and salted products.

Specific threat/risks of climate change and related extreme meteorological events to fisheries

1. Sea surface temperature (SST) – migration of pelagic fish (*R. kanagurta*)

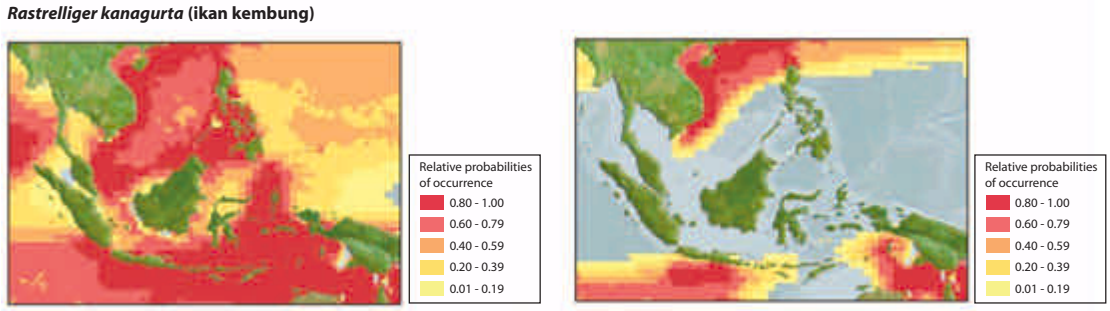
   A study on the spatial and temporal relationship of ocean biophysical parameters and habitat utilization of *Rastrelliger kanagurta* (Indian mackerel) in the South China Sea used SST data to estimate the temperature changes in the period 2010–2039 based on the Representative Concentration Pathways. Thus it is estimated that there could be SST increases of 1.8°C, 2.6°C and 3.3°C and these would result in the disappearance of *R. kanagurta* from the waters of the west coast of Peninsular Malaysia.

Figure 4. Estimated reduction of appearance of Indian mackerel in west coast of Peninsular Malaysia with increasing SST



2. El-Niño in the year 2015-2016 caused an increasing sea temperature of about 1°C to 2°C (Climate Prediction Center NOAA, 2016) effecting the fish stock and altering fish distribution.

Figure 5. Projected changes in relative probabilities of occurance of Indian mackerel between 2016 and 2050 due to increasing SST



Computer Generated Native Distribution Map (present)

Computer Generated Native Distribution Map (in year 2050)

3. Coral bleaching in Pulau Paya and Pulau Redang.
4. Sea level rise (SLR) – an increase in sedimentation of the river bottom, and beach and cliffs erosion could effect fisher's houses, some coastal areas could have problems with saline water intrusion, and there could be damage to fisher's boats and gear.

National efforts addressing climate change and building climate resilience of fisheries:

a) National strategies and action plan development and progress with implementation

In Malaysia, the National Policy on Climate Change has been gazetted since 2010 and provides the framework to mobilize and guide government agencies, industry, communities as well as other stakeholders and major groups in addressing the challenges of climate change in a holistic manner. The Department of Fisheries takes responsibility in ensuring that food security (fish and fish products) is the priority as fish remains an important part of the diet of Malaysians. In order to build resilient fisheries, some strategic measures have been implemented such as reducing catch effort by ending petrol/diesel subsidies, enhancing weather warning and disaster notification systems (tsunami, etc.), changing fishing bases, modernization of fishing boats/vessel, vessel monitoring devices (AIS) installed in fishing boats and personal life insurance to the boat/vessel operator.

b) Research and technology development.

Research in stock assessment, sea water temperature, sea level rise, coral transplanting and green technology have been made from 2010 to 2016.

c) Programme/project activities addressing climate change in fisheries, covering both adaptation and mitigation.

Exit plan programme – for sustainable fisheries and better living – encourage fishers to be involved in fish processing and aquaculture or, as per the "Nakhoda" programme, train local youngsters from fisher families to be involved in deep sea fishing.

d) Lessons learned/good practice from ongoing efforts

Same as a) above.

Major gaps and constraints in building climate-resilient fisheries

The major gaps and constraints in implementing a programme that ensures the resilience of fisheries to the climate change:

a) lack of funding for research;
b) high cost of insurance;
c) lack of actual data, incorrect data; and
d) low level of awareness.

Recommendations on regional strategy and action to support the national effort to build climate resilience in fisheries:

1. establish regional research collaboration with better research funding;
2. provide scheduled and comprehensive training and awareness programme; and
3. standardize regional fisheries and aquaculture climate change policy.

Myanmar

Aye Aye Zaw

Background

Agriculture (including fisheries and livestock) constitutes about 28 percent of Myanmar's GDP and 61 percent of employment and more than 70 percent of the population is living in rural areas.

The rural people are highly dependent on small-scale agriculture such as cropping, livestock raising and fishing.

Climate change is already proving challenging by causing reductions in annual productivity and huge economic losses resulting in food insecurity, poverty and migration.

Myanmar is also suffering from the adverse effects of climate change in terms of droughts, floods, natural disasters, land degradation, desertification and deforestation and severe landslides.

Myanmar is one of the world's most disaster-prone countries exposed to multiple hazards, including floods, cyclones, earthquakes, landslides, and droughts, ranking second out of 187 countries in the 2016 Global Climate Risk Index and ninth out of 191 countries in the INFORM Index for Risk Management.

There are three types of fisheries, namely inland fisheries, marine fisheries and aquaculture in Myanmar. Total fish production is 5. 6 million tonnes and 0.43 million tonnes are exported. Exported fish comprise 8 percent to10 percent of fish production annually. The top species of export fisheries products are rohu, live mud crab, live eel, soft shell crab, ribbon fish, pink shrimp, tiger shrimp, hilsa and big eye croaker. The number of full-time fishers is over 0.8 million and 1.7 million persons are occasional fishers. Most of the rural people are involved in subsistence fisheries. Per capita fish consumption in Myanmar was 61 kg in 2016 in accordance with the official fisheries statistics.

Damages and losses caused by Cyclone Nargis (early May 2008) are still evident and Cyclone Giri (late October 2010) also caused catastrophic damages in some parts of the country. The full extent of such damages is not fully known.

Projections of future changes in climate for Myanmar

Climate change has affected the coastal and marine environment, causing deterioration of mangroves, coral reefs and seagrass beds, which are vital breeding and feeding grounds for fish. Cyclones have caused loss of fishing vessels and impacted marine, coastal and inland fisheries, causing high economic losses.

Ongoing project

Having signed the United Nations Framework Convention on Climate Change (UNFCCC) on 11 June 1992 and ratified the convention on 25 November 1994 and the Kyoto Protocol in 2003 as a non-Annex 1 party, Myanmar is fully aware of the causes and potential impacts of climate change. The Ministry of Environmental Conservation and Forestry and Ministry of Transport are focal points for UNFCCC.

Climate adaptation strategies and work plans for the fisheries sector under the climate change resilience programme

While undertaking political reform and aiming at rapid economic development, Myanmar is striving to reduce its GHG emissions. The Government of Myanmar has recognized the potential of the REDD+ initiative to contribute to green development by protecting global environmental resources (forest carbon stocks, but also biodiversity), helping to reverse land degradation, helping to improve the livelihoods of the rural poor and aiding adaptation to climate change.

The Myanmar Climate Change Strategy and Action Plan (MCCSAP) 2016–2030 presents a roadmap to guide Myanmar's strategic responses to climate-related risks and opportunities over the next 15 years and beyond. The Strategy and Action Plan aim to support key actors in their decision-making at the national and local level to respond to the challenges and opportunities associated with climate change. The full final document was made widely available in digital format in September 2017.

The Myanmar National Adaptation Programme of Action (NAPA) Report 2012 is prepared in the framework of the LCDF funded project Preparation of National Adaptation Programmes of Action implemented by United Nations Environment Programme (UNEP) and executed by the Department of Meteorology and Hydrology, Ministry of Transport of Union of the Republic of Myanmar.

FAO has established two projects for the adaptation of climate change in Myanmar. These are FishAdept Project, which aims to strengthen the adaptive capacity and resilience of fisheries and aquaculture dependent livelihood in Myanmar and the project on strengthening the knowledge base for implementing the ecosystem approach to marine fisheries in developing countries.

Fisheries subsectors

For building the resilience of climate change in fisheries, Myanmar needs to conduct a survey or research on the impact of climate change on fisheries and establish a specific work plan of climate change

resilience in fisheries integrated with an environmental management framework, marine spatial planning, and a national disaster risk management plan. Also, it needs capacity building and technical assistance for climate change smart fisheries. The other most important matter is providing finance for project implementation and coordination among NGOs, ministries and departments.

Recommendation on regional strategy and actions to support the national effort

(a) develop the national plan for climate change adaptation and mitigation for fisheries in line with regional climate change programme;
(b) conduct research and development and extension activities for climate change impact on fisheries; and
(c) manage natural resources conservation and sustainable utilization of fisheries.

Nepal

Rama Nanda Mishra

1. Introduction

Nepal is a mountainous landlocked country with an agro-based economy. Nine of the world's 14 peaks above 8 000 m lie in Nepal and within a distance of 160 km the elevation ranges from 60 m to 8 848 m. The country has three distinct ecological belts, i.e mountains, hills and terai where the mean temperature ranges from less than 3ºC to above 25ºC. Fisheries is a traditional practice in Nepal and fish is considered as the first incarnation of lord Vishnu and a symbol of good luck and is deeply rooted in culture and tradition. Aquatic products such as makhana (*Eurela ferox*) and fish are essential for many rituals. Similarly, fish, crustaceans, mollusks and weeds are very important sources of food in many parts of the country. Total fish production reached 83 000 million tonnes in 2016 of which fisheries contributed nearly 25 percent in annual production. Nepal being land locked has only inland fisheries which are artisanal and subsistence capture fisheries. The share of fisheries in the country's GDP is declining with time. However, the sector has provided direct employment to 581 000 people in which the contribution of fisheries is nearly 80 percent of the total employment provided by the sector. Women's involvement in the sector is 60 percent of the total. There are 24 ethnic communities whose livelihoods are very much dependent on fisheries activities and most of them are poor and deprived. Fish is an important source of animal protein in the southern part of the country. Moreover, the fisheries sector contributes nearly 20 percent of the animal protein supply. Fisheries is a small but important sector of agriculture and the economy. The contribution of this sector is 4.25 percent of agricultural GDP and 1.33 percent of national GDP.

Climate change has a profound effect on lives, properties, biodiversity and the economy of the country. Increased incidence of flooding and drought is of great concern. Moreover, Nepal ranked 137 in the world (2010) in terms of per capita emission of CO_2 with 0.1 tonnes/year and a total emission of 40 million tonnes of CO_2 equivalent greenhouse gas emissions, i.e. one-quarter of the world's average in 2013, in which the share of agriculture was 52 percent with livestock contributing three-quarters of it.

2. Major fisheries production systems and commodities in the country

Nepal is rich in freshwater resources possessing 0.1 percent of global fresh water and aquatic habitat covering an area of about 5 percent of the total area of the country. The surface water available in the country is estimated to be about 225 billion cu m (BCM) per annum or equivalent to an average flow of 7 125 cu m/s, of which only 15 BCM per annum has been utilized so far (7 percent), in which the share of agriculture sector is 96 percent. All these waters are drained to the Ganges river system. Nepal's waterbodies are in the form of rivers, lakes, reservoirs, ponds, marginal swamps and irrigated paddy fields covering an area of 831 060 ha and fisheries activities are carried out in the total water surface area of the country. Nepal has more than 6 000 rivers and rivulets covering an area of 395 000 ha of which many are

seasonal. Similarly, small- and medium-size lakes cover about 5 000 ha and marginal swamps an area of 12 500 ha. In addition there are 1 500 ha of reservoirs built mainly for hydro-electricity and irrigation purposes. Apart from these there are 398 000 ha of seasonally irrigated paddy fields and these provide excellent habitat for considerable freshwater biodiversity comprising 72 species of wetland plants, 217 indegenous fish species, 9 species of crabs, 30 species of aquatic molluscks and many species of aquatic crustaceans of which many are endemic species. Even though, it is an important sector it is highly disorganized with very little involvement of management and governance.

3. Threats/risks of CC and CC related extreme meteorological events to fisheries

National mean temprature is about 15ºC. Analysis of weather data (1971–2012) has shown spatial and temporal variation with increases in temperature from 0.04ºC to 0.01ºC/year. It is estimated that average temperature will increase by 2.2ºC by 2050. Temperature increase is more profound in mountain areas compared to terai. Average rainfall is 1 500 mm (150 mm–5 000 mm) of which 80 percent occurs during three months of the monsoon season. Analysis of weather data (1971–2012) has shown an increase in precipitation of 0.7 mm/yr. It is estimated to increase up to 10.1 percent per annum by 2050. The increase in rainfall is more profound in terai compared to mountain areas.

More frequent floods, droughts and landslides along with changes in flow pattern, threat of glacial lake outburst floods, loss of wetlands and deteriorations in water quality are associated with changing climate and are posing constant threat to aquatic habitats and biodiversity resulting in loss of livelihood opportunities to fishers along with loss of stock and production of fish. The flood in August 2017 alone caused loss of more than 4 billion Nepalese Rupees (USD 40 million) to the fisheries sector alone.

4. National efforts addressing climate change and building climate resilience of fisheries

To address the global climate issues Nepal officially approved UNFCC in 1994 and signed the Kyoto Protocol in 2002. Similarly, it became a party to the Paris Agreement in 2016 and made the first nationally determined contribution (NDC) in 2016. The Government of Nepal has designated the Ministry of Environment, Science and Technology as the focal ministry to formulate, implement and coordinate climate issues.

Climate issues are taken very seriously by the Government of Nepal. The constitution of Nepal (2015) has explicitly made provisions for the conservation and management of forests, the environment, water resources, land, and agriculture. The country's climate change policy, 2011 has the goals of improving livelihoods by mitigating and adapting to the adverse impacts of climate change, and adopting a low carbon emissions socio-economic development path. The National Adaptation Programme of Action (NAPA) to Climate Change, 2010 has agriculture and food security (including fisheries), water resource and energy, climate induced disasters and forest and biodiversity as the four major thematic areas. Similarly, the National Framework on Local Adaptation Plan for Action (LAPA), 2011 framework ensures that the process of integrating climate adaptation and resilience into local and national planning is bottom-up, inclusive, responsive and flexible. In addition the National Strategy for Disaster Risk Management includes identification, assessment and monitoring of disaster risk and strengthening early-warning systems.

Though not specific to fisheries, there are some recent initiatives to address overall climate change issues. The Ministry of Agricultural Development has been implementing a pilot project on climate resilience since 2010. The climate smart village programme was initiated by the Ministry of Population and Environment (MoPE) in 2016. National Climate Resilient Planning has been carried out by the National Planning Commission since 2011, a Nepal climate change support programme has been implemented by MoPE since 2011. Similarly, the Climate Change Adaptation and Disaster Risk Management in Agriculture Priority Framework of Action (2011–2020) and the National Adaptation Plan (2015) have been prepared by MoPE. Moreover, Nepal is preparing a project financed by the Global Climate Fund with the support of FAO-Nepal: Scaling Up Low-carbon and Climate-resilient Agriculture for Community Resilience.

Limited work has been carried out in the field of fisheries in Nepal related to climate change impacts but the successful rehabilitation of Lake Rupa of Pokhara valley for fisheries activities through co-management is a very good lesson to be replicated elsewhere to adopt and mitigate climate change effects on fisheries and the aquatic environment.

5. Major gaps and constraints in building climate-resilient fisheries

The major gaps and constraints in addressing climate change issues in the fisheries sector include lack of assessment and risk evaluation, absence of specific fisheries habitat conservation policy, little or no effort for co-management of fisheries resources and overall poor governance and the inadequate capacity of fisheries institutions.

6. Recommendations on regional strategy and actions to support the national effort to build climate-resilient fisheries

At national level fisheries must be included in the national action plan for adaptation and mitigation. Assessment of various fisheries practices carried out in the country needs to be carried out immediately. Similarly, aquatic habitat protection policy and acts must be formulated and implemented. Attention is needed to approve and implement the draft comprehensive fisheries policy as early as possible along with implementation of an aquatic animal protection act to improve the governance of the sector. Above all, the EAFM should be encouraged through community participation and a programme to provide alternative livelihoods to fisher folks must be initiated. At Asia-Pacific regional level climate smart technologies should be developed and shared. Various models for the adaptation of and mitigation in the sector needs to be developed and tested. The technical capacity of the member countries has to be developed/improved.

An effective information and communication system should be established. In addition, member governments must be helped to obtain support from the Global Climate Fund or find some financial support for increasing their capacity to address climate change issues effectively. Above all, concerned regional level organizations should strongly advocate for the inclusion of the fisheries sector in national plans and programmes at various relevant platforms.

Pakistan

Asad Rafi Chandna

Fisheries as a sector of agriculture plays a significant role in the national economy and in ensuring food security. It is considered as one of the most important economic activities along the coastline of Sindh and Balochistan supporting the livelihoods of about 1.0 million fishers and their families.

Fish production during 2012-2013 was 729 000 tonnes and of this amount exports were valued at about USD 317 million. Major seafood importers from Pakistan are Japan, Malaysia, Thailand, United States of America, various Near East countries, Sri Lanka, China and a number of African countries. About 50 percent of the total production is consumed locally, 22 percent is exported whereas 28 percent is converted into fish meal for the poultry industry.

Pakistan is endowed with vast aquatic resources which includes freshwater, brackishwater and marine resources. Aquatic resources are spread in various climatic zones including coldwater, coolwater and warmwater areas. The Pakistani deltaic area of about 700 000 hectares is a big attraction for the fish farming industry, but it is yet to start operations in Pakistan. Pakistan's total fish production for 2015-2016 was 0.788 million tonnes with about one fourth of the fish coming from freshwater fisheries. The export value during 2012-2013 was USD 325 million. Aquaculture is a relatively new, but rapidly expanding activity in Pakistan.

Pakistan is endowed with huge resources for development of the fisheries sector, having 1 100 km of coastal belt. There is no coastal aquaculture yet started in Pakistan. Various studies place Pakistan among the highly vulnerable countries to climate change. During the last few years the country has witnessed rapid weather shifts in various provinces. The monsoon has become highly unpredictable and the country has witnessed floods in one province and drought in the Indus River Basin – the heart of the Pakistani economy – is becoming highly erratic.

Pakistan depends on irrigation and water resources for 90 percent of its food and crops. The Indus Basin Irrigation System (IBIS) is the largest contiguous irrigation system in the world developed over the last 140 years. The system is comprised of three major storage reservoirs, 19 barrages or headworks, 43 main canals with a conveyance length of 57 000 km, and 89 000 watercourses with a running length of more than 1.65 million km.

The Indus Delta is ranked the seventh largest delta in the world, and is spread over 600 000 ha and comprises 17 major creeks and numerous small creeks. The Indus Delta is 240 km across where it meets the sea. It holds 97 percent of the total mangrove forests of Pakistan. The Indus Delta is home to over one million people of which 135 000 depend on mangroves for their livelihoods. Dams and barrages have resulted in the siphoning off of 74 percent of Indus waters before it reaches Kotri Barrage, the last barrage point on the Indus in the southern Sindh province.

Pakistan is facing a problem of rising sea level and its associated impacts. The tide gauge record of Karachi harbour for the past 100 years shows that the sea level at Karachi has risen at about 1.1 mm/year and 0.5 million hectares of fertile land in Thatta district alone (or 12 percent of the entire cultivated area of the province) is affected by sea water intrusion. The salinity of the Sindh coast increased from 35 ppt to 45 ppt in two decades. Only 15 percent of the existing forests is in a healthy state. Up until the 1950s there were eight mangrove species in the Indus Delta, four of which have disappeared now. According to some estimates, about 70 percent of Pakistan's shrimp fishery is dependent on mangroves. It nurtures some 23 species of shrimp and about 155 species of fish. It provides fodder for 6 000 camels and 3 200 buffaloes.

Some shrimp and fish species require low salinity water (a maximum of 15 ppt) during the early stage of life. But salinity in creeks has increased to 45 ppt to 50 ppt. The palla fish (*Tenualosa ilisha*), has significantly declined from 10 000 tonnes/annum in 1970s to 200 tonnes/annum in the late 2000s. An alarming decline in Jaira shrimp (*Penaeus* sp.) has been recorded. This species registered a fall from 10 000 tonnes in 1971 to 3 800 tonnes in 2016. The Sindh coast is vulnerable to cyclones. On average, four cyclones hit the Sindh coast in a century. The period of 1971–2010 records 17 cyclones on the Sindh coast. Changing climate can make cyclones more frequent and violent.

The Indus Delta faces a variety of challenges in the wake of climate change. Some of the consequences may be:

- an alarming sea level rise;
- sea intrusion and submergence of islands;
- more frequent and violent cyclones;
- loss of mangroves and associated biodiversity;
- loss of livelihoods and drinking water; and
- marginalization and outmigration of coastal communities.

According to the Global Climate Risk Index (2017) Pakistan ranks seventh among the countries most adversely affected by climate change, although Pakistan is still among the countries with very low levels of GHG emissions.

There is no specific policy for addressing the affect of climate change in the field of fisheries but there are some complementary plans, policies and agencies that will help to deal with the effects of climate change in the country's fisheries:

- National climate change strategy and action plan development.
- National Disaster Management Authority.
- Federal Flood Commission.
- National Flood Protection Plan V.
- National Water Policy.
- National Policy for Climate Change.

Philippines

Asuncion J. Maputol

Introduction

The Philippines, with an island-dwelling population of more than 103 million and more than 7 100 islands, is a major fishing nation and the world's second largest archipelagic state.

The Philippines has 18 major river basins, 421 principal rivers, 79 natural lakes, and a 17 460 km coastline. The country has 421 river basins, 20 of which are major river basins ranging from 990 sq km to 25 000 sq km. The country has 79 lakes, mostly utilized for fish production. In terms of area, they make up 80 percent of the total inland fishery resources. Ten major lakes are utilized for aquaculture production. Inland fishery resources of the country have an average production of 163 179 million tonnes per year.

In terms of coastal and marine ecosystem, the Philippines is situated in the vast Coral Triangle area. It hosts one of the most biodiverse marine ecosystems characterized by vast, rich and diverse coastal and marine resources. Its coastline, which extends to 36 289 km, is considered one of the longest coastlines in the world. About 832 municipalitites out of 1 541 munipalities, or 54 percent of municipalities in the country are in the coastal zone where around 1.5 million or 62 percent of the population live and are directly dependent on coastal and marine resources (CMR) for their livelihoods.

More than 50 percent of animal protein intake in the Philippines is derived from marine fishes. The country's coastal and marine resources can be broadly classified as fish stocks, coral reefs, mangroves, seagrass or algal beds and other coastal areas.

The Philippine territorial waters include some 27 000 sq km of coral reefs (measured to a depth of about 40 m) with the most diverse and extensive portions in the southern and central parts of the country. Coral reefs contribute on average from 8 percent to 20 percent to the total fishery production, although about 70 percent of this is contributed by only a few island reefs. The country has about 468 species of hard scleractinian corals (12 of which are endemic, 50 species of soft corals and 2 400 fish species.

The exclusive economic zone (EEZ) of the Philippines has diverse fishery resources with 2 800 species of finfish, of which 1 730 to 1 755 species are dependent on coral reefs for their existence. The country also hosts 168 species or 10 percent of cartilaginous fishes in the world.

In 2014, the Philippines ranked eighth among the top fish producing countries in the world with its production of 4.7 million tonnes of fish, crustacean, mollusk, and aquatic plants (including seaweeds). The production constitutes 2.4 percent of the total world production of 195.7 million tonnes. The fishing industry's contribution to the country's gross domestic product (GDP) was 1.5 percent (P 194 billion) and 1.7 percent (P 128.5 billion) at current and constant 2000 prices, respectively. It is divided between the municipal and commercial subsectors. Commercial fisheries contribute about 23 percent to total fishery production in the country, followed by municipal fisheries of 30 percent and aquaculture accounting for 47 percent. The industry employed a total of 1 614 368 fishing operators nationwide of which the municipal fisheries sector accounted for more than 1 million (1 371 676) operators and the commercial and aquaculture sectors added some 16 497 operators and 226 195 operators, respectively.

Major fisheries production system and commodities in the country

The Philippine fisheries industry comprises marine fisheries, inland fisheries, and aquaculture. Marine fisheries can be further divided into municipal fisheries and commercial fisheries.

Municipal marine fisheries (MMF) operate in coastal waters within 15 km from the coastline ("municipal marine waters"), using vessels ≤3 GRT, as well as fishing without the use of vessels. Commercial fisheries operate outside municipal waters, using vessels >3 GRT. Inland fisheries operate in inland waters such as lakes, reservoirs and rivers, including estuaries.

The Fisheries Code, or the Republic Act 8550, as amended by RA 10654, mandates that the Bureau of Fisheries and Aquatic Resources develops and implement a Comprehensive National Fisheries Industry Development Plan (CNFIDP). Based on the series of consultations conducted, the following are the overall fisheries sectoral targets under the CNFIDP:

Table 16. Overall fisheries sectoral targets set under the CNFIDP in the Philippines

CAPTURE
1 percent annual growth in municipal capture fisheries with considerations of proper management interventions
5 percent annual growth in commercial capture fisheries in new fishing grounds, or conditional on positive results on management inerventions
AQUACULTURE
Increase in aquaculture production for key species mentioned below as well as other high-value species depending on market demand: 4 percent annual increase for milkfish 6 percent annual increase for tilapia 10 percent annual increase for shrimp 25 percent increase over five years for seaweeds 10 percent increase over five years for shellfish 5.4 percent increase over five years for mud crab

Municipal fisheries

- In terms of marine fisheries production, the Philippines ranks twelfth in the world.
- MMF contribute 18 percent to the total fisheries and aquaculture production in the country.
- Inland fisheries contributes 3 percent to the total fisheries and aquaculture production in the country.
- MMF has an average annual value of USD 1 568 889 000.

Municipal fisherfolk – refers to persons who are directly or indirectly engaged in municipal fishing and other related fishing activities.

Municipal fishing – refers to fishing within municipal waters using fishing vessels of three gross tonnes or less, or fishing not requiring the use of fishing vessels.

Municipal waters – include not only streams, lakes, inland bodies of water and tidal waters within the municipality which are not included within the protected areas as defined under Republic Act No. 7586 (The NIPAS Law), public forests, timber lands, forest reserves or fishery reserves, but also marine waters included between two lines drawn perpendicular to the general coastline from points where the boundary lines of the municipality touch the sea at low tide and a third line parallel with the general coastline including offshore islands and fifteen kilometres from such coastline. Where two municipalities are so situated on opposite shores that there is less than thirty kilometres of marine waters between them, the third line shall be equally distant from opposite shore of the respective municipalities.

Major municipal fishing gears used in Philippines

1. Multiple hook and line/hook and line.
2. Gillnet/bottom set gillnet.
3. Surface gillnet/drift gillnet.
4. Fish traps/fish pot/crab pot/crab trap.
5. Squid jigger.
6. Fish corral/filter nets/giant fish corral/tower.

Threats/risks of CC and CC related extreme meteorological events to fisheries

Climate change in the Philippines could trigger a sea-level rise, drought risk, higher typhoon intensity and floods that could result in increased loss and damage as well as detrimental effects to food security. According to the Global Climate Risk Index 2016 released by Germanwatch, who conducts analysis on the impacts of extreme weather events based on fatalities and economic losses and damages, the Philippines was fourth in the ranking of countries to have suffered climate change-related disasters in 2014.

The Philippines is located on a typhoon belt wherein every year an average of 20 tropical cyclones visit the country, six to nine of these enter into the Philippine Area of Responsibility and make landfall. In the last ten years, there were 15 destructive typhoons that made landfall and devastated the country. The most devastating typhoons were: Typhoon Glenda which unleased flashfloods in the Luzon area leaving P 38.9 billion of economic losses; Typhoon Pablo which smashed into Southern Mindanao and hit part of Visayas and Luzon areas with P 42.2 billion in economic losses; and the most destructive and deadliest among the typhoons was Typhoon Yolanda which swept the Visayas area leaving an economic loss amounting to P 89.6 billion in 2013. Aside from destructive typhoons, the country also experienced fluctuations in rainfall, which resulted in drought commonly known as the El Niño phenomenon. There were four major El Niño occurrences in the country from 1982 to 2015. Based on official reports, severe drought occurred in 1982-1983, 1990–1992 and 1997-1998 and caused damaged to agriculture amounting to P 700 million, P 4.1 billion and P 8.46 billion, respectively. The recent occurrence of the El Niño phenomenon started in the second half of 2015 and ended in the first half of 2016 affecting farmers and fisherfolk amounting to losses of P 4 billion nationwide.

National efforts addressing climate change and building climate resilience of fisheries

a. National strategies and action plan development and progress with implementation

Policies

Republic Act No. 9729: "An act mainstreaming climate change into government policy formulations, establishing the framework strategy and program on climate change, creating for this purpose the climate change commission, and for other purposes."

Republic Act No. 10174: "An act establishing the people's survival fund to provide long-term finance streams to enable the government to effectively address the problem of climate change, amending for the purpose Republic Act No. 9729."

Local Government Units (LGUs)

RA 10121 mandated LGUs to ensure the integration of disaster risk reduction and climate change adaptation into local development plans, programmes and budgets as a strategy in sustainable development and poverty reduction; RA 9729 (as amended by RA 10174) states that LGUs shall be the frontline agencies in the formulation, planning and implementation of climate change action plan in their respective areas, consistent with the provisions of the Local Government Code (LGC), the National Framework Strategy on Climate Change (NFSCC), and the NCCAP.

