Guidelines for Integrating Climate Change Adaptation into **Fisheries and Aquaculture Projects**

IFAD
Investing in rural people

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List of abbreviations and acronyms

ACB	Asean Centre for Biodiversity
ACBAAS	Asean Centre for Biodiversity Aquatic Agricultural Systems Program
ACIAR	Australian Centre for International Agricultural Research
ADB	Asian Development Bank
AfDB	African Development Bank
AIT	Asian Institute of Technology
APR	IFAD's Asia and Pacific Division
ASC	Aquaculture Stewardship Council
AUSAID	Australian Agency for International Development
BMPs	Better Management Practices
BMZ	German Federal Ministry for Economic Cooperation and Development
CAARP	Cyclone Affected Aquaculture Rehabilitation Project
CBA	Community-Based Adaptation
CBF	Culture-Based Fisheries
CCAFS	Climate Change, Agriculture and Food Security Program
CGIAR	Consultative Group on International Agricultural Research
CIRAD	Centre de Cooperation Internationale en Recherche Agronomique pour le Développement
COFI	Committee on Fisheries
COP	Conference of the Parties
CPM	Country Programme Manager
CPUE	Catch Per Unit Effort
CRP	CGIAR Research Program
CSRP	Sub-Regional Fisheries Commission for West Africa
DANIDA	Danish International Development Agency
DARD	Department of Agriculture and Rural Development
DFID	Department for International Development
DRAGON	Delta Research and Global Observation Network
EAA	Ecosystem Approach to Aquaculture
EACC	Economics of Adaptation to Climate Change
EAF	Ecosystem Approach to Fisheries
ENDA	Environment and Development Action in the Third World
ENSO	El Niño Southern Oscillation
ESA	IFAD's East and Southern Africa Division
EU	European Union
FAD	Fish Aggregating Device
FAO	Food and Agriculture Organization of the United Nations
GDP	Gross Domestic Product
GEF	Global Environment Facility
GHG	Greenhouse Gases
GIS	Geographic Information System
GIZ	German Society for International Cooperation
HAB	Harmful Algal Bloom
IAA	Integrated Agriculture-Aquaculture
IBRD	International Bank for Reconstruction and Development
ICAFIS	International Collaborating Centre for Aquaculture and Fisheries Sustainability
ICFA	International Coalition of Fisheries Associations
ICSID	International Centre for the Settlement of Investment Disputes
ICZM	Integrated Coastal Zone Management
IDA	International Development Association
IDRC	International Development Research Centre
IFAD	International Fund for Agricultural Development
IFC	International Finance Corporation
IMOLA	Integrated Management Of Lagoon Activities
IMTA	Integrated Multi-Trophic Aquaculture
INTAQ	Integrated Aquaculture
IPCC	Intergovernmental Panel on Climate Change
IUCN	International Union for Conservation of Nature
IWMI	International Water Management Institute

KSF	Key Success Factors
LAC	IFAD's Latin America and Caribbean Division
LCA	Life Cycle Assessment
LCB	Lake Chad Basin
LDC	Least Developed Country
LDCF	Least Developed Countries Fund
MARD	Ministry of Agriculture and Rural Development
MIGA	Multilateral Investment Guarantee Agency
MOIT	Ministry of Industry and Trade
MONRE	Ministry of Natural Resources and Environment
MPA	Marine Protected Area
MRC	Mekong River Commission
MSC	Marine Stewardship Council
NACA	Network of Aquaculture Centres in Asia-Pacific
NAPA	National Adaptation Programmes of Action
NEN	IFAD's Near East, North Africa and Europe Division
NGO	Non-Governmental Organisation
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
NORAD	Norwegian Agency for Development Cooperation
NTP	National Target Programme to Respond to Climate Change - Vietnam
OASIS	One-stop Aquaculture Supplies and Information Shop
OECD	Organization for Economic Cooperation and Development
PaCFA	The Global Partnership on Climate, Fisheries and Aquaculture
PES	Payment for Environmental Services
PRSC	Poverty Reduction Support Credit
REDD	Reducing Emissions from Deforestation and Forest Degradation Programme
REPAO	West African Fisheries Policy Network
SCCF	Special Climate Change Fund
SLR	Sea Level Rise
SPC	Secretariat of the Pacific Community
SVC	Spring Viraemia of Carp
UN	United Nations
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change
UN-ISDR	United Nations International Strategy for Disaster Reduction
USAID	United States Agency for International Development
VINAFIS	Viet Nam Fisheries Society
VND	Viet Nam Dong
WAFICOS	Walimi Fish Farmers' Cooperative Society
WCA	IFAD's West and Central Africa Division
WSD	White Spot Disease
WSSD	World Summit on Sustainable Development
WWF	World Wildlife Fund

Acknowledgements

These Guidelines are the result of an extensive process of consultation and a concerted effort that brought together different fisheries and climate change experts in different moments in time. Substantive inputs were provided by a range of stakeholders, including smallholder farmers, aquaculturists, academics, personnel from ministries of agriculture and environment, and development cooperation partners.

The bulk of the document was prepared in 2010-2011 by ICAFIS, the sustainability arm of the Vietnam Fisheries Society (VINAFIS), an organisation with over 800 local branches and 34,000 members, which is actively engaged in activities in Asia, the Middle East and Sub-Saharan Africa. Flavio Corsin, senior manager, Aquaculture Program, IDH The Sustainable Trade Initiative, and Davide Fezzardi, aquaculture and small-scale fisheries consultant, General Fisheries Commission for the Mediterranean (GFCM), were the lead authors, in collaboration with their colleagues in ICAFIS as well as the following organizations: Asian Development Bank (ADB), Asian Institute of Technology (AIT), Algen Sustainables, ALVEO S.c.r.l., Can Tho University, Centre de Cooperation Internationale en Recherche Agronomique pour le Développement (CIRAD), Danish International Development Agency (DANIDA), Department of Agriculture and Rural Development (DARD) in Ben Tre (Vietnam), the Food and Agriculture Organization of the United Nations (FAO), Fisheries College and Research Institute (India), GIZ-GTZ, Humber Seafood Institute (UK), International Coalition of Fisheries Associations (ICFA), CARE International, International Development Research Centre (IDRC), International Water Management Institute (IWMI), Network of Aquaculture Centres in Asia-Pacific (NACA), Rang Dong clam cooperative Ben Tre (Vietnam), Secretariat of the Pacific Community (SPC), Stirling University (UK), the United Nations Development Programme (UNDP) Vietnam, the United Nations Environment Programme (UNEP), Kenya, University of New Brunswick (Canada), the World Bank, World Resources Institute and WorldFish.

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Executive summary

Climate change is transforming the context in which the world's 55 million fishers and fish farmers live and work, posing a major threat to their livelihoods and the ecosystems on which they depend. For millennia, small-scale fisheries and fish farmers have drawn on their indigenous knowledge and historical observations to manage seasonal and climate variability, but today the speed and intensity of environmental change is accelerating, outpacing the ability of both human and aquatic systems to adapt.

The changes already being witnessed include warming of the atmosphere and the oceans, changes in rainfall patterns and increased frequency of **extreme weather events**. The oceans are becoming increasingly saline and acidic, affecting the physiology and behaviour of many aquatic species and altering productivity, habitats and migration patterns. Sea level rise, combined with stronger storms, severely threatens coastal communities and ecosystems. The world's coral reefs are under threat of destruction over the coming century. Some inland lakes and water bodies are drying up, while in other areas destructive flooding is becoming a regular occurrence. In many cases it is the poorest communities in the poorest countries that are most vulnerable to these changes.

Over the past several years, there has been a rapidly increasing awareness of the need to **address climate change through IFAD operations**, which has led to the formulation of the *Climate Change Strategy* in 2010 and the *Environment and Natural Resource Management Policy* in 2011, and – perhaps most significantly – the launch of the Adaptation of Smallholder Agriculture Programme (ASAP) in 2012.

This study describes a range of **multiple-benefit options** for integrating climate change adaptation and mitigation into IFAD interventions in the fisheries and aquaculture sectors, based on a review of relevant literature on climate change, the fisheries and aquaculture sectors, and related activities of other international organizations.

Most of the proposed measures are not new concepts or ideas but **have been proven time** and again in practice to provide a range of benefits to and increase the resilience of small-scale fishers and fish farmers, as well as the ecosystems on which they rely. This approach is in line with ASAP's first principle of scaling up tried and trusted approaches.

Summary of key multiple-benefit actions

Climate challenges	Potential multiple-benefit actions
Increase climate resilience of small-scale fishers and fish farmers	• Reduce overfishing and excess capacity. • Implement the ecosystem approach to fisheries and aquaculture management (including ICZM and MPAs). • Establish natural resource co-management regimes involving community groups and fishers and fish farmers associations. • Strengthen the knowledge base and climate change advisory capacity of fishery and aquaculture extension workers. • Invest in key infrastructure and ecosystem rehabilitation projects, favouring a “no-regrets” approach. • Encourage diversification of livelihoods and income sources, including activities that are not related to fishing and aquaculture. • Invest in research to develop/identify new commercially viable strains of aquaculture species tolerant of low water quality, high temperatures and disease. • Promote integrated aquaculture and agriculture systems, including using flooded/saline land and water bodies.
Increase capacity to manage short- and long-term climate risks and reduce losses from weather-related disasters	• Establish early warning systems, safety-at-sea, and disaster risk reduction and preparedness plans. • Rehabilitate coastal ecosystems that provide protection from storms and waves (e.g. mangroves, wetlands, marshes and coral reefs). • Increase access to financial services and insurance mechanisms. • Encourage establishment of small-scale fish nurseries to facilitate restocking after disasters. • Improve aquaculture development planning and zoning.
Reduce and/or sequester greenhouse gas emissions	• Introduce more fuel-efficient boats and encourage the use of static fishing gear instead of damaging towed gear such as trawls. • Promote the culture of low-trophic-level species and aquatic plants in polyculture/Integrated Multi-Trophic Aquaculture systems. • Identify opportunities to access carbon finance for mangrove planting and/or restoration.