Republic Act 8550 as Amended by RA 10654 "An Act to Prevent, Deter and Eliminate Illegal, Unreported and Unregulated Fishing"

- Establishment of Fisherfolk Settlement Areas (Sec. 141) in the context of an integrated, holistic and self-reliant community to include alternative sources of income.
- Declaration of closed season either spatial or temporal or by gear or fishing method may be declared as appropriate (Sec. 9).

Department of Agriculture: Creation of the Adaptation and Mitigation Initiative in Agriculture (AMIA) Team upon issuance of Department of Agriculture Special Order No. 156 series of 2014.

BFAR: Creation of CC-DRRM Technical Working Group (TWG) and Command Action Center (CAC) upon issuance of BFAR Fisheries Office Order No. 250 Series of 2016.

b. Research and technology development/publications

- Climate Change Research and Development and Extension Agenda and Program for Agriculture and Fisheries 2016–2022.
- Possible Effects of El Niño on Some Philippines Marine Fisheries Resources.
- Adaptive Strategies for Coping with Climate Variability: Experience of Philippine Traditional Indigenous Fishers.
- Development and application of the fisheries vulnerability assessment tool (Fish Vool) to tuna and sardine sectors in the Philippines.

Priority areas for climate change-resilient capture fisheries/marine fisheries

- spatial distribution and migration patterns of fish and socio-economic implications of changes in resources availability;
- development of early-warning systems inclusive of marine biodiversity and habitat;
- improvement of post-harvest technologies and food safety of major food fish species;
- recommendations for enhancing resiliency of fisheries infrastructures; and
- vulnerability assessment studies of coastal areas.

c. Programme/project activities addressing climate change in fisheries, covering both adaptation and mitigation

- national colour-coded maps for aquaculture and capture fisheries;
- development of fisheries management areas;
- establishment of fisheries reference points and harvest control rules;
- improved fisheries regulatory and law enforcement;
- early-warning systems for fishers;
- national stock assessment programme;
- regulation of municipal fishing gears/removal of destructing fishing gears;
- closed and open season at the LGU level;
- mangrove rehabilitation project;
- Malinis at Masaganang Karagatan (MMK) an award for outstanding farmers and fishers;
- EAFM of bays (integrated LGU management);
- establishment of artificial reefs; and
- inland fisheries enhancement programme – balik sigla sa ilog at lawa.

Major gaps and constraints in building climate-resilient fisheries

a. limited climate information services;
b. limited access to insurance and financial coverage to emergency services in times of disaster;
c. limited access to technologies and other resiliency measures;
d. limited organized communities to support community-based climate actions; and
e. limited capacity for LGUs in developing own CC adaptation and DRR plans.

Recommendations on regional strategy actions to support the national effort to build climate-resilient fisheries

BFAR adopted the Climate Change Disaster Risk Reduction Management Strategic Framework (CC-DRRM), a strategic framework developed under the Republic Act No. 10121 of 2010. The following are the thematic areas with the corresponding strategies and deliverables:

Thematic Area 1: Prevention and mitigation – prevention and mitigation provides key strategic actions to activities revolving around hazards evaluation and mitigation, vulnerability analyses, identification of hazard-prone areas and mainstreaming DRRM into development plans. It underscores the needs to develop a knowledge management and information system network for fisheries CC-DRRM, establish institutional mechanisms for fisheries CC-DRRM and promote fisherfolk empowerment to enhance adaptive capacity towards CC-DRRM.

Thematic Area 2: Disaster preparedness – this provides for key strategic actions that give importance to fisherfolk community awareness and understanding, contingency planning, conduct of local drills, and the development of a national disaster response plan.

Thematic Area 3: Response – provides for key actions that give importance to establishing coordination mechanisms and linkages for fisheries, in other words the CC-DRRM response.

Thematic Area 4: Rehabilitation and recovery aspect covers concerns related to the development and implementation of a rehabilitation and recovery plan for employment and livelihoods, infrastructure and lifeline facilities, and housing and resettlement.

The Republic of Korea

Christine A Young Kim

The Republic of Korea is a peninsula covering a total area of 99 000 km^2. The coastline around the peninsula is 8 693 km. There are also approximately 3 000 islands within the territory. Endowed with an abundance of fisheries resources, Koreans have developed a distinct fish food culture based on marine products.

Aquaculture production in Republic of Korea

The newly released FAO aquaculture statistics have recorded another all-time high world aquaculture production of 106 million tonnes in live weight in the year 2015, with a total estimated first-sale value of USD 163 billion.

According to FAO fisheries statistics total national fisheries production in the Republic of Korea was 2 119 220 tonnes in 2015, with capture fisheries accounting for 1 639 860 tonnes and aquaculture production 479 360 tonnes. This indicates a shift towards aquaculture when compared with historical capture and culture production quantities. The increase was a result of the government's aquaculture promotion policy and fleet reduction programme.

The Republic of Korea accounted for 1.567 million tonnes of aquaculture products in 2014, making it the seventh major producer of farmed species in the world.

The Republic of Korea used to rely heavily on capture production. However, a continuous decrease in capture production in previous decades has led the Republic of Korea to pay greater attention to aquaculture. Aquaculture production has increased from 293 420 tonnes in 2000 to 479 360 tonnes in 2015. Aquaculture has become a very important sector in the Republic of Korea. It provides food security,

revenue and employment to the country. With the development of new technologies, aquaculture production has increased rapidly.

Specific threats or risks of climate change

- albinism under the water in some islands in the East Sea;
- red tides are frequently seen during the summer season in the South Sea;
- typhoons occurring in Jeju Island in the South Sea;
- the natural phenomenon of high water temperatures could be exacerbated; and
- the appearance of subtropical animals including the pelagic sea snake or blue-ringed octopus in the Korean peninsula is also occurring because of climate change.

National efforts building climate-resilience of aquaculture

Further adaptation of legal framework: Republic of Korea has amended two major national acts, namely the Sustainable Development Act and the Framework Act on Low Carbon Green Growth.

The Sustainable Development Act has been elevated to fundamental law.

The Framework Act on Low Carbon Green Growth has been separated into two distinct and supportive acts, the Green Economy Acceleration Act and the Climate Change Action Act to adapt and properly respond to climate change while procuring climate resilience.

Comprehensive governance for pre-emptive response and effective reaction and management to deal with the incidents caused by climate change

As per the example of red tide (algal blooms), the Ministry of Fisheries will have the main responsibility for managing all relevant actions with regard to fisheries, the Ministry of Environment will be responsible for relevant R&D, the Ministry of Interior and Safety will be responsible for procuring all relevant equipment and the Ministry of Science and Information and Communication Technology (ICT) will be responsible for establishing and managing ICT facilities related to disaster prevention. Under the respective authority of each ministry, its subordinate institutes, regional offices, public service-related organizations and local administrations will carry out duties as detailed in the official disaster response manual that will be distributed to them. This cooperative structure constitutes comprehensive governance.

As a leading participant and a diligent member country with respect to international treaties and organizations, the Republic of Korea was invited to The Ocean Conference in June 2017 and submitted voluntary commitments for six distinctive areas under the Sustainable Development Goal 14: Conserve and sustainably use the oceans, seas and marine resources for sustainable development. The Republic of Korea believes that international cooperation for climate-resilient aquaculture will inevitably require a UN convention.

Implementation of climate-resilient aquaculture

A number of developments are being undertaken:

- development of new varieties of aquaculture and marine plants;
- development and industrialization of disease resistant and endothermic new varieties suitable for a subtropical climate;
- increasing the number of endothermic fish – unlike ectotherms, which rely upon environmental temperatures, endotherms are able to metabolically control their body temperature; though rare, some fish are able to internally regulate temperature, e.g. tuna;
- R&D on pollack – pollack is the most popular species in the Republic of Korea; until 1980, it had been a major landed fish, however, pollack resources are reducing because of overfishing and

climate change; an R&D project was started in 2014 with the goal to farm a pollack species on commercial-scale; national public research centres, local public research centres, and a university have all cooperated to achieve this goal;

- transferring shrimp aquaculture technology – the National Institute of Fisheries Science (NIFS) has been transferring biofloc technology of shrimp aquaculture to the National Institute for R&D of Fisheries and Aquaculture in Algeria since 2011. Biofloc technology makes aquaculture possible in the Sahara desert, which has extreme environmental conditions of little water, high temperatures, and unstable salinity. In 2016, the research centre of shrimp aquaculture opened and 5 000 kg of shrimp was produced. With the success of the project, Algeria has decided to expand shrimp aquaculture.

Sri Lanka

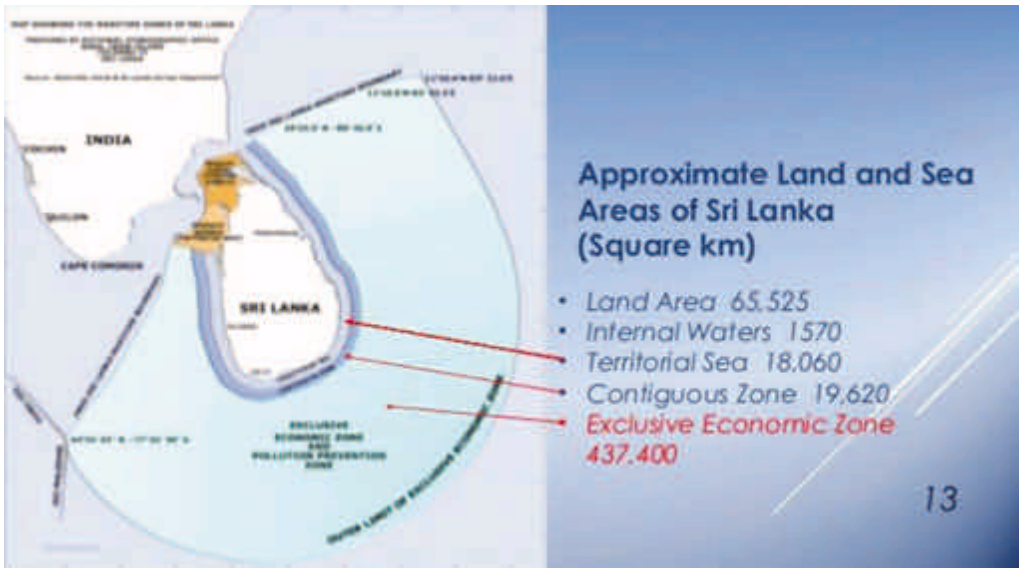
J H A A Jayasekara

1. Introduction

Sri Lanka, the southernmost island of the north Indian Ocean is richly endowed with coastal and marine ecosystems, however the tropical island positioned at the centre of a monsoonal regime is unfortunately prone to ocean disasters and climate change. The coastline of Sri Lanka is about 1 720 km long, ranks as the third longest in South Asia, and exhibits considerable geographic diversity. Almost one fourth of the population, including 65 percent of the urban population live along the coast.

The coastal region contributes 44 percent to the national GDP. The fisheries industry plays an important role in the economy of Sri Lanka by providing livelihoods for more than 2.5 million people living in coastal communities as well as providing more than 60 percent of the animal protein requirement of the country's population. In 2015 the share of fisheries to the gross domestic production (GDP) of the country was 1.3 percent. The total fish production of the country in 2015 was 520 190 tonnes. Marine fish production was 452 890 tonnes with the rest (67 300 tonnes) from inland fisheries and aquaculture. In comparison with the previous year, the offshore fish production increased marginally by 1.9 percent but the coastal fish production experienced a 3.5 percent decline. The total number of fishing families amounts to 610 000 and it is estimated that more than a million people from the coastal area are self-employed traders and depend on fisheries for their livelihoods. The fisheries sector contributes more than LKR 25 000 million in foreign exchange through the export of marine and aquaculture products.

Figure 6. Land and Water resources in Sri Lanka



2. Major fisheries production systems in the country

Table 17. Fish production from different sources in Sri Lanka 2016

Production system	Fish production (2016) tonnes
Coastal or inshore	269 020
Offshore or deep sea	183 820
Inland fisheries	57 060
Coastal aquaculture	10 240

3. Specific threats/risks of CC and CC related extreme meteorological events to fisheries

The climate change induced sea level rise and inflow of surface runoff and river inflow possess the potential to change the physico-chemical characteristics of coastal waters and may have an adverse impact on fishery habitats:

- climate change will affect fisheries and aquaculture via marine water acidification;
- changes in sea water temperatures (temperature rise of 2°C);
- change in weather circulation patterns (El Niño effects);
- frequency and severity of extreme events; and
- sea-level rise and associated ecological changes.

4. National efforts addressing climate change and building climate resilience of fisheries

The development of the national climate change adaptation strategy by the Ministry of Mahaweli Development and Environment was the main national action plan prepared by Sri Lanka in consultation with the Ministry of Fisheries and Aquatic Resources Development.

It followed the five principles devised for the strategy planning and development process. These five principles were to:

- pursue pragmatic solutions, in line with the national development agenda;
- initiate processes to mobilize significant investments that can go beyond advocacy and put in place resources to support and sustain development;
- mobilize people/institutions to work towards integrated solutions that capitalize on interests and opportunities to mobilize resources for climate change adaptation;
- harness the wealth of expertise and knowledge already available in Sri Lanka through a consultative process; and
- contribute towards developing the nation by seeking ways to ensure that Sri Lanka's development trajectory can be supported and made more climate change resilient.

5. Major gaps and constraints in building climate-resilient fisheries

- Climate prediction remains very uncertain mainly because of lack of long-term data and capacity to predict.
- Storms, originating in local waters, are not adequately forecasted and communicated because of the lack of knowledge in predicting local effects from regional and global models.
- A network of automatic recording stations is not yet established to measure atmospheric and ocean parameters, essential for climate/weather prediction and forecasting.
- Lack of financial resources allocation for research on fisheries and climate-related impacts.

6. Recommendations on regional strategy and actions to support the national effort to build climate resilient fisheries

- conduct climate change and fisheries sector related research and studies on possible impacts and adaptation measures for fisheries sector;
- improve data gathering and sharing with parallel agencies who carry out research and studies in the fisheries sector;
- improve fisheries sector's technical capacity to understand the consequences of CC and adopt new approaches;
- promote fisheries sector resilience building at local level; and
- employ sound science and technology improvement in the fisheries sector.

Thailand

Watcharapong Chumchuen

1. Introduction

Thailand has an estimated total length of coastline of 2 614 km along the Gulf of Thailand and the Andaman Sea, which encompasses 23 coastal provinces. The total exclusive economic zone (EEZ) of Thailand is 299 397 km^2. The rich fishery resources in Thai waters support more than 2 500 fishing villages which rely on marine capture fishery.

The marine capture fishery sector has an important role in the economy of Thailand. The total catch from the marine capture fishery was more than 1.5 million tonnes in 2014 that involved about 0.7 million people in fishing and factories, including female workers and migrant workers. The marine capture fishery in Thailand is composed of 11 types of fishing gears, of which the main types are bottom trawl, purse seine, and gillnet. The catches from these main types were 50 percent, 35 percent and 5 percent of the total catch, respectively. Moreover, Thailand is a major exporter and importer of marine fish and products. In 2013, Thailand exported 1.74 million tonnes (valued at about USD 6 506 million) of marine fish products, whereas imported marine fish amounted to 1.67 million tonnes (valued at about USD 2 845 million).

2. Major fisheries production systems and commodities in the country

Marine fishery resources in Thai waters are categorized into three major groups, i.e. anchovy, pelagic fish and demersal fish. As mentioned above, bottom trawl is the main fishing gear that accounts for half of the total catch. It indicates that most of the utilized marine fishery resources in Thai waters are in the group of demersal fish. Furthermore, purse seine is the second main fishing gear that captures, predominantly, anchovies, mackerels, bonitos and scads which are under the groups of anchovies and pelagic fish.

There are three main supply chains for the catch from the marine capture fishery. First, fish are processed by the local people through indigenous knowledge for household consumption or sold to markets. Second, fish are sold to markets, including local markets and supermarkets. Last, fish are sold to factories to produce fish sauce, surimi, canned fish, pouched fish, etc.

3. Specific threats/risks of climate change and climate change-related extreme meteorological events to fisheries

Thailand marine capture fisheries are confronted with threats and risks. There are seven issues that have been identified through risk assessment based on fishers' livelihoods and impacts on fishers, which are: (1) overfishing and overcapacity, especially the commercial fleets; (2) illegal, unreported and unregulated (IUU) fishing; (3) catching a large quantity of juvenile of commercial species; (4) conflicts between artisanal

and commercial fishers; (5) degraded critical habitats, such as mangroves, sea grasses and coral reefs; (6) inadequate fisheries data and information; and (7) inadequate fisheries management capacity.

From the seven issues, the degraded critical habitats issue is the only one that is affected by climate change (acidification and rise of temperature because of global warming) that has an indirect impact on the marine capture fishery. This aspect of climate change has significant effects on coral reefs that serve as nursery grounds for marine fishery resources. This phenomenon has changed the productivity and distribution of marine species.

4. National efforts addressing climate change and building the climate resilience of fisheries

Thailand is aware of the threats of climate change and joined the United Nations Framework Convention on Climate Change (UNFCCC) in 1994. Then the country adopted the Kyoto Protocol in 2002. Thailand founded the Thailand Greenhouse Gas Management Organization (TGO) in 2007. TGO's vision is to support organizations in decreasing greenhouse gas emissions. Also, there are many projects to reduce greenhouse gas emissions in Thailand, such as reforestation, wind energy and appropriate waste management. In 2015, the Prime Minister of Thailand, General Prayut Chan-o-cha, pledged during the twenty-first session of the Conference of the Parties (COP21) in Paris that the country would reduce the emission of greenhouse gas by 20 percent in 2020 and by 25 percent in 2030.

a. National strategies and action plan development and progress with implementation

Thailand established action plans under the National Strategy on Climate Change. The aim is for Thailand to be a climate-resilient society that cooperates with the global community to mitigate climate change based on the principle of sustainable development. The Thailand Climate Change Master Plan 2015–2050 is now established as a framework of integrated policies and action plans relating to climate change. Its purpose is to support climate change preparedness initiatives so that they are in line with Thailand's economic and sociocultural contexts as well as the sufficiency economy philosophy. There are three strategies for the master plan: (1) adaptation for coping with the negative effects of climate change; (2) mitigation of greenhouse gas emissions and increase of greenhouse gas sinks; and (3) strengthening the capacity of human resources and institutions and to manage the risks from the effects of climate change and cross cutting issues.

b. Research and technology development

In the marine capture fishery, bottom trawlers operating in Thai waters were selected for an energy audit in 2014 by the Training Department, Southeast Asian Fisheries Development Center (SEAFDEC/TD) in order to systematically evaluate the potential impact of fuel saving practices (the aim is not only to reduce fuel consumption, but also to decrease carbon emissions). The project results showed that there are many potential beneficial practices that can be implemented and they have a return on investment of less than one year. The potential practices can be applied in fisheries, for example, optimum cruising speed, gearbox and propeller modification, engine maintenance and fishing gear improvement.

c. Programme/project activities addressing climate change in fisheries, covering both adaptation and mitigation

Because of the impacts of climate change on fishery resources, Thailand has adopted management measures for the marine capture fishery to halt the depletion of marine species productivity. Time-area closure has been enforced for Thai fishers in both the Gulf of Thailand and the Andaman Sea. Marine protected areas (MPAs) are also a tool to conserve vulnerable ecosystems, particularly coral reefs, which are very important for the marine fishery resources as mentioned above.

According to ONEP, most greenhouse gas emissions were from fuel combustion. In terms of CO_2 emissions from the energy sector in 2000, the energy industry was responsible for 43 percent, followed by transportation 30 percent and manufacturing and construction 20 percent. It is noted that direct emissions from residences, commerce buildings and institutions reached only 3 percent, and the rest was from agriculture, forestry and fisheries. From this fact, the emissions from the marine capture fishery sector is assumed to be very minor. However, the mitigation of carbon emissions in the fishery sector is still needed through fuel saving practices that can help fishers improve the fuel consumption efficiency and reduce the fuel cost. As a result, it would also improve their livelihoods.

5. Major gaps and constraints in building climate-resilient fisheries

Thai fishers in the marine capture fishery sector are diverse in terms of livelihoods, education, beliefs and fishing knowledge. The major gaps and constraints are how to distribute information to the fishers on climate change, its impacts, and the required adaptation and mitigation measures, and the capability of fishers to understand and accept the information.

Thailand needs to enhance the capacity of fisheries researchers in applying new techniques to assess the vulnerability of fishery resources, and international support on the technical knowledge is still needed.

6. Recommendations on regional strategy and actions to support the national effort to build climate-resilient fisheries

Regional strategies and actions should promote the national effort through consultations and sharing information on building climate-resilient fisheries. The information may be adopted and applied by the country. Also, the international support on the technical knowledge could help in building climate-resilient fisheries in developing countries.

Timor-Leste

Acacio Guterres

1. Introduction

Timor-Leste's household survey found agriculture (including fisheries) to be the major source of income for 94 percent of villages. The fishery sector plays a significant role as an additional source of income and a source of animal protein and contributes 1.4 percent to the total GDP valued at USD 5.7 million.

Coastal fishing is dominated by small-scale fishing because of the absence of domestic fishing vessels exploring offshore fishing grounds. Timor-Leste's seas have a high biodiversity, both in terms of inshore, coastal fish populations (e.g. snappers and groupers) and offshore pelagic and mid-water species (e.g. mackerel and tuna). About 7 600 people, including those in the aquaculture sector, were employed in the fisheries subsector in 2008.

The Government of Timor-Leste has strongly emphasized the need for diversification of livelihoods for the improvement of food and nutrition security in the country. The Strategic Development Plan (SDP) (2011–2030), recognizes the importance of a thriving agricultural sector for food and nutrition security, reduction of poverty and for the economic growth of the nation as a whole.

To achieve the objectives stated in the SDP, the Directorate General for Fisheries Timor-Leste is preparing a Draft National Fishery Development Strategy which is targeting an annual average increase in fish consumption from 6.1 kg/capita to 15 kg/capita by 2030.

2. Specific threats/risks of climate change and climate change-related extreme meteorological events to fisheries

Timor-Leste has been increasingly affected by floods, landslides, strong winds, drought and sea level rise. Sea level surface temperatures have increased at a rate of 0.12°C per decade over the period 1981–2008. A recent report mentioned that the annual mean temperature is consistently increasing at a rate of about 0.016°C per year.

According to a South Pacific Community analysis, the specific impacts of climate change on Pacific fisheries, which is relevant to Timor-Leste, included changes to the distribution and abundance of tuna because of changes in ocean temperatures – stocks of skipjack and bigeye tuna in particular are likely to be affected – as well as reduced fisheries productivity and yields, and a decline in coral reefs and coastal fisheries. Iralalaru Lake's resources are among the most important resources of inland capture fisheries of local communities in Lautem Municipality, which is currently facing reduced water availability because of poor rainfall in the rainy season.

3. National efforts addressing climate change and building climate resilience of fisheries

a. National strategies and action plan development and progress with implementation

Timor-Leste Strategic Development Plan (SDP) 2011–2030 commits Timor-Leste to developing a National Adaptation Programme of Action (NAPA) to identify national priorities to address climate change adaptation and to monitor the implementation of adaptation measures.

Although a relatively young country, Timor-Leste ratified the UNFCCC on 11 April 2006. The country also ratified the Kyoto Protocol in March, Timor-Leste submitted its NAPA in 2011 and its Initial National Communication (INC) in 2014, and climate change impacts and vulnerability assessments were undertaken for both NAPA and INC. Moreover, the country has started its INC to the UNFCCC with the support of the Global Environment Facility, the Australian Agency for International Development (AusAID) and the United Nations Development Programme (UNDP).

Several activities which are relevant to the national implementation plan include NAPA implementation on mangroves and coastal zone management which is supported by GEF and implemented by UNDP. Moreover, the Government of Timor-Leste also participated in a study on climate change impacts and adaptation strategies as these relate to coastal and marine resources in Coral Triangle Initiative (CTI) countries.

b. Research and technology development

Although a relatively young country, in 2014 Timor-Leste established the Centre for Climate Change and Biodiversity (CCCB), under the National University of Timor Lorosae, with the aim to address adaptation research. In order to monitor climate change related parameters, Timor-Leste also established a baseline for future monitoring activities of several climate change-related parameters in the nearshore ecosystem which is supported by USAID and others.

c. Programme/project activities addressing climate change in fisheries, covering both adaptation and mitigation

In order to address climate change in fisheries and aquaculture, several project activities have assisted Timor-Leste, such as establishing a baseline for future monitoring activities of several climate change-related parameters in the nearshore ecosystem, NAPA implementation on mangroves and a coastal zone management project supported by GEF and implemented by UNDP, which is a joint partnership project. The Directorate General Fisheries Timor-Leste and WorldFish, have built a programme aimed at further developing capacity in climate change adaptation and improving coastal livelihood resilience, and the NAPA implementation project on disaster risk reduction (Dili-Ainaro corridor) and others.

d. Lessons learned/good practice from ongoing efforts

Timor-Leste actively participated in several international conventions and agreements to confirm its commitment, particularly adaptation and mitigation measures for alleviating the adverse impacts of climate change to the Timorese and to the international community such as Partnerships in Environmental Management for the Seas of East Asia (PEMSEA), CTI, WorldFish, Coral Triangle Center (CTC) and Arafura and Timor Seas Expert Forum (ATSEF). At the national level, the country has developed national resource management plan activities and policies that benefit coastal communities.

4. Major gaps and constraints in building climate resilient fisheries

Currently, local researchers on climate change on specific areas such as fisheries are poorly represented in the training, research and decision-making organs in the country. Climate change initiatives are limited by inadequate trained human resources at various levels, poor climate data and processing equipment. Experiences from the various training institutions indicate that very few institutions provide specific courses that address climate change impacts on fisheries.

5. Recommendations on regional strategy and actions to support the national effort to build climate-resilient fisheries

Considerable skills development on climate change, vulnerability, adaptation and mitigation is needed within the partner institutions. Such a skills development programme is expected to address issues on promoting national policy, financial aspects of climate change adaptation, data availability and climate modelling by facilitating human capacity and infrastructure development.

Viet Nam

Lai The Hung

1. Fisheries overview

In Viet Nam, fisheries play an important role in the economy. Annually, fisheries have contributed about 4.18 percent/year to the national GDP, over 4.1 percent of total export value, approximately 40 percent of the total animal-based protein for the people and provided nearly 4 percent of employment. Moreover, fisheries have contributed positively to poverty alleviation and food security.

2. Major fisheries production systems (marine and inland) and commodities in Viet Nam

The fisheries sector in Viet Nam comprises marine fisheries, inland fisheries and aquaculture. In marine fisheries, fishing gear types include trawls, gillnets and similar nets, surrounding nets and lift nets, hooks and lines, dredges, pots and traps.

The total marine catch is over 3.1 million tonnes (2016), of which approximately 94 percent is from marine capture fisheries. Species caught from marine capture consist of ground feeders, surface feeders, coral reef fish, crab, shrimp, squid/octopus and others.

Inland fisheries are small scale, fishing mainly conducted in natural basins (rivers, rill, reservoir, lagoon etc.) and account for over 6 percent of fisheries production, providing fish for household consumption.

3. Specific threats/risks of CC and CC related extreme meteorological events to fisheries

Climate change causes a rise of temperature of surface water, reducing the amount of oxygen, leading to changes in the reproductive performance of marine species, most of which are negative in terms of species

volume (especially shrimp). The food chain of seafood species is therefore also declining. Because of temperature changes, coral reefs in the central provinces have died in some areas, so that the habitat of marine species is narrower, affecting ecosystem structure and function particularly in mangroves and sea grasses.

Climate change is changing sea currents, salinity, sediment thickness and has remarkable impacts on the migration of aquatic species, on the fluctuations of marine resources, and on the inherent biodiversity.

The negative impact of climate change causing natural disasters such as terrible storms, unexpected cyclones, floods, that destroyed fishery infrastructures (fishing ports, fish landing sites etc.), fishing boats leading to huge human and financial losses for fisheries industries.

4. Viet Nam's efforts addressing climate change and building the climate resilience of fisheries

4.1. National strategy and action plan development: the Vietnamese Government and MARD have issued many important strategies and policies to cope with climate change, such as:

- *The strategies and policies approved by the Prime Minister:* The national target programme to respond to climate change; the national climate change strategy; the national target programme to cope with climate change in the period 2012–2015; the national action plan on climate change for the period 2012–2020.[15]
- *The strategies and policies approved by the Minister of the Ministry of Agriculture and Rural Development:* the plan of training staff in the fisheries sector and community on mitigation and adaptation to climate change; the action plan to respond to climate change in agriculture and rural development sector to 2020 and vision to 2050; the integration of climate change elements in the formulation and implementation of strategies, master plans, programmes, projects in the period 2011–2015; the project to reduce greenhouse gas emissions in agriculture and rural areas to 2020; the plan to cope with climate change in the period 2012–2020; the building of a community model to actively prevent and mitigate natural disasters and adapt to climate change; the plan for implementation of various tasks under the National Target Programme to respond to climate change.[16]

At this time, the National Assembly is preparing the Fisheries Law, in which Article 5 regulates activities in accordance with climate change in the fisheries sector.

4.2. Research and technology development: especially research from MARD and international organizations including:

- research on trend of the marine fisheries resources in the sea of Viet Nam 2011–2015;
- research on species diversity and marine resources in coastal ecosystems of Viet Nam;
- research on the diversity of marine species in coral reef ecosystem and coastal areas in Viet Nam islands 2010–2015;
- research on hard coral biodiversity and coral reef ecosystem in central Viet Nam's coastal waters;
- research on fishing grounds forecast for squid stick-held falling net in Tonkin Gulf in 2015;
- research on fishing efficiency of gillnet and tuna line fisheries in offshore waters of Viet Nam;
- research on the effects of temperature and salinity on embryonic development of mudskipper (*Boleophthalmus pectinirostris*);

[15] Issued number and date: No.158/2008/QD-TTg; No. 2139/QD-TTg on 5 December, 2011; No. 1183/QD-TTg dated 30 August, 2012; No. 1474/QD -TTg dated 5 October, 2012.

[16] Issued number and date: No. 2493/BNN-KHCN dated 17 September, 2010; No. 543/QD-BNN-KHCN dated 21 March, 2011; No. 543/QD-BNN-KHCN dated 21 March, 2011; No. 809/CT-BNN-KHCN dated 28 March, 2011; No. 3119/QĐ-BNN-KHCN, dated 16 December, 2011; No. 66/2013/QD-BNN; No. 104/QĐ-BNN-KHCN dated 20 January 2014; No. 5508/QĐ-BNN-KHCN dated 23 December, 2014.

- research on water quality in tuna farm at Van Phong bay, Khanh Hoa province;
- estimate of costs of climate change for fisheries in the north and proposal for reducting these costs; and
- impact assessment on method of production of sea products in Viet Nam in conditions of climate change.

4.3. Programme/project activities addressing climate change in fisheries, covering both adaptation and mitigation

In the period 2011–2015, the total number of activities identified in the Action Plan to respond to climate change in agriculture and rural development is 54 with the proposed budget about USD 2.1 million from the national budget; Coastal Resources for Sustainable Development Project (CRSD) with USD 117.9 million in loans from the World Bank.

Specific solutions/activities have been carried out: developing policies to restructure fisheries production in adaptation to climate change; integration of climate change issues into a review of fisheries development planning; development of integrated technical solutions for sustainable fisheries; development of community models which actively prevent and mitigate natural disasters and adapt to climate change.

4.4. Lessons learned/good practice from ongoing efforts

The programme of adaptation and mitigation of climate change in the fisheries sector has not really been linked with the development and implementation of policies, strategies, plans from the ministerial to the local level. Projects and tasks are carried out only in pilot areas, and there is lack of an inter-regional vision, so that they are only effective in the project site, and do not meet the wider requirements. Besides that, the budget limitation leads to a narrow scale of implementation.

5. Major gaps and constraints in building climate-resilient fisheries:

- strategies and action plans are really not sufficiently detailed;
- lack of awareness of climate change among fisheries communities; and
- lack of funding for the investment for research and implementation of climate change projects.

6. Recommendations on regional strategy and actions to support the national effort to build climate-resilient fisheries:

- build a common regional vision of climate change adaptation and mitigation in fisheries;
- develop a regional strategy for adaptation to climate change;
- implement regional projects on climate change adaptation and mitigation in fisheries;
- collaborate and share experience and information on climate change adaptation and mitigation in the region; and
- call for a fund for common adaptation and mitigation programme/project activities in fisheries in order to address quickly and adequately climate changes issues of significance for fisheries.

Extended summaries of country/regional partner/project/private sector presentations: Aquaculture

Bangladesh

Syed Mohammed Alamgir

Introduction

Bangladesh has one of the largest deltas in the world that is located at the confluence of the dense network of the major river systems of the Ganges, Brahmaputra, Meghna and their tributaries. The country has a land area of 147 570 sq km and a population of 163 million. Bangladesh is highly vulnerable to natural disasters because of its geographic location, flat and low-lying landscape and high population density (more than 1 100 per sq km). As a sector of agriculture, fisheries plays a substantial role in the socio-economic development of the country through ensuring food security, generating income, alleviating poverty and earning foreign currency.

The fisheries sector provides 60 percent of the people's daily intake of animal protein, creates direct or indirect employment for almost 11 percent of the total population, and contributes 3.61 percent to GDP (agricultural produce accounts for about 24.41 percent). Moreover, the export of fish and fish products accounts for 1.87 percent of the total export earnings of the country. The fisheries sector of Bangladesh comprises inland capture fisheries, marine capture fisheries and inland aquaculture, which alone contributes 57 percent of the country's total fish production. Over the last ten years (FY 2006-2007 to 2015-2016) Bangladesh has been able to achieve a fairly steady average growth rate in fish production of 5.24 percent. A study found that more than 17 million people including 1.4 million women depend on the fisheries sector for their livelihoods in the form of fishing, fish farming, fish handing and processing.

Major aquaculture systems and commodities in the country

Aquaculture is one of the fastest growing food producing subsectors in Bangladesh demonstrating a continuous increase in total fish production during the last couple of decades. The available fisheries production systems can be broadly categorized on the basis of diverse water resources, into inland capture, inland culture, and marine capture. The country has inland closed waters of 0.79 million hectares consisting of ponds, ditches, ox-bow lakes (*baors*), canals, floodplains, seasonal waterbodies, shrimp ponds in former rice fields (*gher)*, crab farming enclosures, pens and cages that support a remarkably expanding aquaculture system. Aquaculture practices range from simple small-scale backyard pond production systems to semi-intensive, intensive and large-scale, highly intensive commercially oriented farming practices and operations.

Small-scale pond aquaculture has taken off dramatically over the past decades especially under the influence of a number of major government and donor-funded aquaculture development and extension projects. As a result of these projects, the Government of Bangladesh has created a network of fish hatcheries which has ensured a reliable supply of good quality carp seed to the farmers. Then it has identified key parameters of successful pond aquaculture production, undertaken appropriate pond preparation, including preliminary fertilization and stocking with an appropriate fish species to utilize the different ecological niches in the pond and at the right density. Judicious feeding and fertilization during grow-out, maintenance of a good pond environment to ensure efficient utilization of pond fertility and feeding has led to considerable success. Despite remarkable progress in aquaculture production, the sector has faced frequent adverse effects of climate change because of global warming in recent past years.

Aquaculture is dominated by Indian major carps, twelve exotic carps, tilapia, Thai pangas, catfishes, small indigenous species and shrimp and freshwater prawns. In 2015-2016, total aquaculture production was estimated to be 2.20 million tonnes, which accounts for 57 percent of the country's total aquaculture production.

Clearly, Bangladesh needs to formulate policies and institutional arrangements to build climate-resilient fisheries and aquaculture to adapt its fisheries production to changing climatic conditions.

Specific threats/risks of climate change and climate change-related meteorological events to aquaculture

Bangladesh is most exposed to natural hazards and vulnerable to the environmental degradation because of climate change impacts. There are many dimensions of degradation such as lowering of groundwater level and contamination, shrinking water surface, increased pollution, and loss of biodiversity. Climate changes in the form of temperature fluctuations, erratic rainfall and flooding, prolonged drought etc. affect aquatic systems and their productivity. Higher water temperatures bring changes in physiology and the sex-ratio of fish species in freshwater ecosystems. Aquaculture production is threatened by climate change mainly in two ways: first, hatchery operations are adversely affected by climate change because of reduced water level, contamination, and pollution of surface water, lowering of groundwater level, deterioration of water quality and fluctuation of temperature, prolonged droughts etc., which hampers gonadal maturation and reproductive success; second, aquaculture production is reduced because of the limited water retention capacity of pond basins, deterioration of water quality parameters and fluctuation in temperature and salinity causing stress and fish disease, and cyclones, storms and flash floods destroy infrastructure and loss of farmed fish, thus increasing the cost of investment.

National efforts addressing climate change and building climate resilience in aquaculture

Bangladesh has established the Bangladesh Climate Change Trust Fund (BCCTF) and the Bangladesh Climate Change Resilience Fund (BCCRF) to address the challenges emerging from climate changes. There also exist plans such as the National Action Plan on Adaptation and Bangladesh Climate Change Strategy and Action Plan.

The Ministry of Fisheries and Livestock (MoFL) and the Department of Fisheries (DOF) have undertaken policies and measures to build a climate-resilient aquaculture, such as: (i) improvement of aquaculture management and practices; (ii) development and implementation of mechanisms allowing re-use of surface water and temperature control system in hatchery operations; (iii) introduction of fast-growing species and development of suitable short-term management practices; (iv) development and expansion of adaptive aquaculture systems, such as rice-fish culture, cage culture, pen culture, integrated aquaculture etc; (v) establishment of management practices for salinity-tolerant fish species in coastal areas; (vi) introduction of short cycle aquaculture with improved technologies and management practices in seasonal ponds; (vii) introduction of campaigns to create awareness regarding impacts/risks of climate change pertaining to aquaculture; (viii) provision of programmes to increase adaptation and management skills in response to CC effects; (ix) incorporation of development plans into CC-resilient aquaculture; (x) strengthening inter-ministerial cooperation and collaboration to address CC issues; and (xi) development of human resources to increase institutional capacity to handle CC related issues.

Major gaps and constraints in building climate resilient aquaculture

Greater climate variability and uncertainty complicate the task of adaptation to the impacts of climate change on fisheries/aquaculture. Information on impacts of climate change on fisheries/aquaculture is limited. Moreover, there remain knowledge gaps that make it difficult to find innovative means to improve the existing adaptability of fishers and fish farmers. More importantly, the government lacks adequate resources and funds to support national programmes pertaining to climate-resilient fisheries/aquaculture.

Recommendations

The negative impacts of climate change on aquaculture are long-lasting. The unfolding calamity that Bangladesh is encountering from climate change necessitates a response and cooperation from the

international community to support the national efforts of the Government of Bangladesh, especially in terms of:

- awareness raising, capacity building and skill development on climate change issues;
- integration of climate change issues (impacts, risk, threats, vulnerability, adaptation and mitigation) into national fisheries policies, strategies and programmes;
- improving knowledge generation, technologies, scientific research, research and development, access to information and the information dissemination structure;
- improving capacity for planning and implementation of adaptive and mitigation projects in fisheries and aquaculture systems;
- developing and implementing adaptation and mitigation programmes with the vulnerable fishers, farmers communities living in climate hotspots;
- accessing international funding and technology support under the UNFCCC and multilateral funding mechanisms;
- gaining easy access to the information on CC issues; and
- increasing investment in research and actions on climate resilient and sustainable fisheries/ aquaculture and food security

Cambodia

Chin Da

Introduction

Cambodia has total land area 181 035 km^2 with a total population estimated at 14 million in 2010 and a rate of growth of 1.54 percent per annum. Cambodia's coastal zone, which is located in the southwest of the country, has a total length of approximately 435 km. Cambodia's climate is characterized by two major seasons: a dry season and a rainy season. The annual average temperature is 27°C, and rises to a maximum of 38°C and falls to a minimum of 14°C in December-January.

Agriculture is the major occupation for about 85 percent of the population. Rice and fish are the basic diets of the Cambodian people. Fish is the most important source of animal protein for Cambodian people, providing 75 percent of total animal protein intake for the population and also important micronutrients such as calcium, iron, vitamin A and vitamin D. Annual fish consumption based on official statistical data is estimated at an average of 52.4 kg/person, according to the household survey it is on average 60 kg/person to 66 kg/person and for households in the Tonle Sap and plains region it is 67 kg/person to 80 kg/person.

Inland aquaculture has been practiced in Cambodia for a long time. There are diverse farming systems such as culturing in cages, ponds, tanks and rice fields. The farm operations range from small scale using on-farm by-products/domestic wastes to large scale using compound/formulated feed to produce fish. Inland aquaculture production was 55 000 tonnes in 2001 and reached 172 500 tonnes in 2016 with an average annual growth of 15 percent. Fish produced from inland aquaculture is mainly to meet the local market demand. Inland aquaculture contributes to food security and livelihood improvement mainly in rural areas (accounting for 75 percent of aquaculture livelihoods). However, inland aquaculture is estimated to comprise only 30 percent to 40 percent of total aquaculture production. Both freshwater and marine aquaculture production are mainly for domestic consumption.

Government aquaculture development and research centres and institutes have been playing an important role in conducting research experiments on brood stock management/nursing/breeding and producing fingerling for distribution to farmers. However, the fish seeds production has been insufficient to supply them and the government fisheries administration has been establishing freshwater private fish hatcheries at commune level in order to supply the fish seeds to the local farmers. Furthermore, a large

amount of fish seeds is collected from the wild largely for stocking cages. There are no marine private hatcheries yet because of lack of technologies and funds for establishing and operating them.

Major aquaculture systems and commodities in the country

Aquaculture in Cambodia is carried out in ponds, cages, pens, tanks and rice fields ranging from extensive, semi-intensive and intensive culture. Ponds and cages predominate.

Fish culture in floating cages has been undertaken since the tenth-century. About 50 percent of total fish production originates from cage culture. Three main species are cultured, namely *Channa micropeltes, Pangasianodon hypophthalmus* and hybrid catfish. The fish cages can be found in various freshwater areas and there were 6 681 cages (160 344 m^3) in 2016 found in the Great Lake (40 percent), Tonle Sap River (26 percent), the Upper Mekong River (18 percent), the Lower Mekong River (8 percent) and the Bassac River (8 percent). Some main fish species cultured in freshwater cages include snakehead (47 percent), pangasius (27 percent), clarias (23 percent) and other (3 percent). Production differs by species: 40 kg/m^3 to 138 kg/m^3 for snakeheads (average size 0.75 kg to 1.5 kg with a culture period of 6 months) and 46 kg/m^3 to 90 kg/m^3 for pangasius catfish (with a culture period of nine months).

Freshwater pond culture has not been a traditional activity, as it only began in 1960. The aquaculture systems consist of extensive/semi-intensive 75 percent (low input) and intensive 25 percent (high input). The three main fish species operating in pond intensive systems are *P. hypophthalmus* (20 tonnes/ha to 50 tonnes/ha, 1 year growing time, stocking density 8 heads/m^2 to 25 heads/m^2), snakehead fish (50 tonnes/ha to 70 tonnes/ha, 1 year growing time, stocking density 30 heads/m^2 to 40 heads/m^2) and hybrid catfish (10 tonnes/ha to 80 tonnes/ha, 2 crops/year to 3 crops/year with stocking density of 10 heads/m^2 to 150 heads/m^2).

Extensive/semi-intensive culture has been practiced mainly in ponds since 1986, and a small number of households are culturing in cages and rice fields, which are promoted particularly in areas away from wild fish production sites. Both native and exotic species are cultured in ponds of size ranging from 80 m^2 to 300 m^2 and in cages of size ranging from 4 m^2 to 10 m^2. The production from ponds is 25 kg/100 m^2 to 50 kg/100 m^2 with culture period of eight months and the production from cages is 5 kg/m^2 to 30 kg/m^2 with culture period of 3 months to 9 months).

The freshwater rice-fish farming system was introduced in 1997, mainly in rural areas and to farmers who had rice fields close to their houses in order for farmers to utilize the water which was available in their rice fields for about six months. This rice-fish farm system has developed slowly because of lack of water sources for supplying it mainly in the dry season. The fish production is only about 100 kg/ha to 500 kg/ha/in a six-month period.

Marine aquaculture is operated in coastal areas in semi-intensive cage culture systems with grouper and seabass mainly and in ponds with shrimp. Seeds for stocking have almost entirely been imported from neighbouring countries and there no private marine fish hatcheries in Cambodia yet. Aside from conducting experimental research, the government marine aquaculture research and development centre has been producing seeds for distributing to farmers, but not enough.

1) Specific threats/risks of CC and CC-related extreme meteorological events to aquaculture

Climate change in Cambodia could have possible impacts on fisheries resources, aquaculture production, socio-economic welfare and food security and nutrition of the Cambodian people.

In Cambodia, extreme meteorological events related to climate change have occurred almost every year. More than 130 people died and nearly 300 were injured in accidents caused by natural disasters across the country in 2016, according to a spokesman for the National Committee for Disaster Management. Moreover, some of fish raising ponds were damaged, fish production was low and profits were lost.

Flooding has occurred almost every year in some places, and in 2013, many fish raising ponds were flooded (about 2 114 ponds flooded or 5 percent of the total). Floods affected 496 vulnerable fish farmers whose fish farms infrastructure was destroyed, which resulted in the escape of 445 tonnes of table fish, 6 tonnes of brood fish and more than 3 million fingerlings.

Drought is also a serious risk partly because of lack of irrigation facilities. In some locations, rural farmers have the opportunity to plant rice every three months on the basis of the built irrigation systems, but they cannot farm fish because their fish ponds have almost dried up and are far from the irrigation systems. The rural fish ponds have mainly relied on rainwater which might be available for a maximum of six months only in some locations. Hence, farmed fish production which relies on rainwater is always low and rural farmers have shortages of fish for household consumption. One of the aquaculture development strategic plans of the Fisheries Administration is to develop village fish hatcheries in order to supply fish seeds to rural farmers for stocking and raising in fish ponds. In the dry season, almost all village fish hatcheries have difficulties to nurse brood fish and sometimes their brood fish die. Moreover, drought has mainly obstructed the village fish hatcheries from producing sufficient fish seeds and there is alack of fish seeds to supply to farmers' fish ponds.

2) National efforts addressing climate change and building climate resilience of aquaculture

At the national level the National Committee for Disaster Management (NCDM) is the key agency responsible for disaster management in Cambodia. It consists of 22 members from different ministries and supports provincial, district and commune committees. Village Disaster Management Groups are the lowest-level bodies. In July 2014, the NCDM announced that the government had begun constructing more disaster-resilient infrastructure with support from the World Bank and other development partners. Cambodia has developed a Strategic National Action Plan (SNAP) for Disaster Risk Reduction.

There are also other agencies/institutions that play important roles in coping with climate change, for example the Ministry of Water Resources and Meteorology warns about coming floods and develops irrigation systems to provide water in the dry season. Individual ministries also enforce their own strategies, such as the Ministry of Agriculture, Forestry and Fisheries' Plan of Action for Disaster Risk Reduction in Agriculture 2014–2018.

Fisheries Administration (FiA) also has a fisheries and aquaculture development strategic plan for coping with climate change and has set a clear vision, mission, goal, objectives and strategic activities. The goal of the Climate Change Strategic Plan (CCSP) is "to promote development and effective management of fisheries in response to climate change with particular focus on improvement of aquatic ecosystems, prevention of flooded and mangrove forests destruction, promotion of research study and development of aquaculture and processing as well as strengthening more effective community fisheries (CFi) management."

Based on the CCSP of FiA, some of the main activities related to the building of CC-resilient fisheries and aquaculture have been carried out in 2014 as follows:

- capacity building of FiA officers at national, subnational and CFi level for training of trainers and other stakeholders, including women;
- scaling up of some adaptation activities has been achieved with the pilot demonstration of the Cambodian Climate Change Alliance project; and
- conducting some assessment of the climate change impact and vulnerability in fisheries and aquaculture with some modeling capacity to identify the resilience of seed, feed, and technology.

The way forward:

- there is a need to integrate the CCSP and CCNAP into the ten-years FiA-FSP, especially at commune level;

- there is a need to conduct some assessment of the climate change impact and vulnerability in fisheries and aquaculture continuously with some modeling capacity to identify the resilience of seed, feed, and technology subsectors;
- annually, more CC related projects should be implemented in target areas which have suffered from CC impacts and the obstruction of aquaculture development; and
- institutional coordination and cooperation need to be enhanced at national, regional and international level with developing country partners and other stakeholders to implement the FiA-CCNAP.

Lessons learned/good practice from ongoing efforts

The impact of CC poses risks to the development of aquaculture mainly in rural areas where poor households are less educated and have fewer funds to cope with CC. Drought and floods have obstructed aquaculture activities and development among rural fish farmers who have mainly relied on their farmed fish for their households' consumption and for improving their livelihoods. Many fish farmers have lost their profits and lack knowledge, capacity, facilities and funds to cope with the negative impacts of CC. FiA has tried to implement pilot projects with some of selected fish farmers to cope with CC and has achieved good results.

For coping with flooding there are a number of choices:

- raise up the embankments around fish farms;
- raise dikes in a few fish ponds or screen the ponds, particularly for keeping broodfish/big fish in; and
- build cages in fish ponds to secure fish in the floating cages when flooding occurs.

For coping with drought:

- raise some of fish species that grow fast or need less water for stocking and growing;
- construct at least a few very deep fish ponds, particularly for keeping broodfish/big fish; and
- build cages in big water reservoirs in order to secure fish in floating cages.

3) Major gaps and constraints in building climate-resilient aquaculture

There are numerous gaps or constraints as follows:

- shortage of resources and technical knowledge on CC resilience to support and develop aquaculture;
- limited skills, capacity and facilities to conduct research in order to build the climate change resilience of aquaculture;
- lack of good research and CC related data in many areas;
- shortage of funds, including for investment in infrastructure construction to cope with natural disasters;
- lack of funds to rehabilitate fish farms after extreme flooding; and
- loss of quality of brood fish used to produce good quality of fish seeds, because of low water volume and an increase in environmental temperatures.

4) Recommendations on regional strategy and actions to support the national effort to build climate-resilient aquaculture

- increase knowledge base of climate change resilience through regional training, workshops, study tours, field visits and similar events;
- enhance shared systems of updated and innovatory technologies related to building climate resilient-aquaculture in the Asia-Pacific region; and
- prepare regional strategic planning to cope with natural disasters.

China

China is considered as "the cradle of aquaculture". The country is recognized not only for having a long history in aquaculture, but also for its important role in the development of aquaculture in modern times and its contributions to global food security. In the mid-to-late twentieth century, after nearly 30 years of debate, discussion, and practices, China advocated the "culture-oriented" development policy in fisheries in 1986, thus contributing to the rapid development of aquaculture. Aquaculture production increased from less than 100 000 tonnes in 1950 to 3.63 million tonnes in 1985 and to 51.42 million tonnes in 2016, resulting in an increased proportion of aquaculture in fisheries from 8 percent to 45 percent and then to 74.5 percent, respectively, with an almost fourfold production enhancement in the last 30 years. Aquaculture has become one of the fastest growing industries in the large-scale agricultural development of China. Aquaculture greatly contributes to the wide availability of a high quality source of protein and to the national economy, and in 2016 the estimated annual per capita consumption of aquatic products reached 49.91 kg in China.

The initial stage of modern Chinese aquaculture development began in the 1950s with only dozens of species. With the development of artificial propagation technology for the four major aquaculture fish – black carp (*Mylopharyngodon piceus*), grass carp (*Ctenopharynogodon idellus*), silver carp (*Hypophthalmichthys molitrix*), and bighead carp (*Aristichthuy nobilis*), as well as for marine mollusks, seaweeds, and other species, up to a hundred aquatic species became available for culture in the 1980s. In the twenty-first century, because of the continuous progress and improvements in artificial propagation and farming technologies, the number of culture species increased significantly. There are 296 species (including 25 introduced species) and 143 varieties (including 138 new breeding varieties and five introduced varieties) in Chinese aquaculture, thereby providing 439 farmed species and varieties. Through long-term development, the structural characteristics of Chinese aquaculture have been effective, reasonable, and have been in accordance with the needs of modern development. Aquaculture not only solves the problem of the lack of seafood resources, increases the income of fish farmers, provides high-quality protein, and contributes significantly to adjustments in the fisheries structure, but also plays an active role in reducing the release of CO_2 and alleviating eutrophication in waters.

Regarding the specific risks of climate change to aquaculture, Chinese researchers have mainly focused on shrimp, crab and some kinds of mollusks. For example, they have conducted research on the detrimental effects of reduced seawater pH on the early development of the Pacific abalone, and analyzed the impact of seawater carbonate variables on post-larval bivalve calcification, as well as the potential of ocean acidification to suppress larval development in the Pacific oyster and blood cockle. Moreover, research has clarified the relationships between climate change and feed management in shrimp pond culture, and the response of river crab to climate change, and has predicted the developing trends of river crab under climate change by using computer modelling. As a result of creating different climate change scenarios, some aquaculture species have been changed and regulated, and some aquaculture models have been revised and developed. In addition, during the thirteenth five-year plan period, the National Key Research and Development Programme has taken climate change and aquaculture into key account, and a planning project on the response of aquatic organisms to climate change will be submitted in 2018. The effects of climate change on aquaculture have been addressed in the Fourth National Assessment Report on Climate Change in China, which was launched in 2017.

The future development of Chinese aquaculture will follow green, sustainable, and environment-friendly development concepts, aiming at developing aquaculture with "higher efficiency, higher quality, ecology, health and safety". Therefore, Chinese aquaculture will explore new production models for appropriate development with different characteristics, including healthy aquaculture models, ecological farming models, IMTA models, RAS models, and an integrated rice-fish farming models; develop EAA based on carrying capacity to enable the construction of environment-friendly aquaculture. Obviously, such development patterns can better highlight the functions of food supply and ecological services of

aquaculture, thereby meeting the needs of China's social development, the demands of modern aquaculture development, and the balance of human needs and ecological benefit. In turn, Chinese aquaculture development patterns can thereby make a greater contribution to the protection of national food security and the construction of an "ecological civilization".

India

S.K. Singh

Introduction

The country has vast inland fisheries resources, which play vital role in food security, rural livelihoods and aquaculture development. The vast inland resources include a network of rivers, canals, estuaries, floodplain lakes and the ponds and tanks located in different geographical regions. They comprise 2.36 million ha of ponds and tanks, 0.19 million km of rivers and canals, 1.2 million ha floodplain lakes and 3.15 million ha of reservoirs.

India is the second largest producer of fish and also the second largest producer of freshwater fish in the world. Total fish production of India was 10.80 million tonnes (7.210 million tonnes for inland fisheries and 3.58 million tonnes for marine fisheries) in 2015-2016. During the financial year 2015-2016, Indian fisheries had an export value of USD 5.5 billion which is about 0.9 percent of the national GDP and 5.17 percent to the agriculture GDP (2015-2016). The inland fisheries presently have a share of 66.81 percent of the country's total fish production. The historical scenario of Indian fisheries reveals a paradigm shift from marine dominated fisheries to a scenario where inland fisheries have emerged as a major contributor to the overall fish production in the country. About 1.5 billion people are engaged in fisheries activities.

In the country, small-scale and artisanal fisheries constitute a significant part of the fisheries sector. Small-scale actors are usually the most vulnerable to climate change and environmental hazards. In fact, they have limited resources and capacities to adapt to unforeseen events and fishing conditions that may result from climate change. Therefore, it is necessary to adopt specific adaptive measures to make small-scale and artisanal fisheries more resilient to climate change impacts. The future implications of climate change make extremely urgent the need to advance policy reform in capture fisheries, including addressing the problem of overcapacity and overfishing as part of mitigation and adaptation strategies. The adoption of adaptive measures should aim at ensuring the continuation and sustainability of fisheries production and trade. Moreover, adaptative measures in combination with mitigation actions could increase the competitiveness of the sector.

Climate change will increase uncertainties in the supply of fish from capture and culture operations. Such uncertainty will impose new challenges for risk assessment, making it critical for resources planning and management to take into account the greater possibility of unforeseen events, such as the increasing frequency of extreme weather events and "surprises." Expert recommendations on fisheries, climate change and food security is that in the face of these impacts and the existing development and management constraints, the primary challenge for the sector will be to deliver food supply, strengthen economic output and maintain and enhance food security and at the same time ensure ecosystem resilience. The long-term productivity of stocks is related to the carrying capacity of their environment. These may alter as a result of overfishing as well as changes induced by climate change.

The country's rural areas have limited adaptive capacities, mainly because of the small size of their economies with a low degree of diversification and low level human resource development. Moreover, they are highly exposed to climate change, and have a high degree of dependency on the fisheries sector economically, socially and nutritionally.

Major aquaculture systems and commodities in the country

It is obvious that inland fisheries today are dominated by freshwater fisheries. In order to enhance production, there is a need for diversification of fish production in various areas such as by introducing integrated fish farming, cold water fisheries, riverine fisheries, capture fisheries, brackishwater fisheries. Recent measures therefore have targeted intensive aquaculture in ponds and tanks through integrated fish farming, carp polyculture, freshwater prawn culture, running water fish culture and development of riverine fisheries. The following is noteworthy:

1. Indian waters harbour about 2 358 species [877 freshwater, 113 brackish water and 1 368 marine species];
2. the three Indian major carp (IMC) species – *Catla catla*, *Labeo rohita* and *Cirrihinus mrigala* together contribute the lion's share;
3. of late, pangassius and tilapia, native catfishes and freshwater prawns are picking up because culture-based production is increasing at a faster pace;
4. exotic carps form the next important group in the IMC segment;
5. marine resources available to India are estimated at 2.02 million sq km comprising 0.86 million sq km on the west coast, 0.56 million sq km on the east coast and 0.60 million sq km around the Andaman and Nicobar Islands. In the shrimp segment, most of the production comes from *L. vannamei;*
6. rainbow trout culture and rehabilitation of native *Tor* sp. (Mahaseer) in cold waters of the Himalayan corridor are promising ventures; and
7. ornamental fish farming, although a non-food activity, has a promising future and is likely to contribute to the overall growth of the fisheries sector in the coming years in terms of foreign exchange earnings and additional livelihood opportunities both in the urban and rural areas.

Specific threats/risks of climate change and climate change-related extreme meteorological events to aquaculture

The Indian aquaculture subsystem has experienced the impact of climatic changes during the past three decades in many ways, especially changes in temperatures and rainfall patterns in the Ganges basin. The water temperature has increased by 0.99^0C in the upper stretch of the Ganges. As a result the stretch around Haridwar has become a more congenial habitat for warm water fishes in the middle stretch of the river. Likewise, researches conducted during 1979 to 2009 by the Central Inland Fisheries Research Institute (CIFRI) reveal that the average rainfall has declined by 7 percent in the peak breeding period (May–August) whereas it increased by 4 percent in the post-breeding period (Sepember–December) for Indian major carps. When the occurrence of changes in the seasonal pattern of rainfall becomes frequent, a drought-like condition for breeding of Indian major carps prevails. There is a close relationship between the floodplains area, river flow and the wetland surface area and total fish production. Hence a predicted decline in surface water availability in many parts of country is a threat to inland fisheries production.