Introduction

Background

Climate change is transforming the context in which the world's 55 million fishers and fish farmers live and work, posing a major threat to their livelihoods and the ecosystems on which they depend. For millennia, small-scale fisheries and fish farmers have drawn on their indigenous knowledge and historical observations to manage seasonal and climate variability, but today the speed and intensity of environmental change is accelerating, outpacing the ability of both human and aquatic systems to adapt. Oceans, rivers and lakes are experiencing changes in temperature, acidity, salinity and water flows, often negatively affecting ecosystem functions, while losses and damages from extreme weather events are increasing, as droughts, floods, heat waves and storms become more frequent and intense.

Avoiding and managing climate risk is a prerequisite for poor rural people to move out of poverty. Poor rural people are less resilient because they have fewer assets to fall back on when shocks occur. In an environment in which long-standing risks, such as ill health, market volatility, food insecurity and poor governance, are compounded by the degradation of natural resources and climate change, opportunities for growth are beyond the reach of most poor rural people. Innovative policies and investment programmes are needed to help the rural poor respond and adapt to a changing climate, and anticipate, absorb and recover from climate shocks and stresses.

Global climate change response and resources

While the need to respond to the challenges and opportunities of climate change is clear, response modalities and the allocation of the required resources are still the topic of high-level international discussions. The main forum for these discussions is the annual Conference of Parties (COP) of the United Nations Framework Convention on Climate Change (UNFCCC). The Bali Action Plan, agreed at the 2007 COP in Bali, called for the allocation of financial resources to help developing countries adapt to climate change. During the 2009 COP in Copenhagen, developed countries committed to provide "fast-start finance", referring to new and additional resources of US$30 billion for the period 2010-2012, followed by US$100 billion per year by 2020. In 2010, at the Cancun COP, discussions began on an international mechanism to compensate for losses and damages in the most vulnerable countries where certain negative impacts are already inevitable. However, the strategy for mobilizing this scaled-up climate finance is still very unclear and has been repeatedly postponed. A final agreement on the global response to climate change is not expected before the twenty-first session of COP, to be convened in Paris in 2015.

Using currently available resources, such as the Global Environment Facility (GEF), the international community – including development agencies, NGOs, United Nations agencies, research institutes, and international

and regional development banks and funds – is already very actively engaged in building the capacity to address climate change, incorporating adaptation and mitigation best practices into sectoral and national development plans and investment projects (World Bank 2010b). Meanwhile, a number of adaptation-specific global funds have been created under the UNFCCC, such as the Adaptation Fund of the Parties to the Kyoto Protocol of the UNFCCC, and the GEF-administered Special Climate Change Fund (SCCF) and Least Developed Countries Fund (LDCF). IFAD's ASAP is also among the first examples of new finance windows established with the specific purpose of financing climate adaptation.

The Least Developed Countries Fund (LDCF), which is managed by the GEF, has financed the development of National Action Plans for Adaptation (NAPA) in the Least Developed Countries (LDCs). The NAPAs use existing information to identify priority adaptation actions and are action-oriented, country-driven, flexible and based on national circumstances. They are also used as the basis for resource mobilization for adaptation, particularly from the GEF. As pointed out by the UNFCCC, in many countries adaptation planning and practices are in the early stages of implementation and very often centre on NAPAs for LDCs (IFAD 2010b). The GEF views IFAD as an important partner for NAPA implementation in LDCs, given the priority of agriculture in many NAPAs and IFAD's experience in this sector.

IFAD response

Over the past several years, there has been a steadily growing awareness of the need for IFAD operations to address climate change. This has resulted in a series of publications and initiatives, including the *Climate Change Strategy* (2010), the *Environment and Natural Resource Management Policy* (2011) and – perhaps most significantly – the launch of the ASAP in 2012. These initiatives have led to a demand for greater guidance on design and implementation of IFAD-financed climate adaptation and mitigation activities.

Adaptation for Smallholder Agriculture Programme (ASAP)

IFAD launched ASAP in 2012 in order to make climate and environmental finance work for rural people – including small-scale fishers. ASAP is a multi-year and multi-donor financing window, which provides new resources to scale up and integrate climate change adaptation across IFAD's US$1 billion-per-year portfolio of new investments. Thus, ASAP is driving a major scaling up of successful "multiple-benefit" approaches to smallholder agriculture that improve production while reducing and diversifying climate-related risks. In doing so, ASAP is blending tried-and-tested approaches to rural development with relevant adaptation know-how and technologies.

In 2011, IFAD published a paper titled "Climate-Smart Smallholder Agriculture: What's Different?" This paper acknowledged the growing consensus that "climate change is transforming the context for rural development, changing physical and socio-economic landscapes, and making smallholder development more expensive" (IFAD 2011:2). It also highlighted the lack of consensus on how smallholder agriculture practices should change and suggested three major changes that are required to increase resilience of smallholder agriculture to climate change, all of which are also applicable to small-scale fisheries and aquaculture:

- Reflection of higher climate risks in project and policy preparation by combining vulnerability assessments and climate modelling with a better understanding of interconnections between smallholder farming and wider landscapes.
- Scaling up of multiple-benefit approaches that build climate resilience while reducing poverty, enhancing biodiversity, lowering greenhouse gas emissions and contributing to other sustainable development goals.

- Enablement of smallholders to benefit from climate finance in order to reward multiple-benefit activities and offset increasing costs and risks, as well as identification of better ways to achieve and then measure a wider range of multiple benefits beyond traditional poverty and yield impacts.

Purpose and scope of the guidelines

Objective

IFAD has a long history of supporting research institutes and other bodies in testing, adaptation and dissemination of technologies to address climate variability. IFAD-financed projects also provide lessons and practical experience in the mainstreaming of climate change adaptation (IFAD 2010b).

The purpose of this document is to synthesize available knowledge and best practices in climate change adaptation and mitigation in the fisheries and aquaculture sectors with a view to guide IFAD interventions in these sectors. Specifically, the document has the following objectives:

- To review relevant literature on climate change, the fisheries and aquaculture sectors, and the relevant activities of other international organizations.
- To identify best practices in climate change adaptation and mitigation in the fisheries and aquaculture sectors.
- To guide the integration of climate change adaptation and mitigation measures into IFAD interventions in the fisheries and aquaculture sectors, and enhance the quality of IFAD project design, implementation, supervision and evaluation processes, as well as engagement in policy dialogue.

Methodology

The literature review was global in scope and based on a desk review of published and grey literature, as well as interviews, meetings and a series of field visits to sites in the Mekong Delta, Viet Nam. Data and information were summarized and qualitatively analysed to distil best practices.

This document also draws on the IFAD thematic paper, *Fisheries, Aquaculture and Climate Change* (Williams and Rota 2010), which is a comprehensive global review of literature on the likely impacts of climate change on fisheries and aquaculture, as well as on possible adaptation and mitigation measures. The findings of this work were used to prepare the IFAD material for presentation at the United Nations Framework Convention on Climate Change (UNFCCC) and the fifteenth session of the Conference of the Parties (COP 15) in Copenhagen in December 2009.

Scope and limitation of the document

The literature review found that global work concerning the impacts of climate change on fisheries and aquaculture is still at an early stage. Although there is a relatively significant body of knowledge on the biophysical impacts of climate change on aquatic ecosystems, there is less knowledge on the socio-economic consequences and necessary responses (De Silva and Soto 2009). A number of agencies are working on guidelines for mainstreaming adaptation and mitigation measures in fisheries and aquaculture projects, including the Food and Agriculture Organization of the United Nations (FAO) and WorldFish, which are developing, testing and adopting a standardised methodology for assessing and documenting best practices. Gender dimensions are beginning to gain visibility, given that women make up around half of the global workforce in related processing and marketing enterprises. Knowledge gaps and uncertainties remain with regard to impacts, vulnerability, and costs and benefits of adaptation and mitigation, but work is ongoing to address these. Some of the projects discussed below are making notable progress in this regard.

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Climate change, fisheries and aquaculture

The basics

Climate change

The Fifth Assessment Report (AR5) of the Intergovernmental Panel on Climate Change (IPCC 2013) has confirmed that the global climate system is changing in ways unprecedented for millennia.

The latest report also confirms that mankind is responsible for the majority of these changes and that limiting the extent of these changes will require significant mitigation efforts.

"Warming of the climate system is unequivocal, and since the 1950s, many of the observed changes are unprecedented over decades to millennia. The atmosphere and ocean have warmed, the amounts of snow and ice have diminished, sea level has risen, and the concentrations of greenhouse gases have increased." (IPCC 2013:2)

"Human influence has been detected in warming of the atmosphere and the ocean, in changes in the global water cycle, in reduction in snow and ice, in global mean sea level rise, and in changes in some climate extremes. This evidence for human influence has grown since AR4. It is extremely likely that human influence has been the dominant cause of the observed warming since the mid-20th century." (IPCC 2013:15)

"Continued emissions of greenhouse gases will cause further warming and changes in all components of the climate system. Limiting climate change will require substantial and sustained reductions of greenhouse gas emissions." (IPCC 2013:17)

However, while mitigation efforts might limit the eventual extent of climatic changes, many of the trends already visible will likely continue for decades and – in some cases – hundreds of years due to the enduring impact of greenhouse gases that have accumulated in the atmosphere. These changes will have complex impacts on aquatic ecosystems and the livelihoods of those who depend on them. Adaptation actions to build resilience and adaptive capacity are already necessary and should continue well into the future, regardless of future emission scenarios.

The following observed and predicted changes are detailed in the latest IPCC report (IPCC 2013):

Climate

- **Warming of the earth's surface** by approximately 0.85° C from 1880 to 2012. Relative to the period 1986-2005, temperatures will likely increase by an additional 0.3° C to 0.7° C by 2016-2035 and by 0.3° C to 4.8° C by 2081-2100, depending on the emissions scenario. This will equal a total increase of between 1° C and 5° C above pre-industrial levels;
- Observed **increase in temperature and frequency of hot days and nights**, and reduction in frequency of cold days and nights – a trend virtually certain to continue.
- Likely **increase in the frequency of heat waves** – a trend very likely to continue.
- Possible **increase in intensity and/or duration of droughts** – likely to continue.
- **Increase in frequency and intensity of heavy rainfall events** – very likely to continue,

particularly over the wet tropics. The areas affected by monsoon systems will likely increase, with weaker winds but heavier precipitation and some changes in timing.

- Some observed **increase in tropical cyclone activities**, which will more likely than not continue in the future; the El Nino Southern Oscillation (ENSO) will likely intensify.

Atmosphere

- **Increased atmospheric concentrations of greenhouse gases** (carbon dioxide [CO_2], methane [CH_4] and nitrous oxide [N_2O]), which now exceed the highest concentrations known in 800,000 years – the major cause of global temperature increases.

Oceans

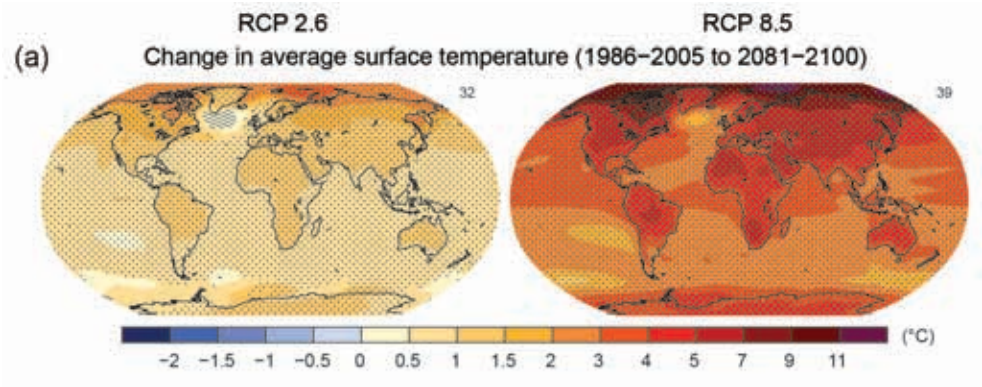
- **Warming of the oceans**, with the upper 75 metres warming by 0.11° C per decade during 1971-2010. Ocean warming accounted for more than 90 per cent of the energy accumulated in the global climate system during this period. Ocean warming will continue throughout the twenty-first century, penetrating deep oceans and affecting circulation and sea level. The strongest warming is expected in tropical and northern sub-tropical areas.
- **Increased ocean acidification**, with a decline in ocean surface water pH of 0.1 since 1750. Continued absorption of carbon by the oceans will continue to increase acidity levels until the end of the current century.
- **Changes in salinity**, with highly saline areas becoming more saline and vice versa, due to changes in evaporation and precipitation.

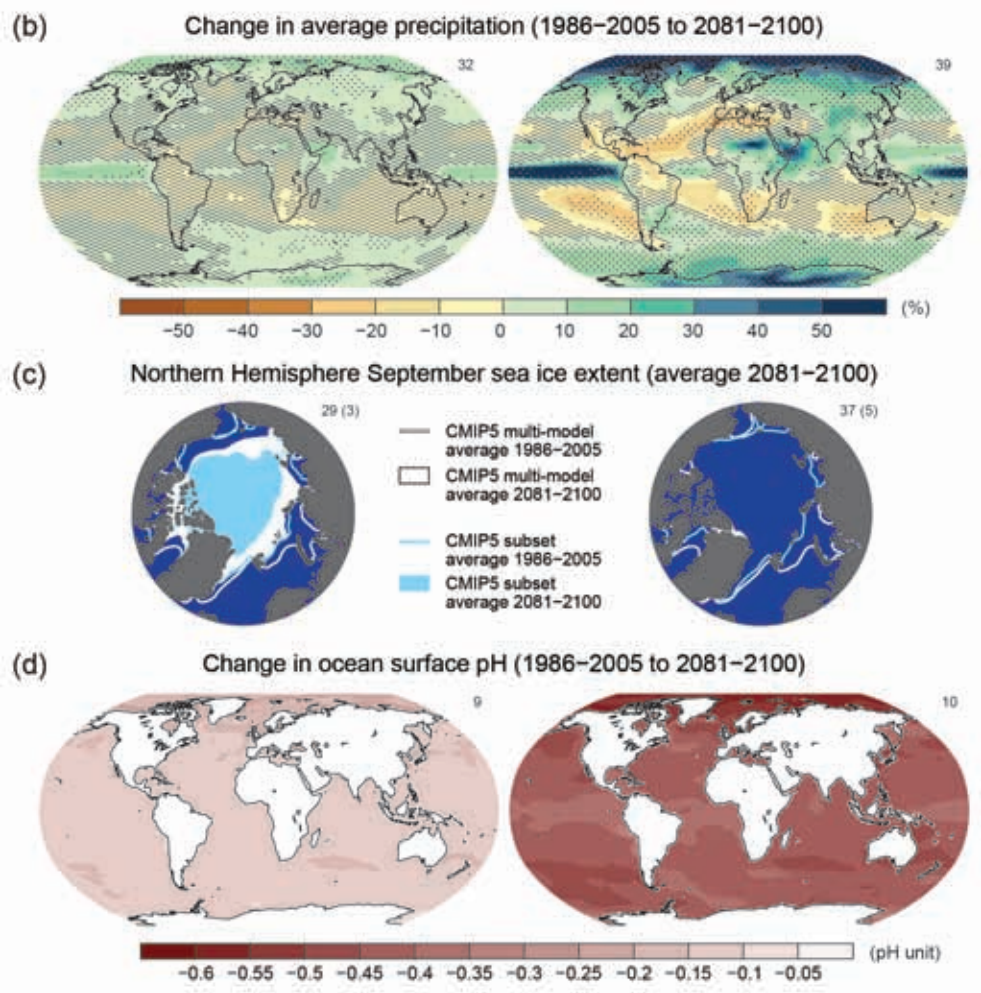
Sea levels

- **Global average sea level has increased** by 0.19 metres during 1901-2010 and the rate of increase has accelerated from 1.7 millimetres per year in the early twentieth century to the current rate of 3.2 millimetres per year. Thus, the total sea level rise by 2081-2100 relative to 1981-2005 will be in the range of 0.26-0.98 metres, with glacier melting and thermal expansion accounting for about 75 per cent of this increase. Sea level will continue to rise during the twenty-first century and beyond under all emission scenarios.
- **Increases in the incidence and magnitude of extreme high sea levels** have begun and are very likely to continue.

The following figures indicate projected changes in average surface temperature, precipitation and ocean surface pH under the best-case (left) and worst-case (right) emission scenarios.

FIGURE 1





Fisheries and aquaculture

Fisheries and aquaculture depend on aquatic ecosystems (freshwater, coastal and marine). These ecosystems are already feeling the impact of climate change due to their high sensitivity to changes in temperature, salinity and acidity. As a result, livelihoods dependent on fisheries and aquaculture are expected to be among the first to be significantly impacted by climate change. Particularly vulnerable are the livelihoods of small-scale fish farmers and fishers in small island developing states, drought-prone countries, and developing countries in South and South-East Asia and Sub-Saharan Africa (Allison et al. 2009).

As reported by FAO (2012), the fisheries and aquaculture sectors provide opportunities to boost global food and nutrition security, reduce poverty, and support economic growth. In 2011, global fish production reached 154 million tons, while consumption reached 130.8 million tons of fish – an average of 18.8 kilograms per capita. Growing demand is driving increased production, making aquaculture one of the fastest growing food production sectors; total production from capture fisheries and aquaculture is expected to reach 172 million tons by 2021, with aquaculture accounting for most of the increase.

Employment in fisheries and aquaculture is also growing faster than in agriculture. Today, the sector provides direct employment to 54.8 million people, approximately 16.6 million of

TABLE 1
World fisheries and aquaculture production and utilisation during 2006-2011

	2006	2007	2008	2009	2010	2011
Production			(million tons)			
Capture fisheries						
Inland	9.8	10.0	10.2	10.4	11.2	11.5
Marine	80.2	80.4	79.5	79.2	77.4	78.9
Total capture	**90.0**	**90.3**	**89.7**	**89.6**	**88.6**	**90.4**
Aquaculture						
Inland	31.3	33.4	36.0	38.1	41.7	44.3
Marine	16.0	16.6	16.9	17.6	18.1	19.3
Total aquaculture	**47.3**	**49.9**	**52.9**	**55.7**	**59.9**	**63.6**
Total	**137.3**	**140.2**	**142.6**	**145.3**	**148.5**	**154.0**
Utilisation						
Human consumption	**114.3**	**117.3**	**119.7**	**123.6**	**128.3**	**130.8**
Non-food uses	**23.0**	**23.0**	**22.9**	**21.8**	**20.2**	**23.2**

Source: FAO 2012. Information does not include seaweed and other aquatic plants.

whom are fish farmers. If secondary activities, such as processing and marketing, are taken into account, fisheries and aquaculture support the livelihoods of 660 million to 820 million people. As 90 per cent of the world's fishers operate at a subsistence level, the importance of the sector to food security and poverty reduction is clear; fish provide essential nutrition for 3 billion people and at least 50 per cent of animal protein and essential minerals for 400 million people, mainly in the poorest countries (FAO 2011). While the vast majority of fishers and fish farmers are in Asia (87 per cent and 97 per cent, respectively), the highest annual growth of people employed in these sectors is in Africa.