Climate changes lead to eutrophication of lakes and streams and can have negative impacts on inland fisheries, in particular in the states of Bihar, Assam and West Bengal. Warming effects have an overall effect on anthropogenic pollution. Acute releases of toxic substances either by human activities or natural causes increase the mortality of fish populations. Warming conditions may lead to changes in the chemical composition of water that fish inhabit, the dissolved oxygen may decline and pollution and salinity levels may increase, which may be lethal to the fish being cultivated.

Tropical cyclones are major hazards in tropical coastal regions, both in terms of loss of life and economic damage. Such cyclones originate in the Bay of Bengal during the spring and fall inter-monsoon periods. These cyclones hit the coastline at tremendous speed and inundate the shores with strong tidal waves, severely destroying and disturbing coastal resources. The intrusion of seawater into the upstream riverine zone through estuaries has a high probability of altering the chemical composition of the inland waters. The most affected Indian states are Tamilnadu, Andhra Pradesh, Orissa and West Bengal.

The study and survey conducted by CIFRI revealed a drastic change in the breeding behaviour of endemic species in the Ganges with over 60 percent less spawning during 2005–2009 compared with 1965–1969. The reproductive behaviour of fishes has obviously changed. The geographical distribution of fish has also been disturbed and changes in the spatial distribution have been observed in certain stretches of the Ganges.

Changes in climate because of natural causes or anthropocentric activities lead to fluctuating temperatures to which fish are very sensitive and become susceptible to pathogens and ultimately poor fish health affects the fish stocks.

Efforts addressing climate change and climate resilience of aquaculture

The Government of India synergistically with various states has focused on the issues affecting aquaculture and launched a national action plan "Mission Blue Revolution: Integrated National Fisheries Action Plan 2016" covering state-specific needs and addressing food security, livelihoods and rural development issues. Although, India has been performing well in the aquaculture sector, it has still not achieved its potential and has targeted a 69 percent increase in production by 2020-2021. A main area of focus is increasing the availability of good quality fingerlings and Mission Fingerling is now operational to achieve this. Another focus is conserving good quality germplasm, and a National Brood Bank has been established to provide improved varieties of breeder seeds. A third focus is to protect the natural fish wealth and in line with this public awareness programmes and rehabilitation of natural broodstock are being carried out through river ranching in special areas of the Ganges and its tributaries under the Namami Ganges National Action Plan to clean the river. Recirculating aquaculture systems (RAS) are being established for intensification of aquaculture to mitigate the impact of climate changes. Moreover, the farming of climate-resilient food fishes in captivity is also being promoted. Promotion of cage/pens in wetlands is also gaining momentum. Culture of endemic varieties of hard fishes such as Indian catfishes and murrels is also a feature of government efforts.

Ensuring the flow of funds and co-ordination through convergence with other National Rural Development Schemes such as the national agriculture development programme, known in Hindi as Rashtriya Krishi Vikas Yojana (RKVY), and the Mahatma Gandhi National Rural Employment Guarantee Act (MNREGA), which are also promoting inland aquaculture and the inland fisheries sector.

Major gaps and constraints in building climate-resilient aquaculture

The major constraints in building climate-resilient aquaculture are the following:

1. Damming of rivers: the flow regime/environmental flow downstream of many rivers has been affected leading to loss of fish habitat, biodiversity and other ecosystem functions.
2. Rampant encroachment of open-water resources – high economic demand of land for real estate has accelerated the pace of encroachment of open waters, especially wetlands, leading to loss of inland open water fishery resources as they are either being filled up or allowed to get polluted. The closure of riverine access into the wetlands by erecting bunds has been a major cause of failure of natural fish seed recruitment into such waters. Increasing levels of eutrophication in wetlands has resulted in predominance of macrophytes causing disruption in the natural foodchain and has depleted fish stocks.
3. Large-scale destruction of estuarine habitats and mangrove wetlands: the estuarine ecosystems of the country including the mangrove wetlands are stressed because of anthropocentric interferences, making conservation of fish/shellfish difficult.
4. Multiple usages and multiple-ownership: the inland open waters have many stakeholders as they are multiple ownership resources and lack the required policy framework for priority setting of use. In the face of continued demand on inland waters for other sectors and unabated anthropogenic stress on our rivers, substantial increase in fish productivity has not been possible.

5. Overexploitation: access to fishing in the open waters in a majority of the states is unregulated. With dwindling fish stocks in rivers and wetlands the increasing demand of fish has led to overexploitation. The mechanization of fishing for example in the lower parts of the Hooghly-Matlah estuary has increased the fishing effort thus producing more fish biomass. Wanton killing of brooders and juveniles of target species is a common feature in the majority of the rivers and wetlands leading to decline in their fishery.
6. Rapid shift in biodiversity and fish stock: in rivers and wetlands, the process of shift in biodiversity and composition of fish stock has assumed a serious dimension. In the majority of the rivers dominated by carp fisheries, carp is being replaced by small-bodied miscellaneous fishery with less market acceptability and resultant lower remuneration to fishers. Unregulated entry of exotic fish species has also resulted in the decline of indigenous fish species.
7. Livelihood loss of fishers: fishers are faced with dwindling fish, resulting in the loss of their livelihoods. This situation has very often resulted in their migration as labourers to other sectors for economic sustenance.
8. Climate change: it will exacerbate the threats posed to the inland fisheries by the other anthropogenic stressors. The concerns for climate-induced threats to fisheries take place in the context of widespread overexploitation of fisheries, which reduces the scope for adaptation and increases the risks of stock collapse through a combination of climate-related stresses and heavy exploitation pressure. Thus sustainability of inland fisheries needs to be addressed in an integrated way by considering all the anthropogenic interferences holistically.

Recommendations on regional strategy and actions to support the national effort to build climate-resilient aquaculture

The following mitigation and adaptation measures are recommended to support the national effort to build climate-resilient aquaculture:

1. estimating future production levels taking into account environmental variability and the impact that this may have on the growth of a stock and on its reproductive and mortality rates;
2. rebuilding fish stocks and improving fisheries governance, including institutional building of fisheries administrations, and representative sector organizations;
3. developing tools for decision making under management uncertainties and expanding societal knowledge;
4. adjusting fleet and infrastructure capacity and flexibility, controlling fishing effort, and enhancing management systems;
5. creating alternative employment and livelihood opportunities, especially investing in education and training in alternative occupations;
6. expanding aquaculture in line with sustainable and equitable development goals with appropriate legal and regulatory frameworks;
7. enhancing emergency preparedness and response, and developing insurance and social safety schemes in the fisheries subsectors;
8. applying international fishery agreements and conventions more vigorously, and strengthening them if necessary to accommodate and support climate change-related activities;
9. integrating climate considerations in investment in the sector, especially in infrastructure;
10. developing options for product and export diversification through appropriate economic and trade policies;
11. adopting measures to reduce the carbon footprint of the fisheries sector (promotion of fuel-efficient methods, support low-impact aquaculture, increase energy efficiency for fishing and storage methods, etc.), and providing payment for environmental services, particularly offering additional livelihood options to poorer communities; and
12. marketing and labelling of goods produced following recognized energy-efficient standards (eco-labelling, etc.).

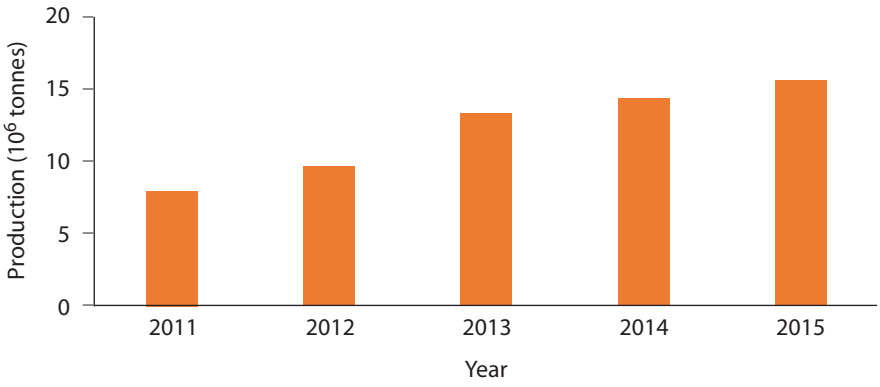
By adopting these measures, the country could make the sector more resilient to external shocks reducing its vulnerability to climate change impacts and environmental hazards. Furthermore, they could increase their competitive trading position, especially if they adopt more efficient methods of production that could, among others, reduce costs. Moreover, given the urgent need of adopting these measures, the country needs to secure additional funding to support key development objectives of the fisheries' sector and foster resilience to external shocks. However, funds currently available are much lower than the requirements on the ground.

Indonesia

Abidin Nur

Aquaculture has an imporant role in the provision of food either for domestic consumption or for export purposes. Aquaculture production is conducted in freshwater, brackishwater and marine waters. At present in terms of the potential area that could be used for aquaculture, only about 1.07 percent, 21.5 percent and 2.32 percent for freshwater, brackishwater and marine waters, respectively is being used. Various species are being cultured and total production has increased from 2011 to 2015 from 7.9 million tonnes to 15.6 million tonnes (Figure 7). Aquaculture production has increased about 16.6 percent annually and major aquaculture products are: seaweed, shrimp, milkfish, tilapia, catfish, grouper, seabass, common carp, giant gouramy and others.

Figure 7. Aquaculture production in Indonesia from 2011 to 2015



Within the species mentioned, shrimp contributes the highest share of fisheries exports. In 2016, it was reported that shrimp (both aquaculture and capture fisheries) exported about 41.71 percent of the total Indonesia fisheries exports. The main shrimp cultured was *Penaeus vannamei* followed by *P. monodon* and freshwater prawn.

In general, aquaculture is performed based on the stocking density applied, ranging from extensive to super intensive systems. There are various methods of aquaculture practiced in Indonesia especially monoculture and polyculture (rice-fish farming, cohabitation of shrimp and seaweed, integrated multitrophic aquaculture–shrimp–fish–seaweed, and lately small-scale aquaculture for fish and vegetable/fruit has been developed). Cage and pen culture is common both in freshwater or marine waters. Aquaculture based on plankton growth (autotrophic) is also commonly practiced, primarily using an extensive system, e.g. milkfish and black tiger shrimp. Currently, biofloc technology was successfully applied primarily to catfish culture with small culture facilities but high productivity. Intensive shrimp culture (mainly *P. vannamei*) is also practiced using this system.

In terms of climate change issues, specific risks relate to extreme meteorological events to aquaculture but it is still difficult to describe risks in detail because of the limited research being done. The main elements of climate change that could potentially impact aquaculture production are sea level and temperature rise,

change in monsoonal rain pattern and extreme climatic events and water stress. A preliminary study on Cirata reservoir regarding the potential impact of climate change on aquaculture concluded that the condition of the reservoir ecosystem might be affected from two directions such as from outside (global climate change) and from inside the ecosystem itself. Further study at the same reservoir, found that from 2008 to 2011, the water temperature tended to increase. Rainfall, humidity and wind speed changed every year and cage culture productivity decreased. Water parameters such as pH, dissolved oxygen also tended to decrease.

The Directorate General of Aquaculture has a strategy and national action plan to build the climate change resilience of aquaculture through four programmes: 1) coastal area rehabilitation; 2) environment-friendly aquaculture practices; 3) enhanced capacity in terms of fish health management and monitoring; and 4) development of resilient local species with respect to environment change. Reseach and technology development is directed toward such aquaculture species as seaweed, mud crab and swimming crab, and toward the development of a domesticated and selective breeding programme for various species of fish and shrimp. Biofloc technology is also a main focus as it is one of the sustainable ways for aquaculture because of the limited amount of water used, it is a new source of protein, and there is a limited amount of waste produced.

In terms of building climate-resilient aquaculture species, more attention is being paid to local white shrimp (*P. merguiensis*) and it is starting to develop as a new shrimp aquaculture candidate for the future. MCBAD Jepara is responsible for further development of this species in terms of broodstock, larviculture, nursery and grow out. Domesticated and selective breeding of this species will be conducted as soon as possible in order to provide high quality broodstock and reduce dependence on wild caught broodstock. Several technical advantages of promoting the species are: it is an indigenous species and broodstock is generally available, short reproductive cycles and they allow the domestication or performance of selective breeding for preparing high quality broodstock, it is highly tolerant of salinity and probably highly resistant to certain diseases, it is a detritus feeder, seed production technology is currently well developed, it has a good taste and good market potential as well. Other species are also being developed namely, catfish, mud crab/swimming crab and seaweed. Catfish has a strong domestic market and can be produced even in small-scale facilities. Implementing biofloc technology on that species can easily increase production and become a reliable technology for farmers. Mud crab and swimmer crab are currently produced at the Center for Brackishwater Aquaculture Development in Jepara (MCBAD Jepara), and the Center is also responsible for the provision of seed for further use in silvo fishery and shoft shell crab production by farmers, post-harvest associations, district and provincial government fisheries offices. MCBAD Jepara also acts as a technical assistant on seed production. Rice-fish farming as a model of sustainable aquaculture is also practiced in Indoensia. This system will expand into many areas of paddy fields. The system not only increases land productivity, but also enhances farmers incomes.

Major gaps and contraints in building climate-resilient aquaculture and recommendations

The major constraints are the low economic value of some of the species being cultured, lack of technology development for such species – technology is not available and adaptable for farmers, environmental data availability is limited to certain periods of time, and lack of awareness of people regarding the need to promote and develop climate-resilient aquaculture species. All of these matters need to be urgently addressed. Moreover, it is recommended to culture seaweed continously for many purposes such as co-culture with other species, as raw material for many industies and as direct food for humans, and for their capacity to absorb CO_2. Furthermore, it is important to develop a domestic selective breeding programme for high-value species that are tolerant to environmental changes.

Lao People's Democratic Republic

Please refer to the extended summary related to fisheries.

Malaysia

Abdul Razak Abdul Rahman and Azlan Md. Nor

Introduction

Fisheries and aquaculture play important roles in food supply, food security and income generation in Malaysia. In 2015, food fish production was recorded at 1.987 million tonnes (RM 12.77 billion) which contributed 1.1 percent to the country's GDP and 14.4 percent to the agriculture GDP. Although the production from the deep sea fishing sector in the country's EEZ still remains a focus for expansion and will be given a high priority by the Government of Malaysia (Department of Fisheries) for exploration and development, a new development strategy for aquaculture expansion has been announced. The total landing of capture fisheries remains unchanged for the past few years, but the aquaculture sector is now contributing significantly to the positive balance of trade for the country and supplies the country's demand for food fish (expected to be 61 kg per capita consumption in 2020). In the aquaculture sector, the total production of aquaculture, increased 76 percent from 287 057 tonnes in 2011 to 506 465 tonnes in 2015 at the value of RM 3.78 billion. Marine aquaculture showed a 139 percent increase from 122 218 tonnes in 2011 to 394 320 tonnes whereas freshwater aquaculture recorded a decrease of 8 percent from 122 218 tonnes in 2011 to 112 145 tonnes in 2015. The decreased production of freshwater culture was a result of drought between April and June 2014 and flooding from December 2014 to February 2015.

Major fisheries production systems (marine and inland) and commodities in the country

The four major activities involved in aquaculture production consist of marine aquaculture (cage culture), freshwater aquaculture (pond and cage culture), seaweed culture, and ornamental fish and aquatic plant culture. The aquaculture commodities include finfish (catfish, red tilapia, black tilapia riverine catfish), shrimp (white shrimp, black tiger shrimp), mollusk (cockle and mussel) and seaweed (*Eucheuma cottonii*). Seaweed contributed the largest share of 47.1 percent of total aquaculture production, which was 520 000 tonnes, whereas, finfish, shrimp and mollusk contributed 32.7 percent, 11.9 percent and 8.2 percent, respectively.

Specific threat/risks of climate change and related extreme meteorological events to fisheries

Not all climate changes are likely to impact aquaculture equally, either directly and/or indirectly. Also, it is difficult to discern the precise effect of different elements of climate change on aquaculture. Furthermore, the potential impacts on farming activities cannot be attributed to one single factor of climate change. Those elements of climate change that are likely to directly impact on aquaculture in Malaysia can be summarized as follows:

a) Global warming and temperature increase (El Niño)

Drought

This phenomenon happened between April and June 2014 and resulted in the aquaculture activities around rivers being affected (mainly freshwater fish cages). A total of 706 farmers were involved with estimated losses of RM 25.16 million. The Pahang River in particular became shallow in some areas (Figure 8) and freshwater fish cage culture was mostly affected, involving 420 farmers, 4 611 units of cage culture whose fish had a culture size of 73 032 m^2. Some impact was also noticed in other systems such as brackishwater cage culture, freshwater pen culture, brackishwater and freshwater ponds.

Figure 8. The Pahang River is shallow in some areas

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b) Change in monsoons and occurrence of extreme climate events, frequency of occurrence of extreme climate events such as flood, change in monsoonal rain pattern or heavy rain.

Flood

In Malaysia, the heavy rains season is usually October to February every year which can cause flooding. However, unusual flooding happened December 2014 and February 2015 in Kelantan, Pahang and Johor. This caused the destruction of aquaculture facilities and also losses of cultured fish mainly in freshwater cage systems. It affected 1 665 farmers with estimated financial losses of RM 45 million.

c) Global warming and temperature increase (El Niño)

Disease

A few cases of mass mortality (Figure 9) have been reported especially in the higher saturated aquaculture areas which resulted in significant (millions of RM) losses to the farmers. As the temperature increased, the dissolved oxygen in the water decreased causing fish stress and triggering disease outbreaks.

Figure 9. Mass mortality of fish after disease outbreak

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National efforts addressing climate change and building the climate resilience of fisheries:

a) National strategies and action plan development and progress with implementation

Disaster action plans from national level to district level have been established and well executed. The establishment of a biosecurity division (Department of Fisheries) is a part of prevention and monitoring disease outbreaks in the country. Intensive culture with a cycle break time period, relocation of fishing grounds to deeper sites, low stocking density culture in saturated areas, promoting use of RAS and IMTA are part of the actions taken to build resilience to climate change.

b) Research and technology development

Research in producing high quality seed, resistant to climate and disease, RAS technology, IMTA and other NBC/BMC related research is ongoing.

c) Programme/project activities addressing climate change in fisheries, covering both adaptation and mitigation:

- monthly SPS programme monitoring;
- toxicity test for biotoxin monitoring programme; and
- encouraging use of GAP in farm certification.

d) Lessons learned/good practice from ongoing efforts

Research findings have been used to improve the culture system.

Major gaps and constraints in building climate-resilient fisheries:

1. constraints of numbers and knowledge and expertise in disease monitoring and analysis;
2. minimum number of auditors for inspection/certification and limited funds for monitoring;
3. constraints of numbers of researchers (90 research officers for multidiscipline area throughout the country);
4. limited funding for risk assessment activity; and
5. available technology is costly and requires skilled manpower, which is lacking.

Recommendations on regional strategy and action to support the national effort to build climate resilience fisheries

1. Establish regional research collaboration with better research funding.
2. Organize scheduled and comprehensive training and awareness programme.
3. Standardize regional fisheries and aquaculture climate change policy

Myanmar

Ohnmar Aung

Introduction

Myanmar has a total land area of 676 580 square kilometres and shares a total 5 858 km of international borders with Bangladesh and India on the northwest, China on the northeast, Lao People's Democratic Republic on the east and Thailand on the southeast. Myanmar comprises different geographical regions namely the northern hill region, the Shan Plateau, the Central Plains. The total coastal line is 2 832 km and there are four major rivers systems: Ayeyarwady (2 170 km), Chindwin (960 km), Sittaung (298 km), and Thanlwin (1 274 km). Myanmar has a continental shelf of 228 000 km^2. The population was approximately 53 million (comprising 135 ethnic groups) living in the new capital Nay Pyi Taw, and seven states and seven regions in 2015-2016. Inland freshwater bodies cover 8.2 million hectares in which 1.3 million hectares are permanent and 6.8 million hectares are seasonal flooded plains, that provide habitats for a considerable diversity of aquatic species.

Myanmar owes the richness of its freshwater and brackishwater fisheries to the extensive large river systems. The Ayeyarwady delta has many branches of rivers. Among the fish/shrimp farms, most of the farming is in the lower part of Myanmar throughout its rivers system in states and regions. Myanmar's economy is chiefly agro-based, including fisheries and forestry. The fisheries sector directly employs

approximately 3 million people and provides livelihoods for up to 15 million. Myanmar has rich aquatic resources offering many opportunities for a thriving economy to create jobs and export earnings. The average per capita fish consumption in Myanmar is 56 kg/year.

In the 2016-2017 fiscal year, the total production of fish in Myanmar was 5.67 million tonnes. In this period, the production of freshwater fish was 2.64 million tonnes (47 percent of the total fish production) and the production of marine fish was 3.03 million tonnes (53 percent of the total production of fish). The exported amount of fish and fish products was 0.439 million tonnes, valued at USD 605.820 million in 2016-2017. It was exported to 40 different countries.

Vision

Sustainable development of fisheries sector for:

- food security;
- improvement of the socio-economic well being of rural people; and
- contribution to the economic development of the nation based on the fisheries industry.

Aquaculture production in Myanmar

Myanmar DOF has established 27 fishery stations and 7 shrimp and prawn hatchery stations that are mainly responsible for seed production, appropriate research and technical assistance to farmers. Aquaculture commenced with freshwater fish farming in 1953 with exotic species such as tilapia, gouramy and common carp culture. After seed production through induced breeding techniques was successful, freshwater fish farming in the early 1960s became widespread throughout the country with the assistance of FAO. Currently aquaculture operations involve over 20 species and major carps are the most cultured species not because of its popularity for domestic consumption but also because it is the most suitable for culture. The predominant aquaculture system is the polyculture system with an intensive culture regime. At present, a private company in the Myanmar Fisheries Federation imports genetically modified tilapia, catfish, and striped catfish from other countries.

Cultured shrimp (*Penaeus monodon*) and prawn (*Macrobrachium rosenbergii*) have been produced mainly in the coastal areas since 1970. Recently, the trade and hold system, extensive-plus, semi-intensive and intensive culture systems were all operating in the coastal area. Private farmers want more shrimp/prawn seeds to increase production but government shrimp/prawn hatcheries stations are unable to provide a sufficient number, and there have been incidences of disease outbreak, unqualified breeders in local areas, climate change and market instability all affecting the production of seeds. Therefore, the Myanmar Shrimp Association has imported prawn/shrimp seeds from countries such as Thailand, Philippines and the United States of America. Nevertheless, private prawn/shrimp farmers rarely achieve high production figures and large profits. Shrimp farming is becoming a significant threat to coastal ecosystems, in particular mangrove forests have have been converted to large numbers of shrimp farms since 1980. Farmers are more interested in grow out culture than in seed production in the coastal area.

Myanmar's aquaculture sector is still struggling with fish farming operations as well as the devastation of the coastal ecosystem caused by climate change (floods, drought, temperature fluctuations, diminishing water resources). Aquaculture replenishes the natural resources and paddy cum fish farming by the release of hatchery bred quality fish seeds. In 2016-2017, 26 hatcheries produced a total of 644.092 million freshwater fish fry and fingerlings to stock the hatchery bred quality fish seeds into natural waterbodies, whereas 39 private hatcheries around Myanmar produced an impressive amount of 1 875 million fry and fingerlings. Total freshwater fish production was 1.88 million tonnes in 2017, which included freshwater aquaculture and inland capture fisheries.

Risk of climate change

Climate change impact has caused many problems/constraints for fisheries and aquaculture in Myanmar: change in aquatic population (species/size), deterioration of habitats, change in migration movement, pollution, reduced water availability, reduced water storage in ponds with high temperatures, decreased primary production in hatcheries because of weather changes, increasing price of agriculture because of floods, flooded pond areas because of the spread of water in waterways and canals, diseases outbreak because of high temperature, social and livelihood changes.

Marine finfish are the most popular commercial species cultured but production is low. The same can be said for mud crab, lobster and slippery eel because of insufficient aquatic feed, unavailability of advanced technology and lack of experience of culture systems, and the cage culture system in the sea is not practiced consistently. Myanmar DOF will implement: (1) a quarantine area for fish disease control; and (2) drugs and chemicals control in fish disease laboratories at national level. Therefore, experts are needed to strengthen the competency of staff in the disease diagnosis laboratory (to deal with parasites, bacteria, and chemical control). Capacity building with advanced technology for parasitology and bacteriology is needed. Knowledge of bacteria control by drug injection or chemicals needs to be transferred to Myanmar's fisheries scientists.

Fisheries/aquaculture sectoral policy

Myanmar's government has established a national policy and an action plan for disaster risk management at the national level in cooperation with the Ministry of Welfare and Resettlement. The government issued a specific sectoral policy and strategy addressing climate change at state/regional level, district/township level to address climate change adaptation and mitigation. The Ministry of Agriculture, Fisheries and Irrigation is tackling climate change with other relevant ministries such as the Ministry of Meteorology and Hydrology, and the Ministry of Forestry. Myanmar's aquaculture sector has implemented action plans that include the adoption of climate smart fish species and their related breeding and culture techniques. Various international organizations are cooperating with the aquaculture division to build climate resilience, in particular:

- the German international cooperation agency, GIZ, which funds the Myanmar Sustainable Aquaculture Programme (MYSAP); and
- the Food and Agriculture Organization of the United Nations which funds a project (FishAdapt) to strengthen the adaptive capacity and resilience of farmers with fisheries and aquaculture dependent livelihoods.

Resilience of aquaculture

The Department of Meteorology and Hydrology takes responsibility for broadcasting weather forecasts on a daily, weekly and monthly basis through various media. According to the government guidelines, the Department of Fisheries provides rapid assistance to fisheries communities in the disaster risk areas and helps to raise their awareness of risks they face. To strengthen the climate resilience of aquaculture both in the short term and long term, the following activities have been implemented:

- the Everygreen development project which has made available 30 million kyats to each village
  - 2014-2015 200 villages
  - 2015-2016 125 villages
  - 2016-2017 30 villages
  - 2017-2018 20 villages
- construction of backyard hatcheries with breeders and technology
  - 2014-2015 62 farmers
  - 2015-2016 60 farmers

- restoration of mangroves in coastal aquaculture areas;
- establishment of an advanced warning system for farm operation management;
- stocking of commercial indigenous species in the paddy fields for food security and conservation in rural areas;
- construction of new local laboratories for analyses of fish disease and water quality management;
- establishment of Good Aquaculture Practice (GAqP) for aquaculture trade products as per European Union guidelines;
- provision of three groups of mobile teams to give on-site support services for fish farmers to prevent fish disease and farm management;
- provision of support in the form of 343.415 billion fish fry within 100 days to local farmers after severe flooding on July 2016 (which mostly affected nine regions and states).

Recommendations

- Establish a network among countries of the Asia-Pacific region to share information.
- Implement effective ways of reducing floods, e.g. strengthen flood forecast system, provide flood risk maps, construct flood walls and flood gates – financial assistance of international organizations is required.
- Transfer advanced technology and provide training in its use by international experts for hatchery operations and produce genetically modified breeders (indigenous species/marine fish/prawn).
- Transfer advanced technology to control disease infected fish by drug injection and chemical control.
- Annualy upgrade the competency of staff working in disease diagnosis laboratories, particularly in the areas of parasites, bacteria, and chemical control.

Nepal

Neeta Pradhan

Being landlocked, Nepal is deprived of any oceanic resources and dominated by mountains, which comprise about 83 percent of the total area of 147 181 sq km. Approximately 5 percent of the total area of the country is occupied by various freshwater aquatic habitats in the form of rivers, lakes, swamps, ponds and rice fields. A total of 223 indigenous fish species have been reported in Nepal distributed widely – from the tropical climate in the Terai to the alpine climate of the Himalayan region. Beside indigenous fish, altogether 12 exotic fish species have been introduced for culture. Major aquaculture systems adopted are carp polyculture in ponds, lakes and enclosures. Cage culture of herbivorous carp species and common carp in rice-fish culture are common practices in subtropical hill regions. The technology of rainbow trout (*Oncorhynchus mykiss*) farming is being scaled up in the temperate region of the country.

The national fish production reached 77 000 tonnes in 2014 with an annual growth rate of 8.5 percent. The contribution of aquaculture to the national fish production has increased significantly over the last decade to reach 71 percent in 2014. Aquaculture is often referred as the fastest growing primary production sector in the last three decades, having an annual rate of growth of nearly 11.6 percent. However, trends data indicate that the rate of growth is decreasing. It is important to bear these growth trends in mind when considering the impacts that climate change might have on aquaculture and its potential for growth. Fish production from capture fisheries was almost stagnant (1.5 percent growth rate) in the past seven years. This means that growing demand for fish consumption, as a consequence of population increase and increasing per capita consumption among certain sectors, will have to be provided primarily through aquaculture.