The aquaculture and fisheries sectors are facing many challenges and constraints, both internal from within the sector (overexploitation of resources, discrimination in access to resources and poor management) and external (competition from other land- and water-use sectors, pollution, and habitat degradation). The sustainability of many fisheries around the world is already under threat from poor management and weak governance, leading to overfishing and environmental degradation; an estimated 30 per cent of stocks are currently overexploited and 57.4 per cent are fully exploited (FAO 2012). Poorly planned aquaculture development has led to serious damage to freshwater and marine ecosystems, disease outbreaks, and human health scares. In addition to these existing challenges, broad impacts of climate change across ecosystems, societies and economies are a compounding threat to the sustainability of fisheries and aquaculture (FAO 2008e, 2010a, 2012).

Climate change impacts on fisheries and aquaculture

Climate change impacts on the fisheries sector in direct and indirect ways, resulting from processes in aquatic ecological systems, as well as through political, economic and social dynamics (Daw et al. 2009).

Capture fisheries depend entirely on the productivity of the natural ecosystems on which they are based. They are, therefore, extremely vulnerable to changes in primary production and the manner in which such production is transferred through the aquatic food chain. They are also vulnerable to changes in the physical and chemical parameters of the ecosystems, including temperature, salinity, acidity, and water levels and flows. Although some climate change impacts on the fisheries sector can be predicted, the overall cumulative impacts are somewhat uncertain due to the complexity of aquatic ecosystems and the lack of data and models (Easterling et al. 2007; World Bank 2010d; World Bank 2012; World Bank 2013; Bezuijen et al. 2011).

Aquaculture is also exposed to direct and indirect impacts of climatic change, although fewer features and consequences of climate change affect this sector due to a greater level of human control (De Silva and Soto 2009). The vulnerability of aquaculture-based communities is primarily a function of their exposure to extreme weather events, as well as the impact of climate change on the natural resources required to undertake aquaculture, such as quality water, land, seed, feed and energy (Easterling et al. 2007; FAO 2008e). This will require adaptation and improvement of aquaculture systems and species, as well as greater disaster preparedness.

Communities that rely on small-scale fisheries and aquaculture are often located in areas that are susceptible to climate change impacts and are therefore particularly vulnerable. Small-scale fishers are likely to be more vulnerable than larger-scale fishers due to their generally limited mobility (Daw et al. 2009) and thus limited livelihood options.

A recent assessment carried out for the World Bank (Sumaila and Cheung 2010) estimated that the fishing sector could face an annual loss in gross revenues ranging from US$17 billion to US$41 billion (in constant 2005 United States dollars) as a result of climate change. Furthermore, the loss would be distributed unevenly, with developing countries suffering a larger loss; for example, under the more severe climate change scenario, developing countries' potential losses could amount to US$25 billion per year, whilst developed countries would lose only US$11 billion per year.

It is important to remember that it is difficult to establish a unique causal chain between particular climate change effects and the impacts on fisheries and aquaculture. Rather, it is the cumulative effects of climate change and human responses that count (De Silva and Soto 2009). For example, where a fish stock is already heavily or overexploited by fishing, stress from climate-induced changes in ocean conditions or ecosystems may push the stock to a "tipping point" causing the total collapse of the stock.

Impacts by climate change effect

The following is a summary of the likely effects on fisheries and aquaculture of a number of changes to aquatic ecosystems induced by climate change (Ahmed 2013; Bezuijen et al. 2011; Daw et al. 2009; De Silva and Soto 2009; Easterling et al. 2007; FAO 2008b, 2009a; Kam et al. 2010; IPCC 2007, 2013; Nicholls et al. 2007; Nellemann et al. 2009; Mohammed and Uraguchi 2013; PEW 2009; Secretan et al. 2007; van Anrooy et al. 2006; World Bank 2010d, 2012, 2013; WorldFish 2010b):

Warming of oceans and other water bodies:

- *Changes in ocean fish productivity* are expected due to changes in ocean conditions, including the timing of plankton blooms and hence food availability, alterations in predator-prey relationships, and fish stock dynamics. An overall increase in marine primary productivity of 0.7-8.1 per cent is expected by 2050, although with large regional variation; productivity will likely reduce at lower latitudes due to rising temperatures and sea warming. The effect on fisheries is uncertain, though the disruption to ecosystems is likely to result in overall declines in fish production in the medium term. Farming of many finfish and crustaceans, such as shrimp, usually requires the use of feed in which fishmeal and fish oil are key ingredients. These commodities originate mainly from small pelagic fisheries in the subtropical and temperate regions. Any negative impact on these fisheries due to climate change is likely to make supplies of fishmeal and fish oil uncertain, thus affecting the feeding regime and cost structure, and possibly making some culture systems unviable. It would also affect the livelihoods of the fishers who target these species.
- *Extinction of some species* has been predicted if the maximum tolerable heat threshold of the species is crossed and there is no possibility of migration (for example, in inland water bodies).
- *Increased incidence of toxic algal blooms and shellfish poisoning* caused by rising temperatures can disrupt market access if monitoring and testing services fail to identify products that do not meet export requirements.
- *Reduced levels of dissolved oxygen* in the water can reduce larval survival, impede fish growth or block migrations. There will be an increase in areas where oxygen levels will decline to very low levels (dead zones), in which no fish or invertebrates can survive.
- *Shifts in distribution of many fish and shellfish* are expected, as the progressive warming of the oceans will push marine fish stocks to migrate toward higher latitudes. Such changes could affect the distribution and phenology of fish larvae, with large impacts on recruitment and production of fish stocks. These shifts could reduce catches by up to 40 per cent in some localized areas in the tropics, while increasing them up to 100 per cent in very localized areas. For example, mackerel – a big part of the wild capture in Cambodia, Viet Nam and Thailand – depends on ocean circulation for recruitment and dietary processes. Changes in circulation could lead to a decrease of mackerel production in this region. Changes in migration would affect mainly small-scale fishermen who lack the means to follow the fish stocks, unlike large-scale deep sea fishers who can travel many thousands of miles. Changes in seasonality or spawning locations would result in a reduction of wild seed for some species that are farmed in ponds, cages and other systems, as well as for broodstock procurement of some important marine farmed species, such as shrimps.
- *Potential increases in growth rates, food conversion efficiency* and duration of the growing season are likely to occur for some farmed fish species due to higher temperatures in tropical and sub-tropical regions.
- *Changes in the incidence of diseases affecting aquaculture* are also anticipated. Although new diseases are likely to appear, the occurrence of some existing diseases, such as the White Spot Disease (WSD) in crustaceans, will decrease at higher temperatures.

Sea level rise

- *Increase in inundation, flood and storm damage* is expected, which will affect nursery grounds and fish habitats and accelerate coastal erosion. Saltwater intrusion in deltaic regions could raise water tables, impede drainage, and cause loss and damage of wetlands.

On the other hand, inundation and intrusion of saline waters into agricultural land might increase the area available for aquaculture or rice-fish farming with saline-tolerant varieties of rice. Brackish-water aquaculture might also be an attractive alternative in those areas where salinity makes land unsuitable for rice or other crop cultivation. However, this form of aquaculture could lead to local power conflicts, such as the recurrent conflict between poor rice cultivators and powerful shrimp farmers in south-western Bangladesh.

Changes in salinity

- *Osmoregulation of marine species will be adversely affected by changes in salinity*. The effects will be more severe for those species that are tolerant to only small variations in water salinity, such as zooplankton living in coastal low-lying tidal lakes and wetlands in tropical areas. This would have grave implications for the food chain relying on them and hence the ecological functioning of coastal wetland ecosystems, with huge impacts on local fisheries.

Ocean acidification

- *Decreased seawater pH (or increased "ocean acidification" resulting from the ocean's absorption of excess CO_2) is effectively irreversible* in terms shorter than millennia and presents a major systemic threat.
- *Many coral reefs will be destroyed* as a direct result of ocean acidification, and the productivity of shellfish and zooplankton is likely to decrease. Calcifers (i.e. animals that use calcium to build their shells or skeletons) are sensitive to acidity, as it impedes their ability to form hard shells and hence reduces their tolerance for high and low temperatures, leading to higher levels of mortality and lower fertilization success.

Changes in rainfall patterns and evaporation rates

- *Changes in run-off are anticipated*, with increases between 10-40 per cent in some wet areas in East and South-East Asia, the Ganges and Nile river basins, and decreases of 10-30 per cent in other regions, including the Mediterranean, North and Southern Africa, the Mississippi, Amazon, and the Danube and Murray Darling river basins, in a +2° C scenario. Changes in run-off will alter flood risk in coastal lowlands, water quality and salinity, fluvial sediment supply to flood plains, and circulation and nutrient supply in inland and coastal water bodies.
- *Impacts on freshwater systems will reduce water levels, flow rates and overall water availability, and increase water stress*, aridity and drought spells, especially in tropical and sub-tropical regions of Africa and Central, South, East and South-East Asia.
- *Changes in hydrological regimes in inland waters* will include increased eutrophication and stratification, which will impact food webs and habitat availability and quality.
- *Decreased river flows* – resulting from increased erosion, sedimentation and increased irregularity of rain – will, in some cases, threaten ecological production and freshwater fish populations in the affected rivers.
- *Increased flooding from rivers and lakes will, in some cases*, result in increased water logging and submersion of land by fresh water. In some places this might create opportunities: for example, Bangladesh could earn US$9.4 billion dollars per year by expanding freshwater prawn farming to the 2.83 million hectares of seasonally inundated crop land, and produce an additional 1.58 million tons of rice by using this space for paddy cultivation.