The number of people directly employed in fisheries and aquaculture is estimated at 700 000, of which 53 percent are women. In addition to those directly employed in the fisheries sector, there are forward and backward linkages to other economic activities generated by the supply of fish (trade, processing,

transport, retail, net making, supply of services, etc.). Taking into account these other activities, over a million people are thought to be dependent on aquaculture and small-scale fishing in Nepal. Total national income from the fisheries sector is USD 154 million which contributed a little over 1.32 percent to the national GDP and 4.22 percent to the agricultural GDP in fiscal year 2015-2016. The sustainable development and promotion of aquaculture and inland fisheries could provide significant benefits to the country through direct nutrition and social and economic development. Demand for fish is very high in comparison to the production level and in general the production is consumed locally. The demand for aquaculture and fisheries products within Nepal is estimated to be about 364 000 tonnes by 2032 in which aquaculture is envisaged as contributing 94 percent and the rest from capture fisheries. If fish demands are to be satisfied by 2032, an increase in both aquaculture and capture fisheries production needs to occur.

There are very few studies about the effects and likely impacts of climate change in Nepal. Scientific evaluations are yet to be carried out to understand the types and degrees of impacts on specific geographical regions and the fisheries sector. Analysis and predictions of climate change in Nepal are still based on literature reviews and analysis of scattered information. The total production of cultured fish from the subtropical Terai region is increasing over the years. This region contributed consistently over 95 percent of the aquaculture production and the cultured component of fish production from the subtropical hill region and the temperate mountain region is insignificant. Climate change impacts, if any, are likely to produce more significant net effects on the aquaculture sector in subtropical Terai regions than elsewhere because production is concentrated there. High value fish (rainbow trout) produced in the temperate mountain region, although insignificant in volume is important for mountain livelihoods. Immediate impact of climate change is expected in the temperate climate zone, therefore, adaptation strategies that are needed to prevent and counteract the potential impacts of climatic change on aquaculture should initially be targeted in this climatic region.

The impacts on aquaculture from climate change, will likely be both positive and negative arising from direct and indirect impacts on the natural resources required for aquaculture. An increase in temperature during the cooler months (December to January) may provide benefit for aquaculture in the form of improved growth performance. May and June are very warm months in the southern plain Terai of Nepal, so a larger increase in temperature will likely not lead to enhanced fish growth. This is the period before the start of the monsoon suggesting that water availability may be limited. The scenario may be slightly different in raceway culture of rainbow trout in temperate mountainous region of the country, although small in scale, they provide livelihoods for poor farming communities. This species has a very narrow optimal range of temperature and a relatively low upper lethal limit. Climate change is likely to induce strong selection on the date of spawning of some freshwater fish. In the past 10 to 12 years of rainbow trout aquaculture in Nepal, it has been observed that the peak spawning season has shifted from late November to mid-December.

Climatic changes could exacerbate eutrophication and produce more pronounced stratification in lentic (still water) systems resulting in oxygen depletion in the dawn hours. Catastrophic fish mortalities occurred in the cage culture of Lake Phewa, Pokhara valley during September–November and there is danger of a reoccurrence of anoxic turnover every year during this period. Proliferation of cage culture practices in Kulekhani reservoir has resulted in the regular occurrence of fish kills, slow growth and consequently, lower profits mostly as a result of a high density of cages in the reservoir without any consideration of the carrying capacity of the ecosystem. In this regard, adaptive measures would need to consider an ecosystem perspective with a high degree of conformity between the extent of cage culture practices and the carrying capacity of each waterbody. The siting of cages should also avoid very shallow areas and limited water circulation zones.

Water stresses brought about by climate change could have major impacts on aquaculture. The predicted stress is thought to result in decreasing water availability in major rivers in Nepal, from where water is diverted to irrigate fish ponds and agriculture lands. Low water level in several hectares of ponds located

alongside of the river bank has already been experienced during the dry period because the discharge of the Koshi River is decreasing over the years. Less water availability during the dry period has resulted in decrease in the productivity of these ponds by 50 percent to 60 percent in recent years. Climate change in Nepal is predicted to increase drought periods, resulting in less water retention time in seasonal waterbodies. This will make such waterbodies relatively unsuitable for aquaculture purposes because a minimum period of six months of water retention is needed for most fish to attain marketable size. It is remarkable to note that such seasonal waterbodies in the form of rain fed ponds, swamps and ditches possess significant area coverage for aquaculture activities in Nepal. For adaptation to climate change a number of changes might be introduced such as the construction of small ponds, harvesting fish at a smaller size, selection of appropriate species (short culture period and minimum input), extension of cage fish culture based on carrying capacity of lake/reservoir. Upstream areas with increased melting of the snow cover may become a possibility for temperate species aquaculture.

It has been emphasized that the ways in which climate change may impact aquaculture and related livelihoods are broad ranging and complex. There has been little focus in current plans and policies on how climate change may affect the fisheries and aquaculture sector of Nepal and on adaptation measures that might be adopted. Much uncertainty remains over the climate trends combined with shocks, which is considered important when assessing potential impact pathways in aquaculture. Impact assessment requires modeling of climate data on extreme events associated with climate change trends. Establishment and application of a geographic information system (GIS) would be worthy not only for the monitoring of changing variables but also for modelling future scenarios of climate change and its impact on fisheries and aquaculture. More focused case studies will be very important not only in guiding policy decisions for the areas concerned, but also for the increased understanding of the ways in which climate change impacts will take place along with possible adaptive measures to counter them. The respective government agencies need to prepare plans of action and strengthen their institutional and technical capability which may require regional and international assistance.

Pakistan

Muhammad Farhan Khan

Pakistan is endowed with vast aquatic resources which include freshwater, brackishwater and marine resources. Aquatic resources are spread in various climatic zones including coldwater, coolwater and warmwater areas. The Pakistan deltaic area of about 700 000 hectares has a huge potential for fish farming, yet the industry has not started farming operations there. Pakistan's total fish production for 2015-2016 was 0.788 million tonnes with about one fourth of the fish coming from freshwater resources. The export value during 2012-2013 was USD 325 million. Aquaculture is a relatively new, but rapidly expanding activity in Pakistan.

Pakistan is endowed with huge resources for the development of the fisheries sector, having a 1 100 km coastal belt. The country is believed to have about 2 million ha of freshwater bodies (lakes, reservoirs and rivers) suitable for aquaculture. There is no coastal aquaculture yet in Pakistan. Freshwater aquaculture is carried out in an area of 300 000 acres in the country. Today, over 40 000 fish farms operate in the country.

Despite its small contribution to the national economy, aquaculture has become an important sector in terms of its potential for increasing domestic supply of quality protein in the country. Promising prospects exist for further growth in carp production in Pakistan for several reasons. First, fish farming is more profitable compared to most other farming activities. Second, the country is believed to have about 2 million ha of freshwater bodies (lakes, reservoirs and rivers) suitable for aquaculture.

However, the aquaculture potential of these resources is only slightly utilized at present. Fish farming in the country is operating at an extensive or semi-intensive level by farmers.

Two major projects have been implemented during the 1980s and 1990s at the national level (involving the provinces of Punjab, Sindh and KPK) with the financial assistance of the Asian Development Bank amounting to over USD 36 million.

Most fish farmers stock their ponds at a low stocking densities ranging from 800 fish/acre to 1 000 fish/acre and use poor quality feed inputs in the form of cow dung. This has resulted in low fish productivity ranging from 1 000 kg/acre to 1 200 kg/acre compared to other Asian countries who are producing up to 2 500 kg/acre through intensive fish culture and utilization of artificial feed. In order to get maximum production from available resources, intensive fish culture is urgently required. Artificial feeding is known to increase the carrying capacity of culture systems and can enhance fish production significantly.

Intensive aquaculture has been initiated in the country. It requires the culture of high-value fish species and the use of commercial fish feed. Two feed factories have been established in Lahore and they have started providing commercial fish feed. Intensive tilapia farming has been introduced in Pakistan which has increased the yield of fish from one tonne per acre to four tonnes per acre. Keeping in view the interest of farmers, a total revamping of the aquaculture sector is expected.

The fisheries and aquaculture subsectors in Pakistan are vulnerable to natural disasters and the impacts of climate change. There has been an undoubted increase in frequency and severity of disasters (floods, earthquakes, tropical cyclones, droughts etc.) in recent decade. There are two major climate threats for aquaculture:

- Floods
- Drought.

The Indus River originating from the Tibetan Plateau flows through Pakistan from north to south. It is the main source of agricultural irrigation, drinking water of urban and rural areas, industrial use and aquaculture. Pakistan fisheries are mostly concentrated in the sea and the Indus River. The major disasters that struck the region such as floods in 2010, 2011, 2012 and 2013 showed how catastrophes can potentially impact fisheries and aquaculture enterprises.

Recent flooding rains with peaks in 2010 and 2011 caused damages to fish ponds and caused reduced seed production in many fish hatcheries. Flood damage across many parts of the irrigation system will incur rehabilitation costs (estimated at up to USD 1 000 per hectare), including for extensive desilting. The floods of 2011 were Pakistan's most destructive ever. It caused USD 2 billion of agricultural losses. The highest damages occurred in the agriculture, livestock and fisheries subsectors, calculated at just over PKR 160 billion (USD 1.84 billion).

Fisheries losses are estimated at about USD 3.4 million (0.2 percent) that includes losses for private fish farms/ponds and hatcheries. Damages to fish farms have been reported only from Sindh where 393 ponds/farms have been damaged by the monsoon floods. In 2014 the flood affected the fishery industry in South Punjab adversely and has caused losses amounting to billions of rupees to the owners.

There is no specific policy on the affect of climate change in the field of aquaculture but there are some complementary institutions, plans and policies that deal with climate change, namely:

- National Disaster Management Authority
- Federal Flood Commission
- National strategy and action plan
- National Flood Protection Plan -IV
- National Water Policy
- National Policy for Climate Change.

The major gaps and constraints in building climate-resilient aquaculture are as follows:

- lack of regulations and implementation of laws;
- no specific policy on the affect of climate change on aquaculture;
- absence of enforcement of regulatory mechanisms by the provincial governments;
- lack of coastal and marine aquaculture;
- limited foreign assistance;
- lack of human resource development;
- no formal/informal education affect of climate change on coastal and marine aquaculture; and
- melting of glaciers, floods and droughts, increased soil and water salinity, drying up of old waterbodies, appearance of new waterbodies.

Recommendations

- formulate policy regarding the affect of climate change on fisheries and aquaculture;
- establish multiple or multilateral arrangements for education in the field of aquaculture and fisheries at university level;
- strengthen fisheries and aquaculture research organizations to be able to conduct research on the impact of climate change in aquaculture;
- formulate different strategies to support the national policy goals of increasing economic growth, food security and poverty alleviation;
- develop new commercial-scale fish production technologies to deal with the impact of climate change;
- support youth education in the field of aquaculture and fisheries; and
- build the capacity of fisheries staff in the public sector.

The Philippines

Lea Myr S. Cadapan and Jayson Paul F. Zulueta

I. Introduction

The Philippines is an archipelagic country, comprised of 7 100 islands, endowed with numerous and rich inland waterbodies, a tropical climate, and abundant rainfall. It is enviably situated in the Coral Triangle harbouring the world's greatest marine biodiversity. In fact, the 24 million hectares Philippine Rise is home to the Pacific bluefin tuna recently auctioned at more than USD 600 000. The country has the fifth longest coastline measuring 36 000 km, 2.7 millon ha of coral reef and an 18.5 million ha continental shelf. Swamplands, lakes, rivers and fishponds make up the 750 000 ha of inland resources.

Over the last two decades, the production of fish and other aquatic products grew by 65 percent from 2.8 million tonnes to 5 million tonnes from 1995. Aquaculture, particularly seaweeds, contributed 1.2 million tonnes to total aquaculture production. Production from capture fisheries averaged about 1.2 million tonnes to 1.4 million tonnes and is shared between commercial and municipal fishers. Interestingly, the value of fish almost tripled – from USD 2 billion to USD 5.3 billion.

In the global context, the Philippines is the eighth largest producer of fish and other aquatic/marine products contributing 2.4 percent of the global production and eleventh in aquaculture production with a 1.04 percent share in 2014. It is also the third largest producer of aquatic plants (including seaweeds) having produced 1.55 million tonnes or nearly 5.6 percent of the total world production of 27.31 million tonnes.

Fisheries contributed 1.5 percent and 1.7 percent to GDP at current and constant prices, respectively in 2015. The industry provides income and livelihoods to close to 1.8 million municipal fisherfolk, 47 000 commercial fish operators and 226 000 aquaculture operators.

Harvests from aquaculture farms reached 2.2 million tonnes in 2016. However, there was a reduction by 6.27 percent compared to its level a year ago. High mortality and slow growth of species were caused by a dry spell. Seaweed farms were affected by ice-ice disease and epiphytes. Scarcity of planting materials and the low buying price offered by seaweed traders all year round resulted in fewer aquafarms in operation. Of the subsectors, aquaculture had the highest contribution of 51 percent to total fisheries.

II. Major aquaculture systems and commodities in the country

To date, aquaculture involves the farming of many species of fish, crustaceans, mollusks and seaweeds in different farming systems in three different culture environments: freshwater, brackishwater and marine. There are about 16 commodity species cultured in the Philippines, namely seaweeds, milkfish, tilapia, tiger prawn, mussel, oyster, carp, mudcrab, catfish, white shrimps, mudfish, endeavour shrimps, grouper, siganids, spiny lobster, pompano, abalone, sea urchin and sea cucumber. The culture technique of these latter four species is still being developed. The predominantly farmed species making a significant contribution to the volume of production are seaweeds followed by milkfish, tilapia and shrimp/prawn.

The majority of aquaculture operations in the Philippines are small-scale to medium scale, making the industry very vulnerable to climate change.

III. Specific threats/risks of CC and CC-related extreme meteorological events to aquaculture

The importance of the aquaculture sector to the country's economy and food security cannot be overstated. Virtually all levels of social strata depend on aquaculture production, thus the need to protect it against external influences and negative factors such as hazards and risks attributed to climate change to which the Philippines is particularly vulnerable.

In 2017, the Global Climate Risk Index published by Germanwatch places the Philippines fifth in the list of countries most affected by extreme weather events in the period 1996–2015. According to the Intergovernmental Panel on Climate Change (IPCC), among the projected impacts of climate change to agriculture and fisheries sector are: a decrease in rainy days (but intensity will be higher than normal); increase in intensity of tropical cyclones; increase in total cloud cover; increase in average maximum temperature; decrease in water availability; poor water quality and salt intrusion; ocean acidification; sea-level rise; increasing frequency of extreme weather events such as El Niño, and severe flooding.

Seaweed harvests production in 2016 was 10.33 percent lower than the previous year's output because of the high water temperature brought by the El Niño phenomenon. Poor water quality also encourages the proliferation of ice-ice disease and epiphytes in most farms which stunts growth and leads to mass mortalities. The increase in intensity and frequency of tropical cyclones has also caused massive damage to most seaweed farms leading some seaweed growers to stop operations because of the high cost of rehabilitation.

Although production of milkfish went up by 2.53 percent in 2016, production of milkfish in Sultan Kudarat and Sarangani provinces diminished as a result of prolonged hot weather conditions during the first and second quarters of 2016. In Davao del Sur, the limited supply of fry/fingerlings was attributed to hot weather conditions.

Tilapia production was also lower by 3.52 percent compared to the previous year's level. Harvested tilapia from Rizal went down this year which was attributed to the hot weather conditions brought by El Niño; this has affected the stocking density in freshwater pens and cages from the second quarter to the fourth quarter of 2016. In Bicol region, a high mortality rate and a reduced area for freshwater cages in operation were reported in Camarines Sur and attributed to a low water level brought about by prolonged hot weather conditions and a sudden change in water temperature specifically during the first semester. The overflowing of fishponds brought about by Typhoon Lando in 2015 contributed to the contraction of the

harvest of Pangasinan at the start of the year. Moreover, decrease in stocking density was reported in the southern part of the province to avoid fish kill. Low water level resulted in small sizes of tilapia harvested, which was also encountered during the second quarter of 2016. Fewer areas stocked and harvested were observed because of extreme hot weather conditions that resulted in the low survival rates of various species. Furthermore, the decrease in tilapia production was also attributed to the high price and poor quality of stocking materials.

The production decline trend continues with tiger prawn, which declined by 0.76 percent from its 2015 level. The negative performances of Zamboanga Peninsula, Western Visayas and Ilocos Region influenced the overall output of tiger prawn production in 2016 as these regions had low output in all quarters of that year. In Zamboanga del Sur, high water salinity and temperature occurred during the first semester and caused the mortality of some stocks. The fishpond area contracted during the second semester and was attributed to the scarcity of quality post larvae (fry). For three quarters, stocks were affected by mortality or low survival rate of stocks caused by abrupt rains and intense heat. Meanwhile, operators reduced the area of their operation during the third quarter because of the scarcity of quality fry. There was high mortality of stocks in brackishwater fishponds as a result of water turbidity caused by Typhoon Lawin.

IV. National efforts to address climate change and build climate-resilient aquaculture:

1) Under the guidance of the Republic Act No. 9729 and 10174 (Climate Change Act of 2009), the Department of Agriculture created the Adaptation and Mitigation Initiatives in Agriculture (AMIA) project with an eye on achieving climate resiliency both in agriculture and fisheries communities. Under the DA-AMIA umbrella is the BFAR-AMIA team which comprises of Bureau of Fisheries and Aquatic Resources (BFAR) and National Fisheries Research and Development Institute (NFRDI).

Initiatives already undertaken by the team include conducting vulnerability assessment for the capture fishery and aquaculture subsectors, formulating a national strategy framework for BFAR on climate change, developing fisheries management strategies to address climate change, and recommending climate change related policies. The development of a disaster risk reduction management operation manual to guide efforts to mitigate the effect of climate change risks for fisheries is also ongoing.

Partnerships with other government and research institutions involved in addressing climate change are also being strengthened so that duplication of related programmes and projects will be minimized and harmonization of policies and regulations will be realized.

2) BFAR and NFRDI have already conducted a series of studies on the effects of climate change on marine fisheries resources and aquaculture in the Philippines. Determination of the possible changes in the distribution and recruitment of marine species and analysis of the relationship of atmospheric data and water parameters is now at the forefront of studies because of its potential impact on food production.

Concurrently, BFAR and NFRDI are collaborating closely to develop a GIS-based Vulnerability and Suitability Analysis (VSA) system for the capture fisheries and aquaculture subsectors. The system will rank areas based on their vulnerability to physical and climate hazards as well as determine if a certain fisheries investment initiative is suitable in a specific area. It is envisioned that the critical information provided by VSA will help, not only in investment planning or programme/project implementation in fisheries, but also in mitigating the effect or preventing potential loss caused by climate change.

3) Last year, BFAR, UN-FAO, and DOST-PAGASA conducted a project entitled Building Capacities for a Climate Resilient Tilapia Farming (TCP/PHI/3502D). The project was implemented to increase the resiliency of the pond-based tilapia producing sector from the negative externalities imposed by climate-weather risks, primarily its impact on farm productivity. Because of the initial success of the project it was expanded to other major aquaculture commodities. Outputs and deliverables produced, such as knowledge materials and web-based and mobile-based ICT applications, are expected to assist tilapia

farmers in mitigating climate hazards and risks through the installation of an early-warning system and provision of relevant climate information and farm advisories at the local level. Sustaining the measures developed by the project will also strengthen the adaptive capacity of the community against climate uncertainty.

Planned future projects and collaborative efforts with UN-FAO, Department of Science and Technology, Philippine Atmospheric, Geophysical and Astronomical Services Administration (DOST-PAGASA) and local government units (LGUs) will focus on how to sustain the past efforts made to address climate change. In fact, a regional Technical Cooperation Programme, TCP 3603, project is currently ongoing to promote the scaling-up of innovative fish farming and climate resilient tilapia pond culture practices recommended by TCP 3502-D.

Overall, it is hoped that the initiatives, projects and programmes implemented by BFAR will add up to the national and collective effort to address climate change in the Philippines, and will become the template for future climate change activities for the fisheries sector.

4) Participation of local communities is critical in the successful implementation of any climate change related programmes and projects. In the aforementioned TCP 3502 project, the project implementers decided to involve the farmers and extension workers in local government units in the production of knowledge materials by eliciting their insights and first-hand information on the subject since they are the one mostly affected by climate change. This process allows the information in the produced knowledge materials to be comprehensible to non-experts.

Also, by strategically engaging the locality in actual project implementation, it may build up a sense of ownership and accomplishment to the community which may lead them to sustain the application of all outputs and deliverables produced beyond the project's life.

The lessons learned and observed good practices will be replicated in future climate change related programmes and projects to ensure the effectiveness, success and a holistic approach in addressing climate change.

V. Major gaps and constraints in building climate-resilient aquaculture

The mapping of zones and inventory of aquaculture farming areas and facilities will be of great help in assessing hazard zones and identifying areas that are highly vulnerable to climate change; it will also be of great use to extension workers in their provision of technical assistance to stakeholders. Mapping of aquaculture areas is now being addressed by BFAR and FAO but earlier initiatives might have provided critical data in the planning and implementation of past climate change programmes and projects.

The poor adoption of aquaculture insurance and Good Aquaculture Practices (GAqP) is also a major constraint especially in promoting mitigation measures to manage risk and hazards attributed to climate change. The importance of an aquaculture insurance instrument is that it provides immediate financial assistance to farmers for their speedy recovery and resumption of their operations. Poor observance of GAqP may also contribute to the failure of the insurance system to gain a foothold in the aquaculture sector; a high moral hazard will entail a higher premium which most farmers cannot afford. GAqP also provides guidelines to minimize or prevent the effects of external influences on aquaculture operations thus low compliance may result in reduced adaptive capacity of farmers especially during the occurrence of extreme weather/climate conditions.

Knowledge gaps on climate change and its projected impact is still apparent especially to those not directly involved in climate change discussions. Massive knowledge information dissemination must be conducted both in the national and local level to level-up the understanding between experts and non-experts on climate change.

VI. Recommendations on regional strategy and actions to support the national effort to build climate-resilient aquaculture

Stronger linkages between regional institutions that are mandated to address climate change should be institutionalized. This would pave the way for efficient data and information sharing between countries, technology transfer and sharing to build capacities, easier collaboration for the conduct of climate change related R&D and harmonization of current and future climate change initiatives and policies across borders.

Also a tougher stand must be made to hold countries with high carbon emissions rates liable for their actions. These countries must be encouraged to reduce their emissions and provide funds for climate change mitigation and adaptation activities. These will greatly benefit the smaller countries that are highly vulnerable to the effects of anthropogenic climate change even though they have made a minimal contribution to it.

The Republic of Korea

Please refer to the extended summary in the section on fisheries.

Sri Lanka

M G G Gunasena

1. Introduction to fisheries, inland fisheries and aquaculture

Fish has been the main source of animal protein (70 percent) for the masses throughout the history of Sri Lanka. Fisheries have also been a source of government revenue and at present account for 1.8 percent of GDP. Annual per capita fish consumption is 15.8 kg.

Sri Lanka is blessed with inland and brackishwater resources. Despite, having a large area of freshwater and brackishwater which extends over 400 000 ha, it does not have a tradition of aquaculture. Shrimp farming commenced in 1980s and was the first major commercial aquaculture activity in the country. The contribution of inland fisheries and aquaculture to the fisheries sector is about 14 percent. Inland fisheries and aquaculture provide livelihoods for 44 000 people directly.

2. Major aquaculture system and commodities

2.1 Culture-based fisheries in reservoirs

Culture-based fisheries in perennial reservoirs is considered the main provider of fish protein to rural village people. In 2016, it contributed 80 percent of the total inland fish and aquaculture production of 73 930 million tonnes. Culture-based fisheries also provide livelihoods directly for 37 727 people. The potential is high to increase fish production in perennial reservoirs by improving management and stocking fish seeds regularly.

2.2 Shrimp culture

The shrimp aquaculture industry is the major commercial aquaculture activity at present in the country. It was begun in the mid-1980s, concentrated in earthen ponds along the northwestern coastal line and it covered more than 4 500 ha of farm area. But this lucrative commercial aquaculture activity has been adversely affected since 1996 by white spot syndrome. With the mitigation measures applied by the government, it is now recovering gradually.

2.3 Ornamental fish industry

The ornamental fish industry is also a large aquaculture activity which brings foreign exchange into the country. In 2016, this was valued at Rs 800 million. In addition to the culture of ornamental fish, marine ornamental fish are also exported and this sector is totally dependent on the wild stocks. Currently, over 200 marine species belonging to 40 families are being exported

2.4 Non-traditional aquaculture

This is one of the newly emerging aquaculture systems that has the potential to contribute significantly to the economic development of the country. Several pilot projects on sea cucumber fattening, sea bass cage culture, oyster culture and seaweed farming have been successful.

3. Specific threats of climate change

Sri Lanka has been identified as vulnerable to the adverse impacts of climate change, especially

- increased frequency and intensity of disasters such as drought, flood, and landslide – Sri Lanka experienced severe drought in the dry zone and severe floods in some parts of the southern and western provinces in 2016 and 2017;
- changed rainfall pattern – overall increase of rainfall in parts of the southern and western provinces and less rainfall in the dry zone area;
- increased temperatures; and
- sea level rise.

4. National effort addressing climate change and building climate-resilient aquaculture

4.1 National strategy action plan

- the climate change secretariat has been established under the ministry of environment to prepare the country for the impact of climate change; and
- there is a national climate change adaptation strategy for addressing impact of climate change.

4.2 Programme addressing climate change in aquaculture

- introduction of climate-resilient fish species for pond fish culture – Saline tilapia for brackish water pond fish culture and blue tilapia for raising in cool water have been introduced; and
- use of untapped minor perennial reservoirs in wet zone for culture based fisheries.

4.3 Research and technology development

Research for tolerance to high temperature has been conducted focused on selective breeding and genetic improvement.

5. Gaps and constraints in building climate-resilient aquaculture

- in most cases, even basic data on the vulnerability of fisheries and aquaculture to CC are lacking;
- even though general impact of climate chance can be predicted, the impact of CC on biological aspects of fish such as maturity, spawning, hatching, survival of larval etc. cannot be predicted;
- the lack of funding is also a major constraint; and
- the lack of capacity of human resources.

Thailand

Jutarat Kittiwanich

1. Introduction

Aquaculture plays an increasingly important role in food security and the economy of Thailand. Aquaculture contributes about one quarter of the country's total fish production of 2.4 million tonnes. In 2016, aquaculture production was about 952 948 tonnes and valued at 87.63 million baht. Aquaculture activities in Thailand can be divided into coastal aquaculture and inland aquaculture. The total production and value from coastal and inland aquaculture was approximately 534 972 tonnes and 418 023 tonnes and 61 729 million baht and 25 899 million baht, respectively. Coastal aquaculture usually produces high-value products for export whereas inland aquaculture is mainly for domestic consumption. Among the coastal aquaculture species, Pacific white shrimp production predominates in terms of volume and value at 314 023 tonnes worth 51 109 million baht. Of freshwater production, Nile tilapia accounts for the biggest volume of about 208 064 tonnes.

2. Major aquaculture systems and commodities in the country

The coastal aquaculture area is located along the coastline of the Gulf of Thailand and the Andaman Sea in 23 provinces. In 2016, the total culture area was about 67 274 ha with 38 209 farms. The main brackishwater cultured species were black tiger prawn (*Penaeus monodon*), Pacific white shrimp (*Penaeus vannamei*), which were cultured in earthen ponds. The major finfish species are seabass (*Lates calcarifier*) and grouper (*Epinephelus sp*.). They are usually reared in cages and ponds. Green mussel (*Perna viridis*), blood cockle (*Anadara* sp.), and oyster (*Crassostrea commercialis*) are cultured along the coast of Thailand. Coastal aquaculture usually produces high-value products; white shrimp and black tiger prawn are mainly for export whereas marine fish and shellfish are mainly for domestic consumption.

Freshwater fish species have been cultured throughout the country in ponds, cages, paddy fields and ditches. Most farms are densely located in areas that have abundant water resources or are irrigated. The culture area is about 128 726 ha and there are 547 913 farms. The main freshwater species cultured were Nile tilapia (*Oreochromis niloticus*), catfish (*Clarias macrocephalus*), silver barb (*Barbodes gonionotus*), giant river prawn (*Macrobrachium rosenbergii*) and snakeskin gourami (*Trichogaster pectoralis*).

3. Specific threats/risks of CC and CC-related extreme meteorological events to aquaculture

It is widely accepted that aquaculture is threatened by climate change. Climate change (temperature, rainfall, flood and drought, heat wave) could increase physiological shocks to cultured fish. This would not only affect productivity but also increase vulnerability to disease outbreak and impose higher risks and reduce returns to farmers.

4. National efforts addressing climate change and building climate resilience of aquaculture

a. National strategy and action plan development

Thailand's Climate Change Master Plan 2015–2050 addresses adaptation, mitigation and capacity building. The Agriculture Strategic Plan on Climate Change 2017–2021 also addresses database knowledge and technology, adaptation actions and mitigation actions and the driving mechanisms of climate change. Department of Fisheries (DOF) also has a plan and activities to acknowledge and support farmers practicing "sufficiency economy aquaculture". Zoning to allocate zones for aquaculture activities, environment-friendly aquaculture and monitoring of impact, and early-warning system development for building the climate resilience of aquaculture are also featured in the plan.

b. Research and technology development

Research and technology development for building climate-resilient aquaculture are focused on genetic improvement of commercial species, aquaculture technology and innovation for adaptation and mitigation and farm system management for environment-friendly aquaculture, for example zero waste aquaculture, water recirculation and closed systems etc.

c. Programme/project activities addressing climate change in aquaculture, covering both adaptation and mitigation

DOF has various projects addressing climate change in aquaculture, covering both adaptation and mitigation, such as: 1) life cycle impact assessment of Thai shrimp products; 2) carbon dynamics in shrimp farms; 3) integrated culture practices between freshwater fish or aquatic plants culture and intensive marine shrimp culture; 4) offshore sea farming of green mussel to remove organic matter in seawater; 5) zero-waste aquaculture system by utilizing drainage from intensive culture practice to generate production of other valuable aquatic products; 6) impact of water temperature variation on growth of shrimp in earthen ponds; and 7) the use of solar cells in fish and shrimp farms.

d. Lessons learned/good practice from ongoing efforts

DOF aquaculture activities are not only to demonstrate a responsible and sustainable aquaculture system but also to support the development of a green/blue economy by improving the efficiency of using aquaculture resources, reducing impact on the environment, increasing resilience of farmers, and improving the quality of life. The knowledge and technology transferred to the local farmers can help them improve their farm management practices to generate increased incomes from various activities and reduce the impact on the environment. This will in turn strengthen aquaculture management in order to support the sustainable growth of aquaculture in Thailand.