Increase in extreme weather events

- *Increased storm intensity* will cause extreme water levels and wave heights, increased episodic erosion, storm damage, risk of flooding, and defence failure. Aquaculture is very susceptible to storms, cyclones and floods, which are predicted to occur with greater frequency in the future, especially in tropical and subtropical monsoon regions. Aquaculture facilities could be damaged and the crop lost, while escapees could increase the risk of disease and parasitic infestation of wild stock, as well as impact the environment and biodiversity. For example, Cyclone *Sidr* hit the southern and south-western areas of Bangladesh in November 2007 with devastating effects, causing loss of life and livelihoods, rendering hundreds of thousands of people homeless and destitute. It polluted waters, killed fish, and overflooded and damaged aquaculture ponds, thus significantly reducing household access to fish for income and nutrition.
- *Changes in storm frequency and storm tracks* are likely to cause altered surges and storm waves, and hence risk of storm damage and flooding. An increase in extreme weather events poses increased risks to safety at sea, loss of fishing equipment and physical capital, and loss of revenue from reduction of fishing activities as a result of increasing frequency of bad weather. Increasing irregularity and intensity of storms and cyclones creates particularly high risks for fishermen catching far from the coast, making them heavily dependent on good weather forecasting systems. Insecurity and vulnerability are also exacerbated by the lack of any kind of insurance, difficulty in accessing credit or public welfare.
- *Changes in wave climate* will cause altered wave conditions (including swell), altered patterns of erosion and accretion, and reorientation of beach plan forms.

Impacts by ecosystem/aquatic habitat

Key ecosystems of direct importance to the fisheries and aquaculture sectors include coral reefs, wetlands, seagrass beds and mangrove forests, which will be impacted in the following manner:

Coral reefs. Although covering only 1.2 per cent of the world's continent shelves, coral reef ecosystems are home to up to 3 million species, including more than 25 per cent of all marine fish species. About 30 million people in coastal and island communities are reliant on reef-based resources as their primary means of food production, income and livelihood (TEEB 2010). For example, Hawaii's coral reef ecosystems provide many goods and services to coastal populations, including fisheries, tourism and natural protection against wave erosion. It was calculated that the net benefits of Hawaii's 166,000 hectares of coral reefs are worth US$360 million per year; therefore, the threats to coral reefs due to climate change and ocean acidification, as well as pressures such as pollution and overfishing, will have major economic implications (TEEB 2010).

Coral reefs are particularly vulnerable to the rise of sea temperature, changes in quality or salinity of water, and light changes, all of which cause coral bleaching. Rising ocean temperatures combined with ocean acidification are already stressing coral reef ecosystems. Bleaching events resulting from elevated sea temperatures have already contributed to substantial losses of reefs, particularly in the Indian Ocean. The continued loss of reefs will not only directly impact fish production and livelihoods, but will contribute to erosion and, in particular, the loss of atoll environments. It is predicted that the impact on coral reef will cause a loss of up to 60 per cent of this ecosystem by 2030, with consequent decline in biodiversity (De Silva and Soto 2009). Coral bleach and mortality will result in increasing

frequency of ciguatera poisoning, which is caused by eating fish that have grazed on algae growing on dead coral. The capacity of corals to adapt is the subject of ongoing studies.

Wetlands and seagrass beds are natural carbon sinks and can sequester significant amounts of carbon within plants both above and below sea level, as well as within soils; vegetated wetlands account for 50 per cent of carbon transfer from oceans to sediments. On the other hand, degraded wetlands could become a significant source of greenhouse gas (GHG) emissions. Therefore, conserving all coastal wetlands and seagrass beds would create an immediate benefit in terms of preventing CO_2 release into the atmosphere (World Bank, the International Union for Conservation of Nature [IUCN] and ESA PWA,[1] 2010). Wetlands are vulnerable to damage by severe storms and can also suffer from changes in flood and run-off patterns, as well as saline intrusion. Seagrass systems are sensitive to changes of light that occur during floods, heavy rains that cause higher turbidity, and the development of algae due to higher ocean temperature.

Mangrove ecosystems provide a habitat for aquatic and terrestrial fauna and flora. An estimated 75 per cent of all tropical commercial fish species pass a part of their lives in the mangroves, where they find nursery grounds, shelter and food. Other ecosystem services provided by mangroves include: protection from strong winds and waves; soil stabilization and erosion protection; nutrient retention and water quality improvement through filtration of sediments and pollutants; flood mitigation; sequestration of carbon dioxide; and protection of associated marine ecosystems. Mangroves are also a source of ecosystem goods, including medicines, food, firewood, charcoal and construction materials. The economic value of mangrove ecosystems is significant. It was estimated that each hectare of mangroves destroyed costs the equivalent of 1.08 metric tons of fish per year (Schatz 1991). Other estimates show that the annual seafood market value of mangroves is between US$7,500 and US$167,500 per square kilometre (World Bank, IUCN and ESA PWA 2010). In India, Glover (2010) found that 1 hectare of mangrove forest prevented damage worth US$43,000 during a super cyclone that battered the State of Orissa in October 1999. Even allowing for the fact that mangroves have no storm protection value during non-storm years, the aforementioned study found a long-term protection value of about US$8,700 per hectare. At the time, a hectare of cleared land was fetching US$5,000; this suggests that leaving mangroves as storm buffers would generate more value to society than clearing them for development.

In mangrove ecosystems, processes such as respiration, photosynthesis and productivity are affected by changes in air and sea temperature, as well as sea level rise. Severe storms can damage mangroves, even as they provide important protection against coastal erosion. Increasing poverty can also threaten mangroves, as communities turn to them as a source of firewood, building material and grazing for animals.

Climate change impacts will also vary by aquatic habitat zones – freshwater/inland, marine/coastal and deltaic.

Inland

- **Inland fisheries.** Inland fisheries in lakes, rivers, dams and flood plains will be greatly influenced by changes in rainfall and run-off resulting from changes in monsoon and ENSO patterns, and will face erosion, siltation and drainage issues (Daw et al. 2009). In addition to changes in precipitation, the impacts on inland fisheries will include changes in water temperature, evaporation leading to drought, river flow and lake level, reduced biodiversity of fish and other aquatic fauna and flora, altered water chemistry, increased turbidity, and habitat loss or habitat decoupling. The impacts will depend on the timing and intensity of climate effects, as

1. www.esassoc.com/

well as the interactions between effects. For example, while droughts will clearly have negative impacts, increased rainfall that does not cause flooding is likely to increase the area of lakes and reservoirs, and thus result in increased production.

- **Inland freshwater aquaculture.** Changing patterns of rainfall, drought periods and more intense storms, with more frequent and higher storm or tidal surges, are likely to impact pond culture systems through increased variations of water levels – potentially resulting in either drought or overflooding – as well as through potential salinization, especially during the dry season. Cage aquaculture in reservoirs and lakes could be challenged by droughts, changing water temperatures and oxygen levels. Studies suggest that both stratification and eutrophication phenomena could occur more frequently due to climate change, causing a lack of oxygen and thus increasing the risk of crop mortality. Oxygen depletion may also result from upwelling events caused by extreme wind and rainfall occurrences.

Coastal

- **Coastal fisheries.** Coastal fisheries will suffer from changes in productivity and distribution of fish species, as well as from the damage caused by climate change to the ecosystems upon which coastal fisheries depend, such as coral reefs. Shallow coastal waters will experience the greatest levels of warming, so impacts on fish populations in such waters are likely to be significant. Changes in rainfall, run-off and flooding will also affect coastal fisheries; these processes bring considerable amounts of nutrients to coastal waters, hence declines in rainfall and run-off could reduce productivity. Conversely, intense storms and rainfall episodes may increase run-off, washing excessive amounts of nutrients – and possibly also agricultural chemicals and pollution – into coastal waters, leading to algal blooms. Coastal fisheries and the communities that depend on them are also highly vulnerable to storm damage caused by wind, waves and accelerated coastal erosion, exacerbated by sea level rise.

- **Coastal aquaculture** – especially small-scale operations, which are very common in Asia – will be threatened by extreme weather conditions, including increased run-off from the mainland, storm surges, coastal erosion and mangrove destruction. Increased ocean acidification will affect shell formation of many cultured molluscs and crustaceans. The Secretariat of the Pacific Community (SPC) warns of dire consequences that this would have for mariculture in the Pacific region – especially for pearl oyster culture – as ocean acidification will make it harder for pearl oysters to form their shells (SPC 2008). Seaweed farming may also be affected, as higher water temperatures increase the risk of disease. Likewise, the warming of water will likely increase diseases and susceptibility to certain diseases in farmed aquatic organisms – for example, the Spring Viraemia of Carp (SVC) and Streptococcosis. The frequency of toxic events such as harmful algal blooms and red tides is also expected to increase due to warming, as well as due to water eutrophication (Easterling et al. 2007). This too will pose a threat to the aquaculture industry, especially mollusc cultivation, by increasing the risk to human health from shellfish poisoning. Moreover, recent studies reveal that climate change could affect transportation and transmission of parasites, with further health-related consequences for aquaculture (De Silva and Soto 2009). Marine and brackish water finfish culture may be affected by changes in salinity, turbidity and temperature, which might limit the development of larvae and juveniles. It should be noted that the most adapted species to such changes is seabass, offering interesting adaptation opportunities (Bezuijen et al. 2011).