5. Major gaps and constraints in building climate-resilient aquaculture

The gaps and constraints in building climate-resilient aquaculture are in the areas of mitigation and adaptation assessment, research and systematic observation and data collection, in addition to the country's financial and capacity building needs. Capacity building and training will be an ongoing effort at the institutional and technical level.

6. Recommendations on regional strategy and actions to support the national effort to build climate resilient aquaculture

Increase and strengthen the capacity of the aquaculture sector by raising awareness of the impacts of climate change and transfer information, knowledge and technology to relevant parties at all levels to enhance the stakeholders reception of climate change-related policies and their ability to implement such policies.

Timor-Leste

Horacio Amaral dos Santos Guterres

1. Introduction

As stated in the Timor-Leste National Aquaculture Development Strategy (NADS), aquaculture contributes significantly to food security, poverty alleviation, and income generation. Currently, major aquatic animals and plants being cultured are tilapia, catfish, common carp, *Vannamae* sp., seaweed, mud crab, milkfish and grouper. Timor-Leste's aquaculture and capture fisheries subsectors' contribution to the total GDP was 1.4 percent valued at USD 5.7 million.

The Government of Timor-Leste has strongly emphasized the need for diversification of livelihoods for the improvement of food and nutrition security in the country. The Strategic Development Plan (SDP) (2011–2030), recognizes the importance of a thriving agricultural sector for food and nutrition security, reduction of poverty and for the economic growth of the nation as a whole. To achieve the objectives stated in the SDP, the Directorate General for Fisheries Timor-Leste prepared a National Aquaculture Development Strategy (NADS) (2012–2030) which targets an increase in the average annual fish consumption from 6.1 kg/capita to 15 kg/capita by 2030.

2. Specific threats/risks of climate change and climate change related extreme meteorological events to aquaculture

The impact of climate change poses serious challenges to sustainable livelihoods and economic development, particularly for least developed countries such as Timor-Leste. Climate change threatens food insecurity and biodiversity loss, damage to government hatcheries and could contribute to the degradation of the country's waterbodies.

One of the major threats to Timor-Leste marine ecosystems is the removal of mangroves which expose the coastal areas to erosion and flooding, consequently threatening the marine ecosystem with serious consequences in terms of coastal and marine biodiversity. There is a noticeable rise in temperature in Timor-Leste, at a rate of 0.12°C per decade over the period 1981–2008. The rise in temperature and consequent increase in evapotranspiration will reduce water availability, especially freshwater. Various adverse impacts to fish farms and government hatcheries are attributed to climate change such as overheating of pond water, poor water quality, insufficient water in the ponds, reduced feeding activity and lower growth rate, and operating costs have increased accordingly. Seaweed farms have been subject to outbreaks of ice-ice diseases.

3. National efforts addressing climate change and building the climate resilience of aquaculture

a. National strategy and action plan development

The adverse impacts of climate change are already noticeable in many countries including Timor-Leste. The Government of Timor-Leste's Strategic Development Plan (SDP) 2011–2030 commits Timor-Leste to develop a National Adaptation Programme of Action (NAPA), to identify national priorities to address climate change adaptation and to monitor the implementation of adaptation measures.

Although a relatively young country, Timor-Leste ratified the UNFCCC on 11 April 2006 and it came into force on 8 January 2007. The country also ratified the Kyoto Protocol in March 2008 and it came into force on 12 January 2009. Timor-Leste submitted its NAPA in 2011 and Initial National Communication (INC) in 2014, and then climate change impacts and vulnerability assessments were undertaken for both NAPA and INC. The country has started its INC to the UNFCCC with the support of the Global Environment Facility, the Australian Agency for International Development (AusAID) and the United Nations Development Programme (UNDP).

b. Research and technology development

Particularly in the aquaculture sector, there are no national country-specific studies and insufficient historical weather data for Timor-Leste to provide comprehensive analysis and evidence of how its climate has changed. A number of preliminary studies, including analysis of data from West Timor, are used to provide an indication of possible changes in climate in the region, and in addition, global models are also used to extrapolate information to Timor-Leste.

In 2014, the Government of Timor-Leste established the Centre for Climate Change and Biodiversity (CCCB) under the National University of Timor Lorosae to address adaptation research.

c. Programme/project activities addressing climate change in aquaculture, covering both adaptation and mitigation

In order to address climate change in aquaculture, Timor-Leste has, with international assistance, implemented several project activities, such as: establishment of a baseline for future monitoring of several climate change-related parameters in the nearshore ecosystem; NAPA implementation of mangrove and coastal zone management project supported by GEF and implemented by UNDP; a partnership project by The Directorate General Fisheries Timor-Leste and WorldFish to develop capacity in climate change adaptation and improve coastal livelihood resilience; and a NAPA implementation project on disaster risk reduction (in the Dili-Ainaro corridor).

d. Lessons learned/good practice from ongoing efforts

Although a relatively young country, Timor-Leste actively participates in several international conventions and agreements to confirm its commitment, particularly to adaptation and mitigation measures for alleviating the adverse impacts of climate change to the Timorese and to the international community. At the national level, the country has developed national resource management plan activities and policies that benefit coastal communities (PEMSEA, CTI, CI, WFC, and ATSEF).

5. Major gaps and constraints in building climate resilient aquaculture

Currently, local researchers in climate change impacts on aquaculture are poorly represented in training, research and decision-making organs in the country. Climate change initiatives are limited by inadequately trained human resources at various levels, and by a lack of climate data and processing equipment. Experiences from the various training institutions indicate that very few institutions provide specific courses that address climate change impacts on aquaculture.

6. Recommendations on regional strategy and actions to support the national effort to build climate-resilient aquaculture

Considerable training for capacity development in climate change, vulnerability assessment, adaptation and mitigation should be made available with the assistance of partner institutions. Such training programmes could help the country to address issues such as promoting national policy, finance and data availability and climate modelling by facilitating human capacity and infrastructure development.

Viet Nam

Nguyen Ba Son

1. Aquaculture overview

Fisheries plays a crucial role in the developing economy of Viet Nam, and aquaculture is one of the most dynamic and fastest growing subsectors. In 2010 total aquaculture production was estimated at more than 2.6 million tonnes, and that of 2016 was 3.6 million tonnes. The export value accounts for USD 6 billion per year, about 25 percent of agriculture export earnings.

2. Major aquaculture systems and commodities in Viet Nam

The total area devoted to aquaculture is 1.3 million ha producing 3.6 million tonnes with an export value of USD 7 billion. Catfish (1.15 million tonnes), shrimp (657 thousand tonnes), mollusks (oysters, clam) (480 thousand tonnes) are the main species cultured. The Mekong Delta accounts for 70 percent of total production and export.

The total area devoted to brackishwater shrimp (white leg shrimp and tiger shrimp) is about 700 000 ha, mostly using an intensive/semi-intensive culture system (20 percent), whereas the total area devoted to pangasius is 5 100 ha, with ony the intensive culture system used. About 500 000 ha are devoted to other species.

3. Specific threats/risks of CC and CC-related extreme meteorological events to aquaculture

- Climate change has impacted some target species: four main groups of brackish and marine species, namely crustacean (e.g. shrimp, crab); mollusks (e.g. oysters, clam); brackishwater fish (e.g. mullet, four-eyed sleeper); and marine fish (e.g. cobia, grouper, seabass). Aquatic plants have also been impacted (e.g. seaweed) as have freshwater species such as pangasius, giant freshwater prawn, other freshwater fish.
- Impacts of drought and salinization in 2016: The effects of climate change were significant causing rising average temperatures. The records showed an average temperature rise of 0.1°C to 1.5°C (the highest temperature went up from 33°C to 37°C). The rainfall increased, but it mostly was concentrated in 2016. In addition, salinity intrusion was also caused by the construction of dams further upstream on the Mekong River and dams on the lower Mekong River, which reduced freshwater flow and prevented the renewal of the delta's silt deposits. Therefore, salility rose significantly and seawater intrusion reached inland to 50 km to 60 km, which affected wider areas of the Mekong River Delta.

These impacts caused extreme damage in Mekong River Delta this year with all 13 provinces affected by drought; 9 provinces were affected by salinization (this accounted for 40 percent of the Mekong River Delta), and damaged 208 000 ha rice (120 000 ha had about 70 percent yield lost), about 9 400 ha rice and fruit, and about 2 000 ha aquaculture.

Forecastes sugest that salinization will affect aquaculture activities in the Mekong River Delta (the scenario of sea level rise will be 50 cm according to Model VRSAP), especially pangasius farms in An Giang, Dong Thap and Can Tho, and 400 000 ha of brackishwater shrimp in eight provinces will be affected. It is also predicted that 20 000 ha will be impacted by the increased salility of 4 ppt to 8 ppt).

4. Viet Nam's efforts addressing climate change and building climate resilience of aquaculture

4.1. National strategy and action plan development: The Vietnamese Government and Ministry of Agriculture and Rural Development (MARD) have issued many important strategies and policies to cope with climate change: on 2 December 2008, the Prime Minister issued Decision No.158/2008/QD-TTg approving the national target programme to respond to climate change, Decision No. 2139/QD-TTg 2011 approving the national climate change strategy, and Decision No. 1474/QD-TTg 2012 approving the national action plan on climate change for the period 2012–2020. The Minister of MARD issued Decision No. 66/2013/QD-BNN approving MARD's national action plan coping with the climate change in the period 2012–2020. Other actions taken by the Minister included issuing Decision No. 1690/2013/QD-TTg approving the Master plan for fisheries and aquaculture development towards 2020 and visions for 2030, issuing QĐ-327/2014/QD-BNN approving the action plan of MARD on coping with climate change. The Vietnamese Assembly is preparing a Fisheries Law in which Article 5 will regulate fishery activities in accordance with climate change.

4.2. Research and technology development

There is some research from MARD and international organizations such as FAO, WorldFish and the World Bank:

- vulnerability and impacts assessment; identification of adaptation options and CBA for aquaculture, including a set of recommendations and actions for inclusion into the National Adaptation Plans (NAPs);

- climate change impact assessment on infrastructure, farming areas and production of coastal aquaculture farming to develop adaptive solutions and pilot farming systems; and
- assessment of the vulnerability of the agriculture sector to formulate feasible solutions and activities to support impacted and vulnerable agriculture areas.

Because of severe drought and salinity intrusion in 2016, the Directorate of Fisheries of MARD issued a document guiding the process of safe brackishwater shrimp culture covering appropriate stocking density, decreasing environmental pollution, and limiting the use of antibiotics. Another document guiding brackishwater shrimp farming in conditions of drought and salinity intrusion was also issued and covered introducing culture in two phases, stocking large size fingerlings, reducing water exchange, not stocking during drought/salinity intrusion, using polyculture of shrimp and fish, shrimp and crab.

4.3. Programme/project activities addressing climate change in aquaculture, covering both adaptation and mitigation:

- The project on "Climate change adaptation and sustainable livelihoods" (MD-ICRSL) involving funding of USD 384 679 million from World Bank, covering the period 2016–2022.
- Enhancing community resilience to climate change by promoting climate smart aquaculture (CSA) in the northern coastal area of Viet Nam (ECO-SAMP project). This was funded by WorldFish and CCAFS/CGIAR, 2015-2016).
- Climate change impacts to agriculture and aquaculture in Mekong Delta for improving and promoting adaptively inclusive business models by agribusiness targeting small scale producers' benefits (Right to Food (R2F)). This was funded by OXFAM Viet Nam, 2016-2017).
- Climate smart aquaculture workshop funded by USDA, 2017).

These strategies and policies have four main objectives: (1) to adapt to changes in temperature, rainfall and salinization*:* transforming production structure (mixing shrimp and rice, shrimp and forest, shrimp farm with other products, domestication, adjusting farmed products, improve farming technology, etc., planning for converting solutions, adapt solution, maintain suitable ratio between white leg shrimp and tiger shrimp; (2) to adapt to changing frequency and intensity of storms, floods (planning and upgrading infrastructure of farming areas and farms; (3) to monitor the environment and manage disease and waste; (4) to raise awareness about climate change.

4.4. Lessons learned/good practice from ongoing efforts:

- raising awareness about climate change; and
- national coordination and multisectoral coordination.

5. Major gaps and constraints in building climate-resilient aquaculture:

- strategies and action plans are not specific, and the public is not aware of the issues surrounding climate change; and
- lack of funding for the investment of infrastructure and research projects on climate change.

6. Recommendations on regional strategy and actions to support the national effort to build climate-resilient aquaculture:

- building a regional strategy for adaptation to climate change; and
- support the Government of Viet Nam to develop projects related to climate change adaptation in aquaculture.

Extended summaries of presentations from international/regional organizations/projects and the private sector[17]

Network of Aquaculture Centres in Asia-Pacific (NACA)

NACA and sustainable aquaculture

Cherdsak Virapat

Climate change will affect food security in Asia by the middle of the twenty-first century, with South Asia most severely affected. Almost 90 percent of aquaculture production takes place in Asia. One study identified Bangladesh, Cambodia, China, India, Philippines and Viet Nam as the most vulnerable countries worldwide. Several strong intergovernmental agencies have been established in support of aquaculture development in the Asia-Pacific region. International agencies such as FAO, NACA, WorldFish, ADB, and regional agencies, e.g. APEC, APFIC, BOB-LME IGO, SEAFDEC, SPC, continuously provide technical and financial assistance for the development and better management of aquaculture. Dedicated NGOs such as the Asian Fisheries Society also contribute immensely through bringing science and scientific knowledge into aquaculture.

To meet increasing demand, the only way is to promote the sustainable intensification of aquaculture (SIA), which means "to produce more with less". Four basic tenets of a sustainable aquaculture strategy are: i) responsible access to and use of aquatic genetic resources and genetic improvement; ii) sustainable farming systems; iii) aquatic animal health, including responsible transboundary movement of aquatic animals; and iv) appropriate responses to climate change impacts. SIA has now been identified as a regional initiative in support of the FAO's Blue Growth Initiative (BGI). With respect to the Sustainable Development Goals (SDGs, goal 14.7), the aquaculture sector plays and will continue to play a prominent role in world food security. Data deficiencies are a key impediment to successful development. Further efforts are needed to quantify and report damage and losses arising from disasters in order to understand and address the main challenges.

Regional initiatives can be categorized into four groups, namely: i) increasing climate resilience of fish farmers, farming systems and breeds available for farming; ii) increasing capacity to manage short-term and long-term climate risks and reduce losses from weather-related disasters; iii) improving sustainability of genetic diversity in broodstocks as a resource for long term, continuous adaptation to climate change; and iv) reducing and/or sequestering greenhouse gas emissions.

NACA and its partners have played a vital role in implementing many activities, such as strengthening adaptive capacities to the impacts of climate change in some member countries (AquaClimate Project); implementing culture-based fisheries development in Lao People's Democratic Republic (low emission food production); arranging meetings on Climate Change and Disaster Risk Reduction in Nepal and Efforts for Strengthening Adaptive Capacity to Climate Change in Aquaculture and Fisheries; environmental monitoring and early-warning systems for fisheries and aquaculture in the Lower Mekong Basin; organization of the Global Conference on Climate Change Adaptation within Fisheries and Aquaculture (FishAdapt); sharing experiences on the ground; adaptive learning in sustainable aquaculture best practices for small-scale shrimp farmers in Thailand; conducting a seminar on food security through sustainable aquaculture development and disaster risk reduction for Bangladesh.

[17] The full text of the presentations may be obtained from the authors.

Some current and proposed future activities are the Second Phase of the Culture-based Fisheries Development in Cambodia Project; activities to address climate change implications for aquaculture and aquaculture inventory to improve the sector's capacity to adapt to climate change impacts in the southern districts of Bangladesh; monitoring and early-warning system relevant to fisheries and aquaculture in the Lower Mekong Basin; a regional training programme in aquaculture governance in the Asia-Pacific region; strategic network programme to promote smallhold farmer networks for aquaculture genetic improvement (e.g. NBIN) in a variety of environments and farming systems; pilot programmes for emergency rapid appraisal of genetic biodiversity, inbreeding and adaptive capacity in small-scale aquaculture systems; and planting mangroves for integrated multiple benefits – a new paradigm.

It is suggested that combined efforts should be made for setting up a regional climate change impact assessment, showing the possible effects of climate change on aquaculture in different countries over the next 15 years (increasing temperature, change in rainfall patterns, storm intensity and frequency, increase CO_2 levels and sea level rise). This would provide farmers with information to make informed choices about how they should be adapting their aquaculture production systems to climate change. It would define adaptation strategies for the main environmental, disease and genetic threats caused by climate change, to inform and guide the aquaculture community. The results of the vulnerability assessment and adaptation planning and strategies would be communicatied at all levels and pilot projects on adaptation could be implemented and capacity building required to manage aquaculture systems could be provided.

Southeast Asian Fisheries Development Center Aquaculture Department (SEAFDEC/AQD)

SEAFDEC's activities addressing climate change and aquaculture

Maria Lourdes A Cuvin-Aralar

The activities of the Southeast Asian Fisheries Development Center Aquaculture Department (SEAFDEC/AQD) climate change and aquaculture programme focus on addressing the important issues and recommendations that were discussed during the ASEAN-SEAFDEC Conference on Sustainable Fisheries for Food Security Towards 2020, Fish for the People 2020: Adaptation to a Changing Environment. Areas in the ASEAN region that are vulnerable to climate change-related effects will be identified and the kind of probable impact(s) will be determined so that appropriate adaptive measures can be proposed. The fish farmers and the general public will need to have better understanding about climate change and its likely impact(s) on their livelihood opportunities for better preparation and adaptation. Since largely almost nothing is known about how climate change will affect the biology of various species presently farmed and the various support systems, important data on this aspect will be generated to serve as a basis for the mitigation measures that will be provided. Improvements and innovations on the different aquaculture holding systems and structures are also necessary in order to lessen and/or reduce the impact to fish supply production. How climate change affects important related ecosystems such as the mangrove and coral reef ecosystems will be ascertained as well.

General Objectives

The general objectives of the programme are to identify the accompanying changes in the environment brought about by the changing climate that may affect the aquaculture subsector, prepare the subsector for the possible effects that these changes may have on aquaculture operations, minimize and mitigate the adverse impact(s) of climate change in aquaculture, and ensure the continued operation of all aquaculture production systems under changing climatic conditions.

Specific Objectives

The specific objectives are to: (1) gather scientific information on the susceptibilities of various aquaculture species to the combined effects of increasing seawater temperature and acidity; (2) gather scientific data on the effects of climate change on the production of natural live food organisms for hatcheries and for pond culture systems; (3) promote public awareness on the possible effects of climate change on aquaculture activities and on the fish farmers; (4) assist other government agencies in the country and in the region in gathering baseline information on aquaculture areas/sites that are vulnerable to climate change effects; (5) gather scientific information that will serve as a basis for the formulation/design of alternative aquaculture systems that are adaptive to climate change; (6) collaborate with other institutions in the country and in the region in gathering baseline information on the effects of climate change on mangrove and coral reef ecosystems; and (7) explore potential adaptive measures to mitigate the impact(s) of climate change on the different aquatic farming systems.

Activities implemented

Since 2012, a number of activities under the programme have been implemented by SEAFDEC/AQD.

1. Research on the effect of elevated temperatures on reproductive performance and embryonic and early larval development of aquaculture commodities such as rabbitfish, milkfish, Asian seabass, mud crab and abalone:

- The effect of elevated water temperature on gonadal maturation and spawning in tropical marine aquaculture fishes was investigated using the rabbitfish *Siganus guttatus* as a test subject. Results show that exposure to 33°C of rabbitfish broodstock resulted in most females having atretic oocytes, very low incidence of spawning and no hatching of spawned eggs. In contrast, those exposed to ambient temperature (27°C to 29°C) and slightly elevated temperature of 31°C did not show any appreciable negative impact on the subject. In fact both groups showed high spawning performance and good gonadal development.
- The effect of elevated water temperature on embryonic development of important marine fishes was investigated in milkfish, rabbitfish and the Asian sea bass. Larval survival was low in milkfish and rabbitfish reared in constant temperatures of 31°C and 33°C. Seabass larvae had a good tolerance to the same elevated temperatures. All three species had the best survival rate at ambient temperatures.
- In the case of mud crab, sensitivity to temperature varies among zoea stages. Zoea 1 survived well in 319°C whereas zoea 3 and 4 prefer ambient temperature (27°C–29°C). Overall, lowest survival in zoea larvae was observed at 33°C.
- The effect of elevated temperatures on various stages of the donkey ear abalone was also studied. Newly fertilized eggs incubated at 339°C showed only a few embryos developing and the hatching rate was low with only 20 percent compared to 86 percent in ambient temperature of 27°C–29°C. Larval survival and settlement success were also adversely affected at 31°C and 33°C. It appears that juveniles are more resilient to the effects of elevated temperature with growth and survival not adversely affected at 31°C and 33°C. However broodstock was highly sensitive to high temperatures with total mortality of females after 45 days at 33°C whereas only 10 percent of males survived. Growth and feeding rates were significantly reduced in the broodstock. Gonads also regressed.

2. Generation of scientific data on the effect of acidic conditions and elevated temperature on corals:

- The coral *Porites* sp. showed low survival and reduced growth when exposed to acidic conditions and higher temperatures.

3. Generation of scientific information on the effects of increasing temperature, pH and salinity on reproduction and growth of natural food organisms used in fish hatcheries:

- Copepods: survival of *Pseudodiaptomus annandalie* was significantly lower in low pH (7.5) and high salinity (38 ppt). Survival of *Acartia tsuensis* was significantly low in low salinity (20 ppt) and low pH (7.5).
- Rotifers: population growth of rotifer is significantly higher at high temperature (33°C) and low salinity (20 ppt), and low at low pH (pH 7.5). No interactive effects on population growth were observed in combination of various salinities, pH and temperature. Sizes of rotifers were not significantly affected in the various treatments and no abnormality in swimming or morphology was observed in all treatments.

4. Ongoing assessment of the economic benefits and losses of seaweed farmers as a result of some climate change indicators.

- A decline in seaweed production has been attributed by farmers to: (1) drastic change in temperatures; (2) changes in quantity and frequency of rainfall; and (3) presence of extreme events such as typhoons.

5. Information dissemination through lectures on climate change impacts on fisheries and aquaculture and their mitigation:

- Climate change impacts, mitigation and adaptation are part of SEAFDEC/AQD's regular training courses.
- SEAFDEC/AQD participates through lectures in fora on climate change.

6. SEAFDEC/AQD participates in the review and crafting of research agenda on climate change, the most recent one was the National Review and Calibration of Climate Change Research and Development Programme for the Bureau of Agricultural Research of the Philippines' Department of Agriculture.

7. SEAFDEC/AQD is also an institutional member of the Committee on Climate Change of the Philippine Council on Agriculture and Fisheries (PCAF).

Southeast Asian Fisheries Development Center Training Department (1)

SEAFDEC's climate change and aquaculture/fisheries programmes

Yuttana Theparoonrat

There are three SEAFDEC programmes on initiatives addressing fisheries/aquaculture related climate change issues as follows:

1) Optimizing Energy Use and Improving Safety in Fishing Activities (SEAFDEC/TD).
2) Adapting to Climate Change (SEAFDEC/AQD).
3) Fisheries and Habitat Management, Climate Change and Social Well-being in Southeast Asia (SEAFDEC/SEC).

Programme 1: Optimizing Energy Use and Improving Safety in Fishing Activities (SEAFDEC/TD, 2013–2019)

In the process of capturing wild fish, the fuel cost obviously takes up the majority of operational costs and directly decreases the incomes of fishers. The major concerns about the use of energy include excess power of the main engine, heavy construction of wooden hull structure, poor maintenance of the engine

and machineries, and inappropriate fishing operations/practices. In the capturing process, the fuel cost takes up the majority of the operational costs, but there appears to be no alternative source of energy available in the near future. With reference to the global concern about climate change that includes the reductions of greenhouse gases by reducing the source of pollutants, this programme deals with fuel efficiency measures that require minimum modification of their existing equipment to optimize energy use for fishing operations. It is therefore, the main activity under the programme and includes transferring appropriate ways to optimize the use of energy for the fishing vessels. It also includes adjustment/ improvement of current practices of the vessels. Awareness raising on safety at sea for fisher includes the improvement of living and working conditions onboard to ensure that human well-being of fishers will be increased.

Objectives

1) enhancement of knowledge and experience of ship owners, fisheries extension officers, and other key stakeholders of ASEAN Member States; and
2) research and development on improving fishing operation/practices and optimizing energy use.

Programme activities:

Activity 1: Regional and national training/workshop

The programme has organized regional training workshops, in collaboration with relevant agencies on optimizing energy use and safety at sea for small fishing vessels since 2011. The programme translated international guidelines, national guidelines, and other relevant training materials to various national languages. Such training materials have been used for onsite training programmes to enhance awareness of fishers and fisheries officials (to further transfer the knowledge) regarding fuel efficiency and safety at sea for the fishing vessels.

Activity 2: Regional meeting on current situation on energy saving and safety at sea, and way forward to promote/improve energy saving and safety at sea for SEA region.

This series of activities aims to apply appropriate techniques, and use or adopt various technologies in order to improve energy efficient utilization (energy saving) in fishing activities. A major focus is on improving the efficiency of vessel design, gears and equipment related to fishing operations.

Activity 3: Information dissemination

The current handbook and promotional materials will be revised. Moreover, major outputs from the implementation of programme activities and their progress will be disseminated to the ASEAN Member Countries and other relevant agencies through a website, training and promotional materials, etc. The outputs from this activity could also be used as the regional reference for optimizing energy and safety at sea for fishing vessels in the Member Countries.

Programme 2: Adapting to Climate Change (SEAFDEC/AQD, 2012–2020)

Climate-related disturbances are projected to impact broadly across ecosystems increasing the pressure on all livelihoods and food supply chains, including the fisheries and aquaculture sectors. In particular, the sustainability of aquaculture will be further challenged since the effect of these climatic changes on farmed organisms is largely unknown. The different aquaculture systems, facilities, and support systems for aquaculture operations, as well as the fish farmers themselves, will be affected. The small-scale fish farmers in the region that produce the great bulk of the aquaculture production are largely vulnerable. Mitigation and adaptive measures are therefore urgently needed to address the threats to food and livelihood provision that may arise because of the changing climatic conditions observed globally.

Objectives

The long-term objective of the programme is to ensure that aquaculture production of important aquaculture commodities will continue even under conditions of higher temperature and more acidic waters for continuous supply of food fish and for income generation. To achieve this, scientific information is necessary as a basis for future interventions. This type of information is addressed in the specific objectives below:

(1) to gather scientific information on the susceptibilities of various economically important aquaculture species to the combined effects of high seawater temperature and acidity;
(2) to generate scientific data on the effects of abrupt changes in water temperature and salinity brought about by long dry spells followed by heavy rains in the outdoor production of natural live food organisms for hatcheries and for pond culture systems;
(3) to promote awareness to the fish farmers and the general public on the possible effects of climate change on aquaculture operations;
(4) to assist other government agencies in the country and in the region in gathering baseline information on aquaculture areas/sites that are most vulnerable to climate change effects/impacts;
(5) to collaborate with other institutions in the country and in the region in gathering baseline information on the effects of climate change on mangrove ecosystems;
(6) to explore potential adaptive measures to mitigate the impact(s) of climate change on the different aquatic farming systems; and
(7) to collaborate with other institutions in the country and in the region in gathering scientific information that will serve as basis for the formulation/design of alternative aquaculture systems that are adaptive to climate change.

Activities

1) investigating the effects of wide and abrupt temperatures, acidity levels and salinity fluctuations on susceptibility and performance of various economically important cultured species;
2) conducting trials to develop breeding and seed production and culture techniques for candidate resilient species;
3) collecting articles and literatures on climate change to deposit in library; and
4) conducting survey of sites and areas used for aquaculture activities in the country and the region that are most vulnerable to climate change.

Programme 3: Fisheries and Habitat Management, Climate Change and Social Well-being in Southeast Asia (SEAFDEC/SEC, 2013–2018)

In Southeast Asia, environmental degradation, overcapacity (illegal and destructive fishing) and threats from climate variability and climate change are seen as the most significant problems for fisheries and aquatic habitats, threatening their sustainability and the livelihoods of the millions of people dependent on these resources. Through support from the Swedish International Development Cooperation Agency (SIDA), SEAFDEC in cooperation with ASEAN (under the ASEAN-SEAFDEC Strategic Partnership (ASSP)) and the ASEAN Member Countries have been implementing regional collaborative programmes to clarify regional policies and priorities as well as to support national efforts in addressing habitat and fisheries management and the management of fishing capacity.