Deltaic areas will be particularly vulnerable to the impacts of climate change. The predicted sea level rise will cause the displacement of millions of people living in the deltaic regions of the Ganges-Brahmaputra, Nile and Mekong megadeltas where aquaculture is well developed. For example, the rise in sea level, salinity intrusion and reduced river flow are expected to have an adverse impact on the flourishing shrimp industry along the Ganges-Brahmaputra in India and Bangladesh, as well as in the Mekong Delta in Viet Nam, where the aquaculture of pangasius (catfish) and black tiger shrimp play a key role in the national economy. In Bangladesh, sea level rise and cyclones threaten to overflow the polders built in the 1960s by the government, thus increasing conflicts between shrimp farmers and rice cultivators. Initially built to prevent the floodplains from frequent flooding and saline water intrusion, as well as to enhance rice culture, the polders are now showing their limits. By diverting the floodplain water into the rivers, they have increased siltation of river beds, thereby decreasing river flows and drainage capacity needed in case of floods. Besides, some of the polders have already been contaminated by saline water, which was either trapped there from the surge caused by Cyclone Aila in 2009 or allowed in by voluntary ingress by the shrimp farmers. The shrimp business was initially developed as an adaptation strategy in response to the salinity of the area but it has become so lucrative that some powerful shrimp farmers started allowing saline water to flow into the polders during the rainy season to increase production. This practice has contaminated the surrounding soils and forced local subsistence farmers to stop rice cultivation, rendered impossible by the high levels of salinity. Nevertheless, shrimp farming makes a significant contribution to the economic growth of Bangladesh; together with prawn farming, it is the second biggest contributor to the country's export earnings after the garment industry. Aside from sea level rise and associated challenges, aquaculture is facing the problem of water stress due to decreasing water availability in major rivers in Africa, Asia and South-East Asia (IPCC 2007).

Impacts by region

Using an indicator-based approach, Allison et al. (2009) compared the vulnerability of 132 national economies to potential climate change impacts on their capture fisheries. It was found that vulnerability resulted from the combined effect of predicted global warming, the relative importance of fisheries to national economies and diets, and scarce capacity to adapt to potential impacts and opportunities. The following table lists the most vulnerable countries. As can be seen, all are lower- and middle-income countries, and 20 of the 32 listed are in Sub-Saharan Africa.

Most of these vulnerable countries are categorized as least developed countries (LDCs) and are highly dependent on fish, which provides up to 27 per cent of dietary protein (compared to 13 per cent in less vulnerable countries). Furthermore, these countries produce 20 per cent of the world's fish exports and are therefore in greatest need of adaptation planning in order to maintain or enhance the contribution that fisheries make to their economies and poverty reduction strategies (Allison et al. 2009).

Planning adaptation at ground level requires progressive downscaling of predicted changes from the global level to the regional level and further below; the higher the level of certainty and the smaller the geographic areas for which predictions are made, the more actionable is the information generated. The effects described focus on the regional and sub-regional levels and are based on assessments conducted by the IPCC (2007), FAO (2008e) and the World Bank (2013).

Africa

- Fish stocks already compromised will be depleted further by rising water temperatures and other physical and ecosystem changes.
- Inundation will threaten the coast of eastern

TABLE 4

Countries most vulnerable to impacts of climate change on fisheries

Rank	Country	Rank	Country	Rank	Country	Rank	Country
1	**Angola (WCA)**	9	**Niger (WCA)**	17	**Zimbabwe (ESA)**	25	**Ghana (WCA)**
2	**DR Congo (WCA)**	10	**Peru (LAC)**	18	**Côte d'Ivoire (WCA)**	26	**Guinea-Bissau (WCA)**
3	Russian Federation	11	**Morocco (NEN)**	19	**Yemen (NEN)**	27	**Viet Nam (APR)**
4	**Mauritania (WCA)**	12	**Bangladesh (APR)**	20	**Pakistan (APR)**	28	**Venezuela (LAC)**
5	**Senegal (WCA)**	13	**Zambia (ESA)**	21	**Burundi (ESA)**	29	Algeria
6	**Mali (WCA)**	14	Ukraine	22	**Guinea (WCA)**	30	**Cambodia (APR)**
7	**Sierra Leone (WCA)**	15	**Malawi (ESA)**	23	**Nigeria (WCA)**	31	**Tanzania (ESA)**
8	**Mozambique (ESA)**	16	**Uganda (ESA)**	24	**Colombia (LAC)**	32	**Gambia (WCA)**

Source: Allison et al. (2009) after Williams and Rota (2010), modified.
Relevant IFAD Regional Division indicated for each country. Countries in which IFAD is active are indicated in bold font.

Africa and coastal deltas such as that of the Nile, accompanied by degradation of marine ecosystems and other physical and ecosystem changes.

- Sub-Saharan Africa will suffer from unprecedented heat waves and droughts, severely affecting livestock, crop production, vegetative cover and the livelihoods of rural communities.
- Climate change impacts on the oceans will increasingly affect fish migration patterns and local availability. In western Africa, where fish is an important source of protein, fish catch could decrease by 50 per cent by the year 2050 when compared to the levels of 2000. Coast catch yield is also likely to decrease by 5-16 per cent in eastern and southern Africa, whereas offshore catch could increase by 16 per cent in the same area. Along the Somalian and South African coasts, catch could increase by 100 per cent.
- In Africa, Ovie and Belel (2010) have recently reviewed the impact on riparian communities living around the Lake Chad Basin (LCB), jointly shared by Cameroon, Central African Republic, Chad, Niger, Nigeria and the Sudan. Over 200 million people rely on the natural resources of the area, where fisheries, agriculture and livestock rearing constitute the major livelihood portfolios. Lake Chad is very shallow, with a depth ranging between 2.5-10.5 meters. Since the 1970s, it has experienced massive environmental changes, including severe droughts that have caused the "shrinking" of the lake area from 25,000 square kilometres in the 1960s to 2,500-6,000 square kilometres in the 1980s and 1990s. Consequently, catches reduced from 220,000 metric tons per year to 100,000 metric tons per year within that period. These changes have likely been caused by a combination of human and climatic pressures on the ecosystem.
- FAO (2007) reports two other examples of African lake fisheries that are already experiencing the effect of a changing climate – mainly declining rainfall and changing wind regimes – resulting in fluctuations in primary production and fish yield:
  - In Malawi, **Lake Chilwa** is considered a closed-basin lake, which shrinks periodically and dries out when rainfall is low but supplies up to 25 per cent of the country's fish requirements in very productive years. However, as rainfall levels have been progressively diminishing, dry periods have become more frequent and fish yields have been declining accordingly.
  - **Lake Tanganyika** is shared among four countries – Burundi, Democratic

Republic of the Congo, Tanzania and Zambia – and supports important fisheries for small pelagic species. However, the fish yields are declining due to – among other reasons – overfishing and climate change impacts, such as declining wind speeds and rising water temperatures, which have reduced the mixing of nutrient-rich deep waters with the surface waters that support pelagic fish production.

Asia

- Water stress will affect many millions of people in Central, South, East and South-East Asia, particularly along the large river basins such as Changjiang.
- Fish breeding habitats, fish food supply and, ultimately, the abundance of fish populations in Asian waters will be substantially altered. Aquaculture industry and infrastructure, particularly in heavily populated mega deltas, are likely to be seriously affected by coastal inundation. Climate change will become the main driver of change around 2050 and until then will act mainly to exacerbate other drivers.
- South-East Asia is increasingly vulnerable to slow on-set changes; the region suffers from sea level rise, ocean warming and acidification, but also from sudden impacts such as increased frequency and intensity of cyclones and heat waves.
- Fisheries and aquaculture are at great risk, particularly in the highly vulnerable river deltas, where they are exposed to sea level rise, erosion and saltwater intrusion. Ocean's warming and acidification and decreased availability of dissolved oxygen will lead to a decrease in the average body size of ocean fish, as well as result in more severe and frequent coral bleaching episodes. Global ocean fish production is projected to decrease by 20 per cent by the end of the century. The aquaculture sector will also suffer from climate change challenges, such as increased temperature, salinity and frequency of extreme events.
- Coastal communities involved in fishing and fish farming are and will be increasingly impacted by more frequent cyclones and storms, sea level rise and associated saline ingress.
- With its very high density of population and high levels of poverty, South Asia is among the most vulnerable regions with regard to climate change impacts. It is anticipated that the region will be exposed to more frequent and extreme heat, increasingly irregular and intense rainfalls, with an increase of up to 40 per cent in annual precipitations in a +4°C world but also an increased number of dry days and glacier melting in the Himalayas. The presence of large deltas also makes South Asia particularly vulnerable to sea level rise.
- The lower Mekong River basin, which produces 2.1 million metric tons of wild fish per year – worth over US$2.1 billion at first sale and over US$4.2 billion on retail markets – supports the livelihoods of over 40 million people. According to the United Nations Environmental Programme (UNEP), fisheries here are threatened by human-induced modifications, including damming, land use change and pollution, as well as climate-induced changes, including sea level rise, salinity intrusion and changing precipitation patterns (UNEP 2010).

Pacific

- For the island countries and territories of the Pacific, SPC (2008) predicts that climate change will cause considerable declines in coastal fishery resources, with potential reduction in production as high as 50 per cent by 2100, due to higher ocean temperatures and acidification, as well as loss of important habitats, such as coral reefs, seagrass beds and mangroves.

- Foreseen impacts include: (i) changes in the distribution and abundance of tuna due to alterations in water temperatures, currents and the food chains that support tuna; (ii) damage to infrastructure due to the greater intensity of storms; and (iii) increased costs of fishing at sea due to the need for upgrading of fleets to increase safety and the reduction in the number of days spent at sea in view of more severe and frequent storms.
- Increasing intensity and frequency of storms and cyclones could also cause serious damage to mangrove forests, which often play the role of a natural barrier, as well as a precious ecosystem and nursery for marine species, with numerous benefits for local communities.

Latin America

- Low-lying areas will be impacted by sea level rise and extreme weather events, particularly those associated with the ENSO phenomenon, which will affect the La Plata estuary, coastal morphology, coral reefs, mangroves, location of fish stocks and availability of drinking water.
- Variations in the ENSO will dramatically affect small pelagic productivity along the coasts of Peru and Chile.

Small island developing states

- Fisheries will be affected by rising sea surface temperatures, rising sea level and damage from tropical cyclones.
- Degradation of coral reefs will have a major impact on local livelihoods, affecting fishing and tourism incomes, as well as entire economies.
- Agricultural land and food security will be affected by sea level rise, inundation, soil salinization, seawater intrusion into freshwater lenses and decline in freshwater supply.

Contribution of fisheries and aquaculture to climate change

It is widely acknowledged that fisheries and aquaculture will be among the first sectors to feel the effects of climate change. Some of these effects are now unavoidable (e.g. ocean warming) and irreversible over periods of less than millennia (e.g. acidification), but the severity of other impacts will depend to some extent on the magnitude of future climatic changes and, thus, on future global emission scenarios. Therefore, planning for the future development of the fisheries and aquaculture sectors should ensure that their contribution to global emissions is minimized and that – where feasible – mitigation options are leveraged. Fisheries and aquaculture make a minor, though still significant, contribution to global GHG emissions – which are responsible for human-induced climate change – all along the value chain (Daw et al. 2009; FAO 2009a). Concerns to promote Green Growth – that is, "fostering economic growth and development while ensuring that natural assets continue to provide the resources and environmental services on which our well-being relies" (OECD 2011:9) – explicitly take fisheries' contribution to global emissions into consideration.

Fishing. Estimates of emission from fishing operations vary according to authors. Tyedmers et al. (2005) calculated that the global fleet consumed 42 million metric tons of fuel per year (or 1.2 per cent of global annual fuel-oil use, which could be reduced with improved technology and management of stocks [FAO 2007; Daw et al. 2009]) and generated 134 Teragrams (Tg^2) of CO_2 per year. The main determinants of energy use in fishing operations are: (i) the fishing methods adopted – generally, mobile fishing gear (for example, bottom trawl and purse seine) is less fuel efficient compared to static/passive gear such as gillnets; and (ii) the status of the stock targets – overfished stocks at

2. A Teragram is equivalent to 10^{12} grams.

lower densities require more input and increased fuel use per metric ton of landings (FAO 2008e). Other emissions are associated with processing, storage and trading of fish products worldwide, requiring the use of air freight, shipping and refrigeration.

Aquaculture has, perhaps, a more complex relationship with carbon emissions. Part of aquaculture's contribution to climate change results from mangrove clearing, especially that caused by shrimp farming development, though this has declined over recent years (De Silva and Soto 2009). While terrestrial livestock are significant contributors to global emissions (accounting for 18 per cent of GHG emissions and 37 per cent of all human-induced methane emissions by some estimates), farmed aquatic animals emit only CO_2 as part of normal respiration and do not emit methane, hence their contribution is much lower (De Silva and Soto 2009). Energy consumption and feed constitute the most important sources of carbon emission in the aquaculture industry, with a notable difference between intensive recirculating aquaculture systems that require pumps and filters, and the more extensive low-input systems such as seaweed and shellfish farming (Bunting and Pretty 2007). Other associated impacts along the value chain are linked to the energy consumption of processing plants, fish feed production, and product storage and transportation.

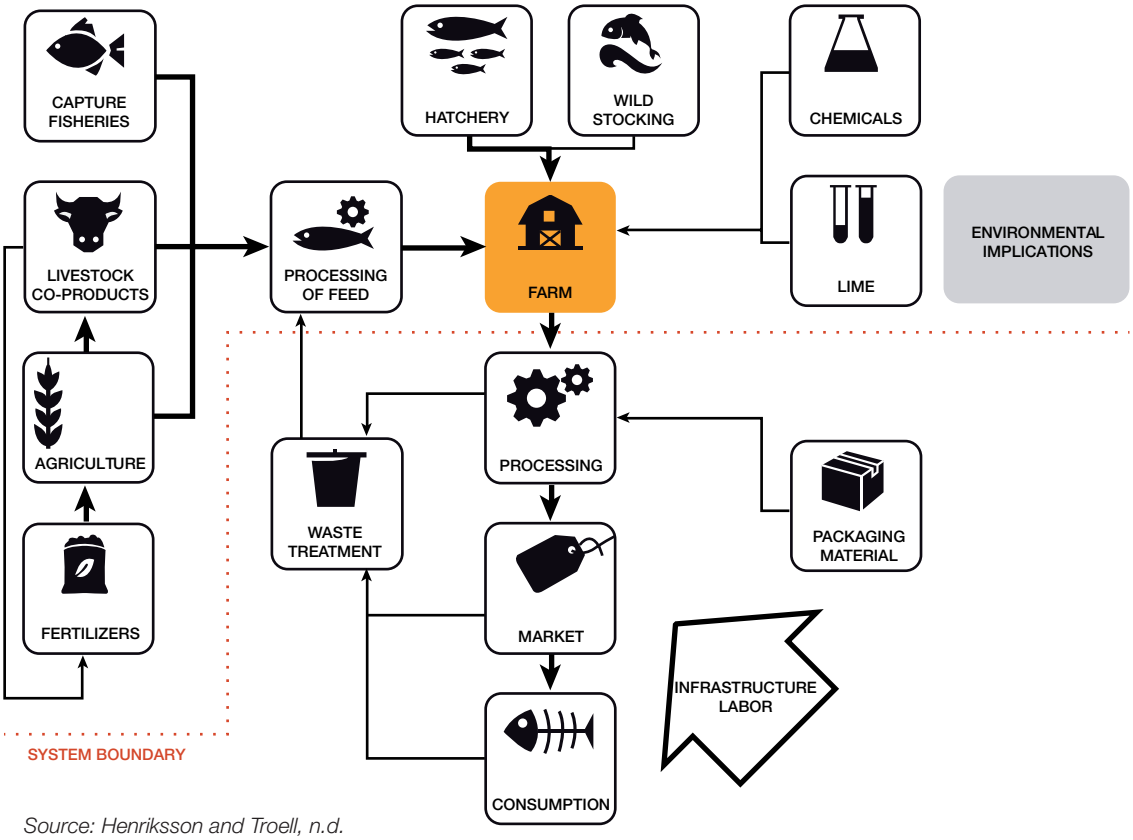
A life cycle analysis (LCA[3]) of different shrimp farm techniques in China evaluated the environmental impacts of intensive versus semi-intensive shrimp farming systems (used respectively for export and domestic markets), including global warming, acidification, eutrophication, cumulative energy use and biotic resource use. The results showed that intensive farming had significantly higher environmental impacts per unit of production than semi-intensive farming in all impact categories, with the highest emission levels generated by feed production, electricity use and farm-level effluents. Energy use per metric ton of shrimp was found to be 470 per cent higher for intensive systems than for semi-intensive systems (Cao et al. 2011).

However, according to the study on energy intensity in tropical aquaculture (Henriksson and Troell, n.d.) farming intensity is not necessarily the major factor in GHG emissions, and energy use can be substantially reduced by using ecosystem services instead of anthropogenic systems. The study highlights feed production as the major energy consuming practice. The figure on page 27 illustrates the energy consuming stages in aquaculture, which were taken into account by the LCA in the review of energy consumption.

A life cycle analysis of fish feed in aquaculture in Bangladesh – which was conducted by the Centre of Excellence on Environmental Strategy for Green Business (VGREEN) in 2012 and considered global warming potential, acidification potential and freshwater/marine eutrophication potential – showed that the production of industrial floating and sinking feed ingredients accounted for more than 70 per cent of total feed-associated impacts. The feed ingredients generating the highest impacts were soybean meal, meat and bone meal, wheat flour, and maize. The study also demonstrated that sinking food has a slightly lower global warming potential than floating feed, and that home-made feed has a lower impact in all categories compared to industrial floating or sinking feed. However, feed conversion ratios (kilograms of feed per kilo of fish growth) are much higher for

3. LCA studies the environmental and other potential impacts of a product throughout its life, starting at raw material and following it through production, use and disposal. LCA can also be used to assess the environmental impacts of a process or service along its entire life cycle from design to disposal.

FIGURE 4
Energy-consuming processes in aquaculture



Source: Henriksson and Troell, n.d.

home-made feed than for sinking/floating feed (feed conversion ratios are, respectively, 3.5 and 2.0). This annuls or significantly reduces the difference in global warming potential between the two types of feed, since the extra quantity of home-made feed that is not consumed by fish releases additional emissions through decomposition (VGREEN 2012).

It should be remembered that most aquaculture production systems have carbon emission values lower than those of other farm-raised protein industries. For example, in Sweden, meat production produces about 14 kilograms (kg) of CO_2 per 1 kg of beef and about 4.8 kg of CO_2 per 1 kg of pork. In Belgium, these values are even higher at 34 kg and 11 kg of CO_2 per kilogram of beef or pork meat, respectively. In comparison, the average CO_2 footprint of the top 10 retail seafood species (including products from both fisheries and aquaculture) is 6.1 kg of CO_2 per 1 kg of seafood (Davies 2010). In aquaculture, shrimp farming is the industry with the highest carbon footprint (11.10 kg of CO_2 per 1 kg of shrimp), while tilapia, carp and bivalves (oysters and mussels) can be considered low-impact species, generating 1.67 kg, 0.80 kg and 0.01 kg of CO_2 respectively, per kg of seafood produced (Davies 2010).