The basic strategy of the SEAFDEC-SIDA project is to build upon the expressed needs to improve social well-being and environmental health, by promoting processes to improve the management of fisheries, fishing capacity and better management of aquatic environments and habitats of importance for key species. To incorporate all relevant aspects (social, governance and aquatic resources/environment) an ecosystems approach will be applied. This includes management matters, such as (larger) fish resources conservation areas (e.g. building upon MPAs and refugia), management of fishing capacity (combating IUU fishing), social mobility and conflicts, etc. The perspective includes the establishment of subregional

agreements or other arrangements of relevance to fisheries and habitat management in the Gulf of Thailand and the Andaman Sea to support processes for cooperation among countries in the Sulu-Sulawesi Seas and the Mekong River Region.

Project Objectives

The main objective is to achieve the sustainable use of aquatic resources and reduced vulnerability to climate change by coastal/rural (fishing) communities in the ASEAN region.

- bridging objective 1: implementation of regional and subregional aquatic resources management actions by national institutions and organizations.
- bridging objective 2: establishment and implementation of regional and subregional fisheries and habitat management agreements and action plans.

Activities

Activity 1: capacity building for integration of habitat and fisheries management and adaptation to climate change.

Activity 2: capacity building and systems improvement for the management of fishing capacity (monitoring, record and control).

Activity 3: capacity building and policy development processes improved for the drafting and implementation of regional and subregional agreements.

Activity 4: project management and coordination.

Southeast Asian Fisheries Development Center Training Department (2)

Application and review of energy audit in small and commercial fishing vessels

Suthipong Thanasansakorn

Background

The profitability of the global commercial fishing fleet is now challenged by volatility in oil prices, despite recent global reductions in the price of oil. Coupled with concern over greenhouse gas emissions from the combustion of fossil fuels, greater focus is being placed on energy-intense fisheries and the application of fuel-saving practices to fishing vessels and fishing gear.

An energy audit is an important step toward systematically evaluating the potential impact of fuel-saving practices in fisheries, including their suitability and relative contribution to fuel conservation. This presentation describes the outcome of an extensive energy audit of the Thai single-boat trawl fleet. The methodology that was applied was based on energy audit protocols designed for the Australian fishing industry and further modified following completion of a pilot energy audit study in the Thai single-boat trawl fleet in 2014.

The energy audit protocol consisted of two key levels. The Level 1 audit involved interviewing a total of 150 fishers about the operation of their trawler and fishing gear, including operational specifications, duty cycles, and catch and expenditure details. Six trawlers were then selected for further evaluation, including at-sea measurement of fuel consumption over a period of six months. A variety of fuel saving options were then identified and a first order estimate of their suitability and fuel saving impact on the entire trawl fleet was calculated. The payback period (return on investment) for many potential options was estimated to be less than one year. Potential fuel savings across the entire trawl fleet are also discussed.

Methodology

The methodology used in this project was based on a three-level audit process developed for Australian fishing vessels. This process built upon the Australian Energy Audit Standard (AUS/NZ 3598:2000) that was initially developed for land-based enterprises and later modified to suit the Australian fishing industry. This process was designed to collect data systematically on energy consumption, vessel specifications and machinery, and vessel operation so that relative sources of energy consumption could be identified and a prioritized, focused, cost-effective effort made to reduce consumption and avoid waste.

Energy audit process

A Level 1 audit involves meeting with a fisher or trawler owner to estimate energy consumption and outputs including landed catch from the fishing operation. Data regarding the annual and seasonal rate of energy consumption and associated costs are provided by the fisher or through the provision of historical records or receipts, ideally from the past 24 months. Catch data, by species, volume, and value, are also provided over the same corresponding period. These data can then be used to provide an initial assessment of peaks, troughs, and trends in energy consumption, catch, and energy consumed per unit of output, for example litres of fuel used per kilogram of landed seafood. This assessment can then be used to provide a benchmark from which future energy consumption can be monitored, especially after application of fuel saving technology or operational behaviour. It can also be used to evaluate if energy consumption is reasonable or excessive against established benchmarks if available. Potential options to reduce fuel consumption may be identified at this time along with first order estimates of fuel savings, the accuracy of which is likely to be ±40 percent of actual savings.

A Level 2 audit identifies all sources of energy used on the trawler, how each energy source was consumed, the amount of energy consumed, and the associated rate of consumption. This usually relies upon information from the Level 1 audit and a site visit to identify and view sources of energy consumption. During the site visit important specifications and details of the trawler are collected, such as fishing operation, energy sources, and energy consumption patterns including sources of inefficiency and loss, to identify future data collection needs to fill gaps and to begin to identify areas that require further investigation. At this time a list of applicable fuel saving options should be developed with estimated cost of installation, expected fuel-saving targets and annual savings, and payback periods based on knowledge of the trawler's fishing operation. The accuracy of fuel saving estimates after a Level 2 audit should be ±20 percent of actual savings.

The final level provides a detailed analysis of energy use, savings, and associated costs. Based on the outcomes of the Level 2 audit, this level focuses on critical areas that affect the energy efficiency of the fishing operation. A specialist may be required to carry out specific parts of the audit or to install metering or logging equipment. The outcome is a thorough evaluation of energy consumption and precise cost estimates for the implementation of energy saving options and their associated savings. This analysis should be ±10 percent of actual savings.

In this project a Level 1 audit was completed using methodology similar to that described using the Australian Energy Audit Standard. However, for convenience, efforts to collect Level 2 and Level 3 audit data were combined. For example, one or more site visits to collect Level 2 audit data also served to install metering equipment and prepare for the Level 3 audit. Furthermore, during sea trials data was collected that served both the Level 2 and Level 3 audits. Because of these combined efforts, hereafter these efforts are referred to as a Level 2 audit.

Data collection

In this project the first level of the audit process included randomly selecting single-boat bottom trawlers from several fishing ports. The fishing ports where trawlers were selected from were located at Songkhla and Chumphon provinces in the western Gulf of Thailand, and Satun and Trang provinces in the

Andaman Sea. Details about the trawler and fishing operation were collected by interviews with participating fishers/skippers and their completion of a questionnaire with included details such as:

- trawler design characteristics, condition, age, degree of hull-fouling, and rudder dimensions;
- trawler engine, transmission and propeller characteristics;
- fishing gear characteristics, design, and rigging;
- photographic profile of each trawler;
- characteristics of a typical fishing trip, including steaming and fishing time, time lost to weather or damaged gear, typical handling of trawler, and maintenance schedule; and
- major operating costs – fuel, crew, food, lubricant, and ice.

Bay of Bengal Programme – Inter-Governmental Organisation (BOBP-IGO)

BOBP-IGO and its work related to climate change

Yugraj Singh Yadava

Active engagement of the Bay of Bengal Programme – Inter-Governmental Organisation (BOBP-IGO) in building climate-resilient fisheries started with the implementation of the South Asia component of the Global Safety at Sea Programme (S@S Programme) of the Food and Agriculture Organization of the United Nations. The BOBP-IGO implemented the S@S Programme in its four member countries (Bangladesh, India, Maldives, Sri Lanka) with the focus on building a database on accidents at sea; improving weather warning and complying with weather warning within fishing communities; promoting use of safety and communication equipment; and identifying social security programmes that could support families in the event of fatalies at sea and natural calamities that frequently occur in the Bay of Bengal region. Subsequently, in 2013, the Governing Council of the BOBP-IGO approved the Strategic Plan of Action 2014–2018 (SPA: 2014–2018) with the goal of ensuring that an "enabling environment for sustainable fisheries governance is in place in the region." Under the SPA: 2014–2018, BOBP-IGO is undertaking three umbrella activities in its member countries: (i) building capacities in fisheries management agencies to monitor and report possible impacts of climate change; (ii) trial of green technologies to reduce the carbon footprint of fisheries; and (iii) assisting in community preparedness. The first activity addresses the juxtaposition of familiarity with the phrase "climate change" and the lack of documentation or coherent information to prepare a strategy. The second activity looks into possible uses of solar energy in fishing fleet and post-harvest activities aiming both at reducing the carbon footprint and improving the cost-effectiveness of fishing operations. The third activity engages member countries in improving weather forecasting and ocean monitoring and improving social security nets for the fishers. Moreover, the BOBP-IGO is also engaged in capacity-building activities and knowledge dissemination in building climate-resilient communities and working in close cooperation with both fisheries and environmental agencies. Resilience of fisheries to climate change depends to a large extent on the health of the fish stock and sound fisheries economics. Without a proper fisheries management system in place, addressing climate change will be a dressing of the malady and not the remedy. Therefore, the focus of BOBP-IGO is on building good governance in the subsector through EAF in the region.

Mekong River Commission

Assessment of the impact of climate change on fisheries resources under different climate change conditions and scenarios in the Lower Mekong Basin

Phattareeya Suanrattanachai

Global warming is expected to bring significant changes to the hydrology of the Mekong Basin and this could have substantial implications for capture fisheries in the Lower Mekong Basin (LMB), which have an

immense value for the economy, food security, and heritage of the region. Therefore, the overall objective of the research on which this presentation is based was to assess the impacts of climate change on wild fish catches under different climate change conditions and scenarios in the LMB and provide policy recommendations for climate change adaptations with regards to capture fisheries in the LMB.

The analytical tasks of the research assessed the impacts of flood-driven habitat changes on wild fisheries. This assessment found that the magnitude of changes in habitat cover is expected to be greater for the flood zone than for the rice paddies. Overall, a wide range of variable projections were found according to all factors considered in the climate change scenarios without development, with shifts in the flood zone from -5 922 sq km (-13 percent) to +6 293 sq km (+13.7 percent), and shifts in rice paddies from -3 597 sq km (-2.7 percent) to 3 043 sq km (+2.3 percent). Cumulative yields from both habitats could experience a net change of -155 000 tonnes/yr (-5 percent from baseline) to 97 000 tonnes/yr (+4 percent) for all future scenarios. Small changes are expected in the short term when development is absent from the scenarios; however, losses become much more significant in the short term when development is considered. Conversely, this tendency is not as strong when comparing scenarios in the medium term.

Future adaptation strategies should focus on those areas expected to be resilient despite the unfavourable conditions dictated by climate change and development. In terms of capture fisheries, rice paddies production appeared to be marginally unaffected by climate-driven flooding shifts. Hence, programmes to promote and enhance fish production within rice paddies could greatly build resilience in the region, in particular if rice agriculture continues to expand in the lower Mekong, a scenario that was not considered in this assessment.

Sustainable Development Foundation

Coastal livelihood resilience in the context of climate change: experience and lessons learned from Bang Taboon Subdistrict, Ban Laem District, Phetchaburi Province

Ravadee Prasertcharoensuk

Introduction

The Sustainable Development Foundation is currently implementing the project Strengthening Good Governance and Democratic Process in National Climate Change Adaptation Planning. The project is working in target sites identified as especially vulnerable to future climate change impacts, with the aim of implementing concrete climate change adaptation initiatives in each site, and simultaneously using the lessons learned from field level implementation to inform public policy development at the national level. This European Union-funded project is being implemented in collaboration with Good Governance for Social Development and the Environment Institute.

There are a total of seven different target sites under the aforementioned project, including coastal target sites where local communities are engaged in a mixture of both capture fisheries and coastal aquaculture. One such coastal site is Bang Taboon Subdistrict, Ban Laem District, Phetchaburi Province. Implementation of the project began in February 2016, and is ongoing. The case study that follows is based upon a detailed climate change vulnerability and capacity assessment (VCA) that was carried out as part of the project, and which has helped to highlight the ways in which local communities, capture fisheries and coastal aquaculture are vulnerable to climate change impacts, as well as how they can be made more resilient when faced with climate change. The Sustainable Development Foundation is currently consulting and coordinating with relevant government agencies at both the field level and the central level to see how potential climate change adaptation measures might best be integrated into plans for both field level operation as well as nation level policy development.

The pre-existing situation of shellfish aquaculture in Bang Taboon Subdistrict

Bang Taboon Subdistrict is located in Ban Laem District, a low lying coastal area in the northern part of Phetchaburi Province. The area is enriched by sediment and nutrients from the Bang Taboon River, a tributary of the Phetchaburi River whose waters flow out into the Gulf of Thailand at Bang Taboon Subdistrict. The subdistrict is part of the Phetchaburi Watershed, well known for its rich geographic, biological and ecological diversity. The lower part of the watershed, much of which is covered by mangrove forest, has particularly abundant biodiversity.

The coastline in this part of Phetchaburi Province is characterized by estuarine ecosystems, comprising active tidal flats, mud flats, estuaries and mangrove forests. There are also low lying beaches rich with minerals and organic matter brought to the area along myriad waterways originating from the Phetchaburi River and also the Mekong River. As a result, the area is highly suitable for aquaculture, and in particular shellfish aquaculture. Currently the area plays host to oyster, mussel and blood cockle farms, nestled alongside existing natural shellfish populations and a diverse range of other capture fishery activities.

Ban Laem District was one of the first places in the country to begin intensively farming shellfish, and today it is home to some of the largest shellfish farms in Thailand, in particular blood cockle farms. In Bang Taboon Subdistrict, shellfish farming operates via a concession system, where certain areas of the nearshore coastal zone were specifically allocated for the purpose, starting from the northern part of Ban Laem District and extending to the mouth of the Phetchaburi River. These large concession areas are then subdivided into smaller aquaculture plots. Farmers wishing to make use of these smaller aquaculture plots must request an appropriate concession or access rights from the Department of Fisheries. Only then can they invest in shellfish spat and introduce it to their allocated plot. It is interesting to note that, whereas the oyster spat and mussel spat used in the area is sourced from Thailand, the particular type of blood cockle spat used has to be specifically imported from Malaysia.

According to the Decree on Aquaculture of Phetchaburi Province with Respect to the Demarcation of the Coastal Aquaculture Zone 2017, there are a total of 38.1 square kilometres of shellfish farms in the area.

In recent years, local cockle and mussel farmers from Bang Taboon Subdistrict in Phetchaburi Province and Bang Taboon Nok Subdistrict in Samut Songkhram Province have been negatively impacted by large volumes of water expelled from Pak Tor District in Ratchaburi Province, Ampawa District in Samut Songkhram Province and Kao Noi District in Phetchaburi Province during periods of high rainfall. These periods, typically from October to December, tend to coincide with the harvesting season of shellfish farmers, with the sudden influx of freshwater devastating shellfish populations before they can be harvested. Shellfish, being less mobile than other marine animals such as fish and crustaceans, are particularly vulnerable to such sudden inundations of freshwater.

At the time that project implementation began in Ban Taboon Subdistrict, this was the prevailing situation. Large volumes of freshwater inundated the shellfish farms every year, obliterating shellfish populations and decimating the yields of local shellfish farmers. The management efforts of government agencies in the area focused on providing the shellfish farmers with compensation for their lost investments and earnings. But the project was determined to carry out a comprehensive and holistic assessment of the exact nature of the problem, and the various underlying issues involved, before coming to any conclusions about what the most appropriate solutions and management approaches should be.

The Bang Taboon Subdistrict climate change vulnerability and capacity assessment (VCA)

As a result of carrying out the VCA, the project identified four key problems:

1. the presence of high levels of pollution in the flood waters, mostly the result of agricultural runoff and industrial wastewater from higher up in the watersheds;

2. a failure to properly understand the nature of the wider ecosystem, in particular the fact that much of the water resulting in the inundations was coming from the Mekong Watershed in Ratchaburi Province, and not just from the Phetchaburi Watershed in Phetchaburi Province;

3. water management measures were heavily focused on reducing the impact on rice farming and other agricultural activities throughout the Phetchaburi Watershed, and failed to take into consideration the diverse capture fishery and coastal aquaculture activities along the coastal zone; and
4. the problem of plankton blooms and red tides.

All of these problems were part of the pre-existing situation in Bang Taboon Subdistrict, but all were equally likely to be further exacerbated by climate change.

Waters polluted by agricultural runoff and industrial wastewater

The coastal waters of Bang Taboon Subdistrict are fed by both the Phetchaburi River in Phetchaburi Province and the Mekong River in Samut Songkhram Province. This accounts in part for the area's biological and ecological diversity, as rainy season flows bring with them deposits of nutrient rich sediments, but it also makes the area especially susceptible to waterborne pollution from upriver sources, which tends to accumulate and concentrate around the delta. Waterborne pollution from both agricultural runoff and industrial wastewater severely exacerbates the negative impacts of freshwater inundations upon both capture fisheries and coastal aquaculture in the area.

The project interviewed Mr Chaloem Kraijit, a community leader and shellfish farmer from Bang Taboon Subdistrict who clearly diagnosed the problem:

> "There are approximately 14.4 square kilometres of shellfish farms in Bang Taboon Subdistrict. In the past there were about 420 shellfish farmers, but now there are only about 40, because pollution has killed their shellfish and destroyed their yields. The problem tends to be most severe during the rainy season, when flood waters from Pak Tor District in Ratchaburi Province flow down through the Yee Sarn Waterway and bring waterborne pollution into the coastal waters. Pollution also arrives in Bang Taboon Subdistrict which come from the Mekong River, some 12 kilometres away. All the wastewater discharged from households, communities, industrial estates and pig farms ends up here."

Ecosystem-based approaches and water management measures

Freshwater inundations and waterborne pollution have continued to decimate farmed shellfish populations and threaten shellfish farmers' livelihoods in Bang Taboon Subdistrict for more than five years. The area's shellfish farmers have approached relevant government agencies at the subdistrict, district, provincial and departmental levels in an attempt to address these ongoing issues. An irrigation system focused on reducing negative impacts on rice farmers and other agriculturalists in the Phetchaburi Watershed, but failed to take into consideration potential side effects and their impact on capture fishery and coastal aquaculture. As a consequence, agricultural runoff and industrial wastewater from upriver sources have been identified as the key underlying issues.

Furthermore, the conclusion has been reached that to address these issues, Phetchaburi Province will not be able to act alone. Both the freshwater inundations and the waterborne pollution result not just from the waters of the Phetchaburi River, but also from the waters of the Mekong River which flows through Ratchaburi Province and Samut Songkhram Province. To facilitate an approach that encompasses all three provinces, a formal agreement has been drawn up between Phetchaburi Province, Ratchaburi Province and Samut Songkhram Province, identifying the need to collaborate across their own administrative boundaries and work towards increasingly ecosystem-based approaches to water management.

Plankton blooms and red tides

Red tides have become an increasing problem in the coastal water off Bang Taboon Subdistrict, further contributing to the death of farmed shellfish in the area. Human activity along riverbanks and coastlines in the area has led to an increase in organic matter in coastal waters, the result of improperly treated wastewater from households, communities, agricultural plots, industrial estates, and even shellfish farms themselves. This increase in organic matter has reduced water quality – specifically levels of dissolved oxygen – and caused certain species of plankton to thrive. Some of these species of plankton release biotoxins into the water which are harmful to many types of marine life, including shellfish.

Mr Anek Sawad explained that red tides occur annually, especially in the coastal waters off Bang Taboon Subdistrict, with the worst impacts usually occurring during the rainy season. For example, the 2016 red tide occurred on 10 October, and though it was most intense some distance from the shore, it still impacted negatively upon the area's shellfish farms:

> "Plankton blooms or red tides occur every year in the Ban Laem Gulf, Phetchaburi Province, causing severe problems for shellfish farmers all along the coast. But this is the worst problem we've had in the past 40 years, with negative impacts occurring across three provinces, namely Phetchaburi Province, Samut Songkhram Province and Samut Sakhon Province."

Water resource management in the context of climate change

With regards to the potential impacts of climate change on shellfish farming in Bang Taboon Subdistrict, the Faculty of Engineering at Ramkhamhaeng University downscaled global climate models to anticipate the effect of climate change on the timing and duration of the rainy season, total annual rainfall, and average annual temperature.

Timing and duration of the rainy season

Based on the climate change projections, rainfall patterns during the rainy season, which runs from May to October, are unlikely to see any significant change over the next 20 years or so. However, it is expected that the duration of the rainy season will lengthen, with the rains starting earlier in the month of May and continuing until the middle or end of November.

Total annual rainfall

The climate change projections indicate that total annual rainfall in the area is likely to decrease slightly by 2040. This in turn will lead to reduced tidal activity and increased salinity of nearshore waters, both of which will impact upon shellfish farming.

Average annual temperature

By 2040, the average annual temperature is expected to have increased by about 1°C compared to the average annual temperature in 1981. Such an increase is likely to have direct and significant impacts on both terrestrial and marine ecosystems in the area, affecting both capture fishery and coastal aquaculture, including shellfish farming.

In aggregate, these anticipated climate change impacts are also likely to impact on the marine ecosystem, and thereby on shellfish farming, in other, subtler ways. Changing tidal activity will affect sedimentation rates in coastal aquaculture plots, which will in turn impact upon the survival rates of farmed shellfish. Changes in salinity and water temperature will likely interfere with both growth patterns and survival rates of farmed shellfish.

Conclusions and recommendations

1. Thailand has a host of national level policies and plans related to climate change and climate change adaptation. However, gaps still exist in terms of integrating these policies and plans into concrete operational practices at the lower levels within government agencies. Furthermore, insufficient consideration is given to human resource capacity building in this context. If government officials are to be able to properly integrate climate change considerations into their business-as-usual roles and responsibilities, they require training which goes beyond developing a basic understanding of climate change and its impacts, but extends to practical considerations regarding how that knowledge can be integrated into their day-to-day work.

2. One of the biggest obstacles to effective management of the issues uncovered by the study is the segregated approach that continues to prevail within government agencies. Under normal circumstances, promoting collaboration between agencies from different government departments is a challenging task, even when those agencies are operating within the boundaries of the same province. But to properly address the issues encountered in Bang Taboon Subdistrict requires coordination and cooperation between two completely separate provinces, namely Phetchaburi Province and Ratchaburi Province, because of the nature of the wider ecosystem. Furthermore, many efforts related to water management end up under the oversight of the Irrigation Department, which tends to be heavily focused upon water management in the agricultural and livestock sectors, and often overlooks the unintended side effects that might impact upon the coastal fisheries subsector. This is something that requires a significant change of approach amongst officials in this agency.

3. Information is crucial. Getting different government agencies to establish common goals and objectives and to work together towards achieving those jointly identified aims requires a firm foundation of quality data in order to allow the government agencies to properly understand their roles and plan accordingly. Subsequently, there needs to be adequate follow-up, monitoring and evaluation to ensure plans and budgets are put in place, and measures and initiatives are implemented to tackle the issues identified. It is a case of trying to set up a common framework for resolving the problems that is both multi-agency and cross-sectoral, and that is able to effectively coordinate support across several neighbouring provinces.

4. Apart from promoting and facilitating coordination and cooperation among different government agencies from different government sectors, it is also important to ensure the meaningful participation of other non-government actors and stakeholders, especially coastal communities and local authorities. Since women's groups can be particularly vulnerable, especially to changing economic conditions, and also lack access to information and opportunities, addressing their differential vulnerabilities to climate change requires special measures that will build their capacity, develop their roles and increase their confidence to participate.

5. Thailand has excellent weather forecasting capabilities, but access to the information is often difficult or restricted for those outside of the government sector. Efforts to improve technical access to this information for the general public and other non-government actors would greatly strengthen management efforts. At the same time, there needs to be an increasing focus on long-term climate change, not just short-term extreme weather events, properly taking into account changing temperature profiles, rainfall patterns and seasonal variations over time.

6. Pollution and water quality are additional non-climate factors that need to be addressed. Even in the absence of climate change impacts, factors such as poor water quality, contamination and pollution themselves have a serious detrimental impact on capture fishery and coastal aquaculture. Effectively addressing these issues requires the coordination and integration of a whole new group of actors, such as the Pollution Control Department and local level agricultural extension offices.

WorldFish

Climate smart fisheries and aquaculture in Bangladesh

Malcolm Dickson and Md. Emdad Hossain

Introduction

Bangladesh is one of the most vulnerable countries in the world to the impacts of climate change. There are over 150 million people on a land area of only 150 000 sq km, with almost one third living below the poverty line. Most of the land area is very close to sea level and the coastline is highly vulnerable to storm surges and cyclones from the Bay of Bengal, which could increase as the climate changes. Meanwhile, shrinking glaciers in the Himalayas and increasing abstraction from and blockage of the main river systems mean the country could also face surface water shortages in the dry season. Nevertheless, the country has shown strong economic growth, averaging 6 percent per year, poverty has been reduced, life expectancy has increased, as has literacy and food security. Analysts predict that Bangladesh will soon transition into a middle income country built on textile exports, agriculture, public investment and remittances.

WorldFish in Bangladesh

WorldFish is an international research organization, one of the 15 agricultural organizations under the CGIAR network. It has operated in Bangladesh since 1987; at that time called the International Center for Living Aquatic Resources Management (ICLARM), with its headquarters in Manila, Philippines. The headquarters is now in Penang, Malaysia and there are Asian-Pacific research programmes in Cambodia, Myanmar, India, Timor-Leste, Solomon Islands as well as Bangladesh and Malaysia.

The aquaculture and fisheries situation in the country has changed remarkably since the establishment of the Bangladesh office. In 1987, aquaculture production was 166 thousand tonnes and capture fisheries 640 thousand tonnes. In 2015 aquaculture was over 2 million tonnes and capture fisheries 1.6 million tonnes. In 1987, aquaculture was dominated by carp polyculture. In 2015, feed-based aquaculture now dominates along with the rise of pangasius and tilapia.

The current WorldFish Bangladesh research programme is based on four main projects:

- Enhanced Coastal Fisheries in Bangladesh (Ecofish), focusing on hilsa management.
- Aquaculture for Income and Nutrition (AIN), USAID Feed the Future in southwest Bangladesh.
- Suchana: Ending the Cycle of Undernutrition in Bangladesh, a consortium led by Save the Children focused on two districts in northeast Bangladesh.
- Fish Food Agri-systems Research Programme (FISH CRP), which is managed by WorldFish as part of its global research strategy and funded by the CGIAR.

There are also a series of smaller projects including community-based fisheries management in northeast Bangladesh, work on fish health, multistakeholder networking projects, ecoponds and the CGIAR Climate Change, Agriculture and Food Security programme, which has been testing climate-smart technologies.

Although Bangladesh is very vulnerable to climate change, not enough is being done to understand the impacts that climate change is having on fisheries and aquaculture as well as the potential impacts that aquaculture has on greenhouse gas emissions and other contributing factors.

Climate change and Bangladesh

Seven main impacts are predicted: variable or erratic rainfall; temperature rises; sea level rise; more extreme weather events; water-logging; salinity intrusion; and drought or seasonal reductions in surface water availability. South and southwest Bangladesh is likely to be most impacted by salinity intrusion and this

will reduce the capacity of communities to feed themselves. In fisheries the situation is more complex but there will be further changes to systems that are already heavily impacted by overfishing. There may be opportunities for adaptation – for example using saline tolerant species for aquaculture or short-cycle species in areas that will be affected by drought.

WorldFish has tested a number of technologies including:

- installing fish rings or habitats in seasonally flooded rice fields;
- using raised beds and ditches as an integrated farming system;
- improving the quality of habitat in small ponds and ditches to protect fish;
- community water management schemes; and
- providing alternative income generating opportunities for fishers.

Climate Change, Agriculture and Food Security (CCAFS), Climate Smart Farm Project

This project has tested a range of technologies in southwest Bangladesh, mostly alternative growing methods for vegetables in saline affected areas. The best performing system was tower gardens. Other systems that have been widely adopted include growing vegetables over fish ponds on bamboo racks. Tower gardening systems are now being increasingly adopted by households in this region and taken up by other projects and communities.

Summary

The main climate change threats to fisheries and aquaculture in Bangladesh are because of erratic rainfall, temperature increases, extreme weather events and salinity intrusion. These will have direct impacts on inland and coastal fisheries as well as aquaculture. A limited number of solutions have been tested including livelihood diversification, improved information, infrastructure development and ecological conservation initiatives but much more needs to be done to mitigate the impacts on a highly vulnerable population.

Asian Institute of Technology

Climate-resilient aquaculture in Thailand – the role of AIT

Krishna R. Salin

Climate change poses a grave threat to the sustainability of aquatic life. Conservation and sustainable use of inland, coastal and marine resources are essential to sustainable development, poverty alleviation and sustained economic growth in Asia. Aquaculture, which is the farming of aquatic animals including finfish, shellfish, and other invertebrates, and aquatic plants present several alternative livelihood options to meet the food demands of future generations without overly depending on capture fisheries. In response to both local and international demand for food fish, profit-driven commercial aquaculture rapidly expanded throughout Asia from the late 1970s fuelled by the seed availability and newly-developed science-based hatchery technologies. However, the undisciplined growth of commercial aquaculture had its consequences as it adversely impacted the natural environment. In Thailand, aquaculture production started to decline recently because of a sharp decrease in coastal aquaculture output, mainly caused by a reduced farmed shrimp production because of diseases. Total aquaculture production in Thailand in 2012 was 1.2 million tonnes, and it dropped to 0.9 million tonnes in 2014. In 2012, Thailand was the seventh largest aquaculture producer in the world, and the country fell to thirteenth place in 2014 with a decline of about 12 percent of its fish exports.

Aquaculture is capable of complementing the current efforts towards mitigation and adaptation of climate change on aquatic environments if it is practiced responsibly. Several sustainable aquaculture innovations

have recently emerged, transforming the global aquaculture industry to adopt highly intensive, yet sustainable modes of food production. These include biofloc technology, aquaponics, IMTA, and other innovative practices that are based on a zero-effluent mode of production. These technologies ensure that there are no pollutants from an aquaculture system to the surrounding environment as most of these are converted into useful products for the farmed animal, either by their microbial reduction or by the efficient use of plants integrated with the culture system. For the past four decades, AIT has been in the forefront of promoting research and capacity development on sustainable aquaculture technologies in the Asia-Pacific region. This has resulted in a more extensive adoption of responsible aquaculture, both among smallholder farmers and intensive producers. New farmer-developed innovations such as aquamimicry farming systems in Thailand are also promising. Intensification of technologies by adopting ecosystem-based approaches would enable aquaculture to more effectively contribute towards climate change mitigation and adaptation in the Asia-Pacific region, where the lion's share of the global aquaculture production originates.

Charoen Pokphand Group Co., Ltd.

Climate change and the aquaculture industry

Komgrid Sriwattanangkul

It is undeniable that global climate change has impacts on aquaculture business operations throughout the supply chain. It is therefore necessary for aquaculture industries to consider and take actions to adapt to and handle the impacts, effectively. In general, climate change, i.e. unusual variations of weather and seasons, means that the environmental conditions that are vital to aquaculture operations also change.

As a result, the way the aquaculture industry is run has to change. To address this issue, there are many important criteria to consider and numerous projects to implement to maintain an aquaculture business and operations when faced with climate change.

Before addressing the concept of "SMART Aquaculture", it is important to understand the evolution of aquaculture as shown below:

- Aquaculture 1.0: Labour intensive and extensive culture.
- Aquaculture 2.0: Skills intensive and semi-extensive culture.
- Aquaculture 3.0: Intensive culture by applying more sophisticated technologies and related devices including automated control systems (e.g. DO controller system, monitoring system, auto feed).
- Aquaculture 4.0 (or SMART Aquaculture): Intensive culture applying more precise data, even more sophisticated technologies and also related devices to manage and fully control the whole culture environment for aquaculture.

In fact, there are several important criteria and innovative projects, particularly, for medium-scale and large-scale aquaculture operating units in the private sector. All attempt to minimize their production costs substantially, promote greater productivity with the highest efficiency and achieve fewer adverse environmental impacts. These are done by means of applying the principle of "SMART Aquaculture". With respect of this, the major areas where the "SMART Aquaculture" concept is applied are as mentioned below.

- Smart facilities: recirculation system and smart greenhouse.
- Water quality management: probiotic and bioremediation.
- Biosecurity control system: disease monitoring system.
- Aeration system improvement: aerator and oxygenator.
- Feeding system: automatic feed on-demand.
- IoT (Internet of things) covering electronic sensors: environmental monitoring and control system.

Finally, the key to implementing "SMART Aquaculture" successfully is "to continuously search for any opportunities and room for improvements".

To achieve that we need to explore advanced technologies, electronic devices, precision systems, big data management, and automatic control systems. With careful planning and the right execution, we believe that increasing productivity, adapting to the climate change effects, and reducing the contribution of aquaculture to climate change can be achieved simultaneously.

Southeast Asia START Regional Centre

An occurrence of hypoxia phenomena in the Upper Gulf of Thailand

Penjai Sompongchaiyakul

It is long recognized that the Upper Gulf of Thailand (UGOT) serves as one of the main mariculture areas in Thailand, especially for bivalves. The UGOT receives water, nutrients, and organic matters from the north and the central plain of Thailand through four main rivers, namely Mekong, Tachin, Chaopraya and Bangpakong (Figure 10). As such, this part of the Gulf provides substantial marine resources and other ecosystem services. However, the environment in this region has been altered by human activities. The application of chemical fertilizers and expansion of cultivated land are often seen as the two main options to increase agricultural production. These practices lead to the enrichment of nutrients in the river waters that flow into the UGOT. Other nutrient sources to the UGOT are from food and feed-related industrial wastes and domestic wastes.

The nutrient and organic matter enrichment process in the UGOT has been going on for some decades. At present, it causes undesirable phytoplankton bloom and depletion of bottom dissolved oxygen. These phenomena could lead to massive mortality of fishes as reported occasionally in Phetburi and Prachuap Khirikhan (Figure 11). Our study report dissolved oxygen lower than 0.5 mg/l in the bottom water column 25 km to 30 km offshore. In the same study, the depth profiles of dissolved oxygen in the water column at the Bangpakong and Tachin River mouths in October 2012 show permanent low oxygen in bottom water (Figure 12). A similar situation was found in October 2017, low oxygen content in the bottom water was found in most stations, with some stations containing no oxygen. Consumption rate of oxygen by sediment (sediment oxygen demand or SOD) suggested that the sediment near the river mouths required higher oxygen to oxidize organic matter in bottom sediment (Figure 13). The high SOD leads to the loss of dissolved oxygen which will directly affecting the flora and fauna. It leads to migration and a high mortality rate of fishes.

In order to solve this problem, it is required to lower the load of nutrient and organic matter (BOD input) to the UGOT. Effective legislative measures to control the pollutants and the awareness programmes pertaining to the present threat to water resources should be a crucial concern.

Figure 10. The four main rivers that empty into the Upper Gulf of Thailand

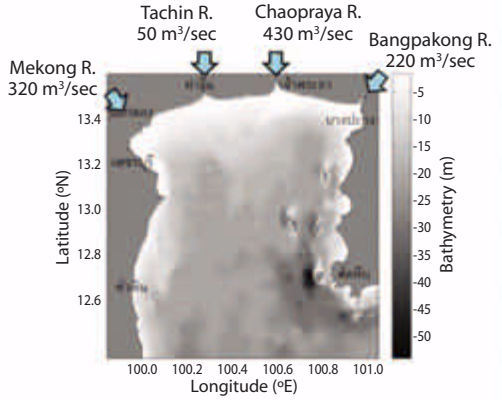


Figure 11. Massive fish kill at Hua-Hin, Prachuap Khirikhan on 17 October 2017

Source: https://www.thairath.co.th/content/1101017

Figure 12. Low dissolved oxygen at the bottom water in the Upper Gulf of Thailand in October 2012 extending 25 km to 30 km offshore (a and b); depth profiles of dissolved oxygen at Bangpakong River mouth from 5 pm 25 October 2014 to 5 pm 26 October 2012 (c) and at Tachin River mouth from 2 am 27 October 2014 to 3 am 28 October 2012 (d)

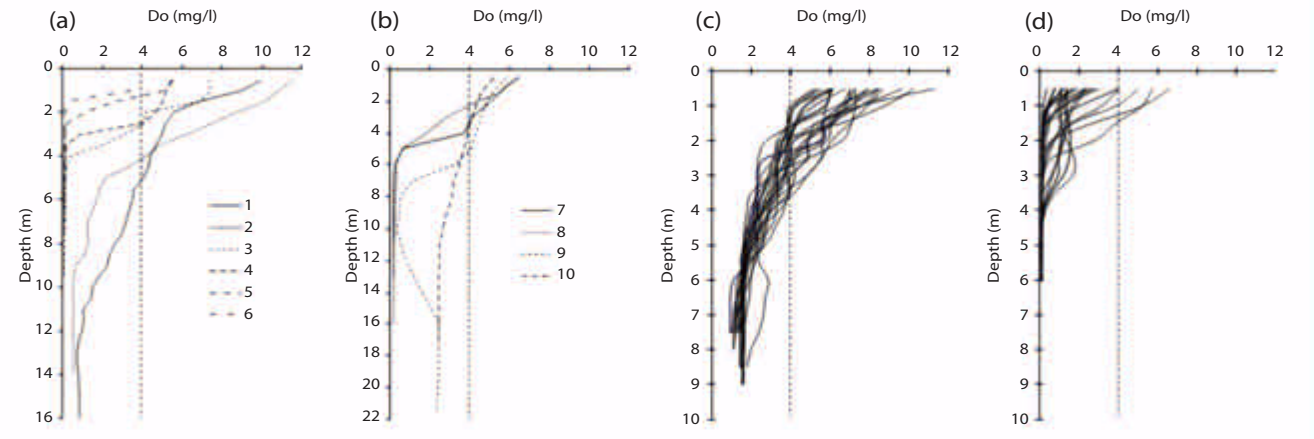
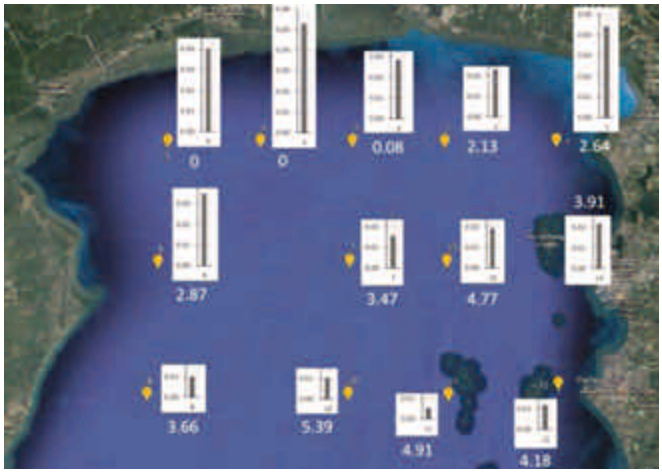


Figure 13. Rate of sediment oxygen demand in mg/g/hr (bar graph) and dissolved oxygen in mg/l in bottom water (number below graph) in the Upper Gulf of Thailand in October 2017



FAO FishAdapt

Strengthening the adaptive capacity and resilience of fisheries and aquaculture-dependent livelihoods in Myanmar

Le Le Win

The fisheries and aquaculture sector in Myanmar is critically important to the country's food and nutrition security and economy. Climate change is forecast to have a significant impact on the sector. For capture fisheries (marine and inland) these impacts include changes in sea surface temperature, higher inland water temperature, changes in ocean currents, changes in the frequency of El Niño-Southern Oscillation (ENSO) events, sea level rise and changing levels of rain and water availability. The aquaculture sector is also exposed to hazards such as salt water intrusion, flooding of ponds, shortages in water supply, invasive species and ad hoc development planning altering local ecosystem dynamics and undermining their resilience, integrity and functionality. The fisheries sector and dependent livelihoods are also under stress from a range of other factors such as illegal unreported and unregulated (IUU) fishing, overfishing and pollution. Myanmar is vulnerable to extreme climate events, which have caused significant loss of life, damage to infrastructure and also impacted fishers and fish farmers' livelihoods. In order to address these issues, Myanmar has developed its National Adaptation Programme of Action (NAPA) for climate change. In 2015, Myanmar also outlined a range of mitigation and adaptation actions under its Intended Nationally Determined Contributions (INDC).

At present, Myanmar faces significant challenges in addressing these issues and achieving sustainable management and utilization of its aquatic resources. These include weak governance, organizational capacities and institutional arrangements, limited technical capacity and knowledge; and limited resources for the development and implementation of adaptation plans.

In order to address these issues and to support implementation of its NAPA, the Government of Myanmar requested FAO (in collaboration with other GEF agencies, government agencies, development partners, NGOs and civil society) to prepare this GEF – LDCF funded project. The project "FishAdapt: strengthening the adaptive capacity and resilience of fisheries and aquaculture-dependent livelihoods in Myanmar" addresses three main barriers to climate change adaptation, namely:

- lack of climate-resilient sector policies, and limited integration of fisheries-specific climate responses into national policies;
- lack of capacity and resources within the sector to support communities in planning and responding to climate-related stressors and fisheries and aquaculture adaptation to climate change impacts; and
- limited knowledge sharing and communication within the sector and with fisheries and aquaculture dependent communities, limited coordination and lack of real-time/working level understanding of climate change and its impacts on fisheries, aquaculture and their livelihoods.

The project objective is to assist government to enable inland and coastal fishery and aquaculture stakeholders to adapt to climate change by understanding and reducing vulnerabilities, piloting new practices and technologies, and sharing information. Key areas of focus for the project will include strengthening of national, regional, and local regulatory frameworks and adaptive capacities, fisheries co-management measures, integrating mangrove fisheries and aquaculture, inland fisheries and small-scale aquaculture, and critical issues related to land and resource tenure.

The project has four components:

- Component 1: strengthening the national, regional/state and township level regulatory and policy frameworks to facilitate the adaptive capacities of the fisheries and aquaculture sector.

- Component 2: enhancing critical adaptation practices demonstrated by fishers and fishing communities in vulnerable coastal and inland water regions of Myanmar.
- Component 3: developing and applying adaptation models to strengthen the resilience of Myanmar's aquaculture sector to the impacts of climate change.
- Component 4: knowledge management, monitoring and evaluation, training and scaling up adaptation practices, identifying lessons learned and dissemination.

The project builds on existing government and partner programmes and emerging good practices. It adopts EAFM and EAA. EAFM provides practical approaches to implement sustainable development of fisheries by identifying and encouraging a balance between ecological and human well-being through good governance. These will be applied to enhance the resilience of aquatic ecosystems to climate change impacts and fishing and fish farming activities. These approaches also reduce the underlying vulnerability of fishing and fish farming communities.

The project also addresses Myanmar's NAPA priorities for its coastal zone, including: (i) adaptation to climate change through Integrated Coastal Zone Management (ICZM); (ii) community-based mangrove reforestation for building climate-resilient ecosystems and rural livelihoods in degraded coastal areas in the Rakhine State; (iii) community-based eco-friendly aquaculture systems (e.g. mud crab, clam, shrimp and tilapia) for enhancing the climate change resilience of rural livelihoods and supporting the recovery of mangrove forest ecosystems; and (iv) small-scale aquaculture and mangrove buffer demonstration sites for transferring adaptation technologies to coastal communities. Under its INDC, the project also addresses the first priority level sector of resilience in the agriculture sector, developing early-warning systems and forest preservation measures; the third priority level sector in coastal zone protection, and; the fourth priority level sector, which targets the energy, and industry sectors, as well as biodiversity preservation.

A national Climate Change Vulnerability Assessment to be delivered by the project will identify "at risk" ecosystems and dependent communities, in particular small-scale traditional fisheries and fish farming systems for specific action. Environmental sustainability will be ensured through positive impacts of the introduced climate change adaptation plans, fisheries management plans, technologies and approaches on a range of ecosystem services, which will be developed in local community user areas and in the longer term on larger areas through upscaling of best practices. Long term strengthening of climate change adaptation knowledge sharing networks and environmental monitoring will be undertaken by ensuring these will operate within national mechanisms and resources by project completion.

In line with effective and comprehensive capacity development practices to address individual, organizational and institutional capacities, the project will work at the national and region/state level on laws, policies and institutional strengthening, coordination and knowledge management. Community level adaptation approaches and technologies will be carried out in the Ayeyarwady Region, Yangon Region and Rakhine State. Small-scale inland aquaculture climate adaptation planning will also be carried out in a limited number of townships in the Central Dry Zone (CDZ).

The primary stakeholders of the project at community level are fishers, fish farmers, and those with fishery and aquaculture-dependent livelihoods and the private sector. Women and vulnerable groups will continue to be targeted to ensure their active engagement throughout the project cycle, including through gender-sensitive vulnerability assessments, adaptation actions and capacity building. The Department of Fisheries, Ministry of Livestock, Fisheries and Rural Development will be the main institutional partner for the project, which will coordinate and collaborate with a wide range of other partners (including specifically Myanmar Fisheries Federation, the Livelihoods and Food Security Fund, WorldFish, Japanese International Cooperation Agency), NGOs, government agencies, development partners and the private sector.

Bay of Bengal Large Marine Ecosystem

The Bay of Bengal Large Marine Ecosystem, Strategic Action Programme development: how it addresses climate change concerns

C.M. Muralidharan and Rudolf Hermes

The implementation phase for the Strategic Action Programme (SAP) of the Bay of Bengal Large Marine Ecosystem (BOBLME) Project, called the BOBLME Programme, will build on the foundations laid during the "SAP development" or first phase. In this new phase, capacity development on the Ecosystem Approach to Fisheries Management (EAFM) will continue, and there will be a new focus on EAFM pilot plan design and implementation, incorporating climate change (CC) concerns. These will be plans for management of key resources, such as hilsa shad. Conservation of blue carbon (mangroves, seagrass habitats), associated biodiversity, and endangered species will also be one of the new focus areas. Developing pilot resilience plans for coastal communities, based on valuation of ecosystem services and threats related to livelihoods to support decision making in the BOBLME at regional, national and local levels will be another focus, directly benefitting the coastal population of the Bay of Bengal. There will also be a new partnership with the Asian Development Bank (ADB), addressing specific water quality management issues in Myanmar.

The first phase of the Bay of Bengal Large Marine Ecosystem (BOBLME) Project was implemented by the Food and Agriculture Organization of the United Nations across the eight countries of the Bay of Bengal (Bangladesh, India, Indonesia, Malaysia, Maldives, Myanmar, Sri Lanka and Thailand) from 2009 to 2015 with a focus to lay the foundations for a coordinated programme of action designed to better the lives of the coastal populations through improved regional management of the Bay of Bengal environment and its fisheries. The project worked in addressing the three areas of: 1) sustainable fisheries management; 2) critical marine habitats management; and 3) coastal and marine pollution management.

The project produced the SAP now signed by all eight countries for implementation. FAO has now submitted the Programme Framework Document (PFD) to the Global Environment Facility for funding support.

Although the BOBLME's phase one did not specifically focus on addressing climate change (CC), many of the interventions laid the foundation for incorporating factors related to climate change in the future during the SAP implementation phase. The study on seasonal migratory patterns of hilsa, the capacity development on the Ecosystem Approach to Fisheries Management (EAFM) and exploratory ecosystem modeling are important initiatives for incorporating CC issues in fisheries management. Ecosystem characterization of the BOBLME, coral reef studies along Malacca Straits and the Myeik Archipelago are interventions that also address the CC effects on critical habitats. Contributions to Monsoon Onset Monitoring and its Social and Ecosystem Impacts (MOMSEI) and the installation of biogeochemical sensors in the RAMA data buoys are other aspects of CC-related work.

FAO-Bangladesh

Development of a GEF project supporting community-based climate resilient fisheries and aquaculture development in Bangladesh

A.K. Yousuf Haroon and B.N. Naher

Background and justification

Bangladesh formulated the National Adaptation Programme of Action (NAPA) in 2005 and updated it in 2009. The country also formulated the Bangladesh Climate Change Strategy and Action Plan (BCCSAP) in 2009 to lay the foundation of all activities regarding climate change and adaptation. NAPA prioritized two

fisheries concepts: Concept #13: adaptation of fisheries in areas prone to enhanced flooding in the northeast and central region, through adaptive and diversified fish culture practices. Concept #14: promoting adaptation to southwest coastal fisheries through culture of salt tolerant fish species. FAO and WorldFish initiated discussions on 10 June 2012 with DOF and MoFL to prepare the Concept Note (CN) prioritizing NAPA. FAO and WorldFish developed and elaborated the CN to draft the Policy and Investment Framework (PIF) and shared this in a workshop to DOF and all stakeholders on 29-30 August 2012. The full PIF was drafted by FAO and WorldFish, reviewed by DOF and submitted to MoEF (GEF Operational Focal Point (OFP)) through MoFL in July 2013. GEF OFP in MoEF endorsed the PIF and sent it to GEF on 14/7/2013. GEF approved the PIF on 5 February 2014 and allocated the Project Preparation Grant (PPG) to FAO for full ProDoc formulation.

Project objectives

- remove key barriers of adaptation to CC;
- build resilience through capacity development and policy reform;
- enhance local adaptive capacity through: i) transfer and adoption of site-specific climate resilient interventions and approaches; and ii) effective knowledge management (e.g. use of ICT-based climate and disaster information services);
- strengthen awareness and knowledge of local communities; and
- ensure wider dissemination of best practices and lessons learned.

Components, outcomes and outputs

The project results will be delivered through following four components including its outcomes and outputs.

Component 1: climate-resilient fisheries subsector through relevant national capacity development.

Component 2: strengthening knowledge and awareness of fisheries/aquaculture dependent communities facing the adverse impacts of climate change.

Component 3: enhancing local adaptive capacity to support climate-resilient fisheries and aquaculture management and alternative livelihoods in the face of climate change.

Component 4: dissemination of best practices and lessons learned, monitoring and evaluation.

Key interventions to deliver the outputs

Component 1: CC risk and vulnerability assessment focusing gender in southwest coastal and northeast wetland area; fishery sector policy and strategies revision incorporating CC adaptations and gender considerations; capacity building strategy revised for DOF, other GoB agencies and the private sector; training manual on climate forecast application, Disaster Risk Management (DRM), CC mitigation, adaptation and early-warning system (EWS) in fisheries and aquaculture.

Component 2: community (30 percent to 40 percent female) trained in using equipment and tools, understands and monitors CC adaptation; EWS in place (community radio, mobile SMS gateway and training manual); local development plans integrate DRM considerations.

Component 3 for northeast and southwest: climate-resilient aquaculture and fisheries adaptations; climate-resilient integrated aqua-agriculture adaptations and non-fisheries adaptations.

Component 4: establish project website, linked to MoFL, DOF, MoEF, DoE and FAO-BD portal; produce and widely distribute bi-annual newsletters, communication and dissemination of materials; produce and widely distribute promotional materials; support special events/days, newspaper supplements; produce regular reports (technical, financial, PIRs); perform monitoring and evaluation (mid-term final); roduce monitoring and evaluation reports and PCR.

Adaptation benefits/impacts

Overall 4 488 sq km of northeast wetland and southwest coastal area under climate resilience plans and management practices. About 314 000 people with reduced vulnerability to CC including 30 percent to 40 percent women.

Component 1: Two revised fisheries strategies with gender differentiated CC considerations; one revised fishery policy with gender differentiated CC considerations; confirmation of CC sensitive fisheries areas with focus on gender; one report on capacity needs assessment of DOF, Bangladesh Forest Research Institute (BFRI) and related GoB agencies and design of a capacity building strategy to strengthen them; 24 community leaders/people (40 percent female) and GoB personnel trained in the Asian region on EAFM and EAA; 14 private entrepreneurs trained in-country on climate resilient adaptation and management; 30 GoB (DOF and partner organizations) personnel trained in neighbouring countries on climate resilient adaptation and management; one DOF and one BFRI personnel trained on mud crab (*Scylla serrata/ olivacea*) hatchery techniques in Indonesia for three to four months; 100 DOF, BFRI and other GoB personnel trained in-country on climate resilient adaptation and management; one training manual on climate forecast application, DRM and adaptation, mitigation options and EWS in fisheries and aquaculture produced and widely distributed.

Component 2: risk and vulnerability of 92 communities in 9 subdistricts assessed with special focus on gender and climate sensitive areas; 70 communities in 9 upazilas adopt 15 local development plans and integrate DRM; about 5 880 households (30 percent to 40 percent female) trained in using equipment and tools, understand CC variability, adaptation and trained in-country; collaborative EWS in place and connected to local environmental monitoring (community radio, mobile SMS gateway and training manual) in at least 50 communities.

Component 3: at least 50 community-based organizations (CBOs) (30 percent women) adopt 15 climate smart gender differentiated adaptation technologies; mud crab hatchery establishment feasibility report produced; freshwater giant prawn hatchery improvement report produced; 1 post larvae/fingerling market in Bagerhat-Dacope area of the southwest; 9 location-specific fishery habitat maps produced; 20 DOF/ community trainers trained on environmental monitoring systems (linked to EWS and DRM); 100 communities (2 500 persons, 40 percent female) distributed with and trained on implementing local environmental monitoring systems; small feed making machines distributed to 16 CBOs and trained for producing low carbon footprint feeds; insulated fish box on rickshaw van distributed to 16 CBOs and trained for reducing post-harvest quality loss and easy marketing; gender differentiated ICT-based dissemination systems in place and used by 60 percent of communities; 25 Farmers' Field Schools (FFSs) established, 75 percent functional for CC adaptations; 10 types of user-friendly dissemination materials and other outreach materials produced and distributed; environmental monitoring systems (connected to EWS and DRM) in place in 70 percent of communities; 3 training manuals produced and widely distributed: i) climate-resilient fisheries and aquaculture best practices; ii) fisheries habitat conservation-management; iii) Community management and women empowerment in fisheries and aquaculture.

Component 4: project website established, linked to MoFL, DOF, MoEF, DoE and FAO-BD portal; 8 biannual project newsletters produced and widely distributed; dommunication and dissemination materials (training manuals/flyers/booklets/leaflets/posters/fact sheets, videos, news on website etc.); promotional materials (desk calendar, note book, year planner, caps, T-shirts, etc.) and documents etc. produced and distributed to wider stakeholders; gender differentiated ICT-based dissemination systems in place; support special national days, newspaper issues (Fish Week, World Food Day, World Environment Day, International Biodiversity Day, etc.) and CC awareness issues/days of DOF and DoE; produce regular half-yearly, quarterly, and annual reports and annual PIRs, financial reports, monitoring reports and PCR (as per FAO-GEF guidelines and GoB requirements); mid-term and final evaluations with recommendations (as per GoB, FAO-GEF requirements).

Workshop agenda

FAO/APFIC Regional consultative workshop
Building Climate-Resilient Fisheries and Aquaculture in the Asia-Pacific region

14–16 November 2017, Bangkok, Thailand

Day 1		
09.00–09.45	**Opening ceremony** – Welcome address – Mr Chumnarn Pongsri, Government of Thailand – Opening remarks, FAO – Ms Xiangjun Yao – Introduction of participants	
09.45–10.15	*Group photo* *Refreshment break*	
10.15–10.30	**Introduction to Workshop objectives and programme** *FAORAP/APFIC Secretariat*	
10.30–12.00	**Plenary presentation and discussion** – The Paris Accord and its implications for national actions – Regional overview of the efforts to address climate change in the fisheries sector in the APFIC region – Regional overview of the efforts to address climate change in the aquaculture sector in the APFIC region	
12.00–13.30	*Lunch break*	
13.30–15.00	**Parallel session: country presentations** National policy/strategies and actions addressing climate changes and issues/gaps – **Aquaculture** 4 countries: Bangladesh Cambodia China India	**Parallel session: country presentations** National policy/strategies and actions addressing climate changes and issues/gaps – **Fisheries** 4 countries: Bangladesh Cambodia India Indonesia
15.00–15.30	*Refreshment break*	
15.30–17.00	**Parallel Session: country presentations** National policy/strategies and actions addressing climate changes and issues/gaps – **Aquaculture** 4 countries: Indonesia Lao People's Democratic Republic	**Parallel Session: country presentations** National policy/strategies and actions addressing climate changes and issues/gaps – **Fisheries** 4 countries: China Lao People's Democratic Republic

	Malaysia Myanmar	Malaysia Myanmar
18.00–20.00	**Dinner hosted by FAO** **Venue: The Bar, Lower Lobby, Amari Watergate Hotel**	
Day 2		
08.30–08.40	Recapture of Day 1 **(Plenary)**	
08.40–09.00	Presentation by Southeast Asia-START Regional Center (SEA-START)	
09.00–10.20	**Parallel session:** **country presentations** National policy/strategies and actions addressing climate changes and issues/gaps – **Aquaculture** 4 countries: Nepal Pakistan the Philippines Republic of Korea	**Parallel session:** **country presentations** National policy/strategies and actions addressing climate changes and issues/gaps – **Fisheries** 4 countries: Nepal Pakistan the Philippines Sri Lanka
10.20–10.40	*Refreshment break*	
10.40–12.00	**Parallel session:** **country presentations** National policy/strategies and actions addressing climate changes and issues/gaps – **Aquaculture** 4 countries Sri Lanka Thailand Timor-Leste Viet Nam	**Parallel session:** **country presentations** National policy/strategies and actions addressing climate changes and issues/gaps – **Fisheries** 3 countries Thailand Timor-Leste Viet Nam
12.00–13.00	*Lunch break*	
13.00–15.00	**Plenary session:** Presentations by international, regional and intergovernmental bodies/programmes: on initiatives addressing fisheries/aquaculture related climate change issues Network of Aquaculture Centers in Asia-Pacific Southeast Asia Fisheries Development Center (3 presentations) International Union for Conservation of Nature (IUCN) Bay of Bengal Programme – Inter-Governmental Organisation (BOBP-IGO) Mekong River Commission (MRC) Sustainable Development Foundation (SDF)	
15.00–15.20	*Refreshment break*	
15.20–17.00	**Plenary session:** Presentations by international, regional and intergovernmental bodies/programmes: on initiatives addressing fisheries/aquaculture related climate change issues	

	WorldFish Asian Institute of Technology (AIT) Charoen Pokphand Group Co., Ltd. Myanmar GEF Project "FishAdapt" The Bay of Bengal Large Marine Ecosystem, Strategic Action Programme Development: how it addresses climate change concerns FAO-Bangladesh GEF Project "Community-based climate-resilient fisheries and aquaculture development in Bangladesh"	
17.00–17.30	**Wrap-up session and introduction to working group sessions on Day 3**	
Day 3		
08.30–10.00	**Working group discussion 1 (Aquaculture):** 1. Major risk/threats of CC impacts and climate variability 2. Major contribution to GHG emissions 3. Gaps and issues in adaptation to and mitigation of climate change in Asia-Pacific region	**Working group discussion 1 (Capture fisheries):** 1. Major risk/threats of CC impacts and climate variability 2. Major contribution to GHG emissions 3. Gaps and issues in adaptation to and mitigation of climate change in Asia-Pacific region
10.00–10.15	*Refreshment break*	
10.15–11.45	**Working group discussion 2 Aquaculture:** Recommendations on a regional strategy and priority actions at country and regional levels for building climate resilience covering both adaptation and mitigation	**Working group discussion 2 Capture fisheries:** Recommendations on a regional strategy and priority actions at country and regional levels for building climate resilience covering both adaptation and mitigation
11.45–13.15	*Lunch break*	
13.15–15.00	**Plenary session:** Presentations of working groups and discussion on proposed regional strategy and priority actions for building climate resilience in Asia-Pacific region fisheries and aquaculture	
15.00–15.30	*Refreshment break*	
15.30–16.00	**Workshop summary and closure**	

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