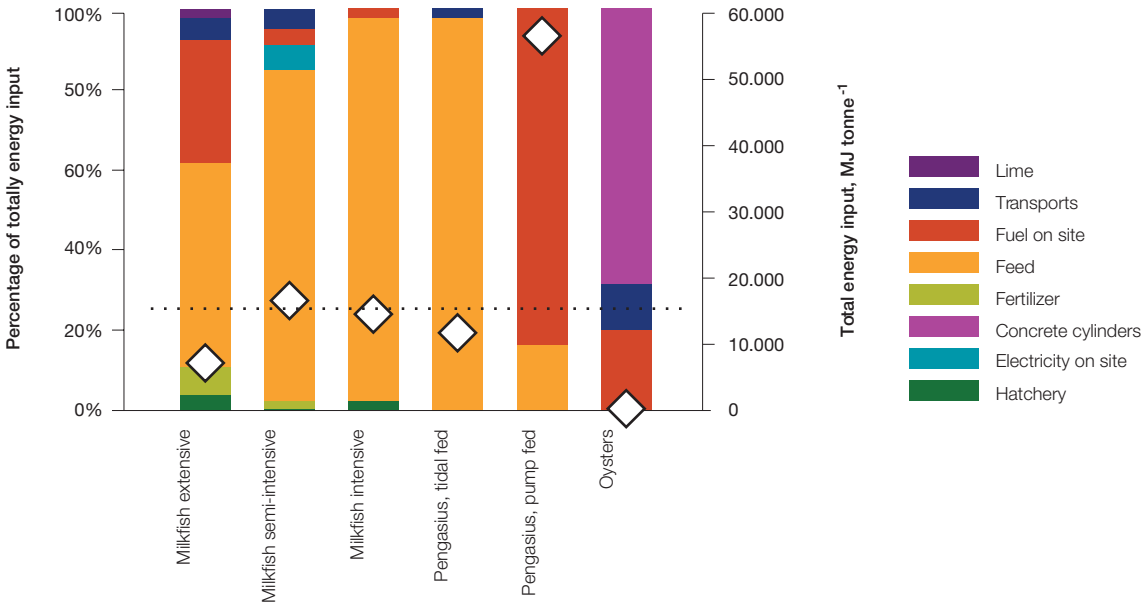
Another interesting practice to consider in the discussion on aquaculture and its environmental impact is rice-fish farming. The integration of small fish with rice provides valuable food and income and is a good adaptation strategy in flooded environments. However, some studies have shown that it increases the emission of

greenhouse gases from the rice fields. Datta et al. studied the emissions of nitrous oxide (N_2O) and methane (CH_4) from integrated rice-fish farming under rainfed lowland conditions in comparison to emissions from rice cultivation alone (Datta et al. 2008). They demonstrated that, in comparison to rice cultivation alone, rice-fish farming increased the emission of methane by 74-112 per cent while concurrently reducing nitrous oxide emissions. In terms of CO_2 equivalent global warming potential (GWP), the total greenhouse gas emission was much higher with rice-fish farming due to the fact that methane has a much higher share in the emissions (Datta at al. 2008).

A green growth agenda for fisheries? A green growth agenda in fisheries and aquaculture would focus on reducing the carbon footprint of the value chain while maintaining its social and economic contribution and sustainability.

The figure below shows the different inputs to total energy demand for different farming systems and species, where the diamonds represent the total cumulative energy (Henriksson and Troell, n.d.). Oyster farming clearly appears as the most energy-efficient type of sea food farming, whereas pump-fed pangasius farming is the most energy consuming due to its high fuel requirement.

FIGURE 5
Inputs to total energy demand for different farming systems and species



Source: Henriksson and Troell, n.d.

Climate change adaptation and mitigation options for fisheries and aquaculture projects

"As climate change is already having effects on fisheries and aquaculture systems and communities, it is imperative that steps to improve the adaptive capacity and resilience of these vulnerable systems be implemented without delay, especially in those economies and communities deemed most vulnerable to change" (FAO 2010c).

Vulnerability, adaptation and resilience

According to the IPCC (2007), vulnerability is "the degree to which a system is susceptible to climate change, and is unable to cope with the negative effects of climate change." The vulnerability of a household or a fishing community to climate change impact is a function of three main variables: (i) *exposure to impacts* – the nature and degree to which fisheries, fish farms and communities are exposed to climate change; (ii) *sensitivity* – the degree to which a system will respond to a change in climatic conditions; and (iii) *adaptive capacity* – the ability to change so as to cope with climate stress.

For communities identified as vulnerable to climate change, adaptation efforts should address some or all of these variables: exposure, sensitivity and adaptive capacity (Allison et al. 2007; Daw et al. 2009). At the most basic level, such efforts should aim to ensure resilience – that is, the ability to absorb climate change induced disturbances while retaining a sufficient quality of life. Ideally, win-win or "no-regrets" options should be pursued, which both build resilience to climate change and expand opportunities to thrive economically and socially, while maintaining or enhancing the natural resource base, contributing to poverty reduction, food security and sustainable development goals. These options would be beneficial even in the absence of climate change and particularly valuable in the contexts where there is considerable uncertainty about the future direction of climate change. Understandably, adaptation strategies are location – and context-specific and therefore difficult to model and predict (FAO 2008e).

Nicholls et al. (2007) divides adaptations into two categories: *autonomous adaptation*, which is the ongoing implementation of existing knowledge and technology in response to the changes experienced in climate; and *planned adaptation*, which is the increase in adaptive capacity created by mobilising institutions and policies to establish or strengthen conditions favourable for effective adaptation and investment in new technologies and infrastructure.

It is important to stress that in the fisheries and aquaculture sectors, climate change is only one of many interacting stresses: others include environmental degradation, weak governance, poverty, pollution and various other factors. Win-win/no-regrets adaptation options, which reduce exposure and sensitivity and increase adaptive capacity, are typically those that also tackle these non-climatic stresses. Improving the socio-economic status of communities, governance and management of natural resources is key to enhancing the capacity to deal with multiple stresses (Mangroves for the Future [MFF] 2010).

It should be emphasized that not all climate change effects are negative; hence, adaptation strategies need to ensure that the benefits of climate change are accessible to targeted communities.

IFAD

Project cycle

When developing projects and programmes, IFAD relies on several tools and guidelines that have been developed to assist IFAD staff and consultants involved in each step of the process to deliver quality development projects, which respond to the realities in the field, as well as to the needs and aspirations of project partners – especially poor rural women (IFAD 2007b).

IFAD's operating model comprises a project cycle with two main components: project development and project implementation. "Project development" includes three steps: (i) a project concept note; (ii) a detailed project design; and (iii) design completion. Project development and implementation are typically guided by a Country Strategic Opportunities Programme (COSOP), which is a framework for making strategic choices about IFAD operations in a country, identifying opportunities for IFAD financing and related partnerships, and facilitating management for results.

These Guidelines are particularly aimed at the COSOP and project development stages, providing a range of options for diagnosing and responding to climate threats to communities engaged in small-scale fisheries and aquaculture.

Fisheries and aquaculture within IFAD's response to climate change[4]

IFAD's Climate Change Strategy aims to maximize IFAD's impact on rural poverty in a changing climate. As recognized by ASAP, responding to climate change does not mean throwing out or reinventing everything that has been learned about development. Instead, it requires a renewed effort to tackle wider and well-known development challenges, and putting a proper appreciation of

ASAP Goal: Poor smallholder farmers are more resilient to climate change.

Purpose: Multiple-benefit adaptation approaches for poor smallholder farmers are scaled up.

Key ASAP indicators applicable to fisheries and aquaculture:

- Number of poor smallholder household members whose climate resilience has been increased.
- Number of individuals (in particular, women), community groups and institutions engaged in climate risk management, environment and natural resource management, or disaster risk reduction.
- US$ value of new or existing rural infrastructure made climate resilient.
- Number of tons of greenhouse gas emissions (CO_2) avoided and/or sequestered.

risks at the centre of the development agenda. A coherent response to climate change requires continued focus on country-led development, community-based natural resource management, gender equality and women's empowerment, land tenure security, access to financial services and markets, environmental sustainability, and institutional capacity-building. For IFAD, it is about doing more of the things that work and doing these things better, hence ASAP's first principle is to scale up tried and trusted approaches to rural development – those that have proven successful in delivering resilience benefits to smallholders.

However, climate change also requires the introduction of new approaches in rural development programmes that will improve their effectiveness and impact in a changing and increasingly uncertain environment. Such new approaches include the use of downscaled climate models for long-run scenario planning, community-based climate vulnerability and capacity analysis, and empowerment of local institutions to engage with national climate policy. They also involve improving the collection,

4. From ASAP Brochure

analysis and dissemination of meteorological data, establishing evidence-based monitoring systems for climate resilience, providing access to risk transfer and insurance schemes, and reassessing infrastructure and land and water use management plans, taking new and emerging risks such as sea level rise into account.

In line with this logic, IFAD's response to the climate change challenge focuses on: (i) basing projects and policies on an in-depth risk assessment and a better understanding of the interconnections between small-scale fishers and fish farmers, the ecosystems on which they rely, and the competing demands of other users; (ii) substantially scaling up successful multiple-benefit approaches to sustainable small-scale fisheries and aquaculture development. These multiple-benefit approaches not only build resilience to climate shocks but also contribute to other public policy goals such as reducing poverty, conserving biodiversity, increasing harvests and lowering GHG emissions; (iii) enabling small-scale fishers and fish farmers to become significant beneficiaries of climate finance and achieve a wider range of multiple benefits, going beyond the traditional "poverty and yield" approach.

The options outlined below have been selected based on the above logic. They have been identified through a review of best practices in climate change adaptation and mitigation, and are – in general – multiple-benefit approaches that offer combined solutions to climate threats and to the numerous, compounding problems currently affecting small-scale fisheries and aquaculture, as well as the communities that rely on them.

They also contribute to the goal and purpose of the ASAP programme and would typically be eligible for financing through one or more of the climate funds that IFAD has access to, including the ASAP, as well as the GEF, the SCCF, the LDCF and the Adaptation Fund and other major sources of climate finance. For example, within ASAP there is the potential to finance activities such as: (i) rehabilitating natural ecosystems, mangroves, coastal wetlands, sand dunes and coral reefs to protect livelihoods in coastal areas against climate risks; (ii) using integrated water resource management to maintain and improve healthy functioning of watersheds; (iii) providing communities with access to weather and climate information; and (iv) strengthening expertise in research, advisory and extension services on climate risk management and adaptation.

Adaptation basics

There are two multiple-benefit approaches to natural resource management that are particularly applicable to fisheries and aquaculture, and which deliver a wide range of social, environmental and economic benefits, including support to climate change adaptation. These approaches – which should be supported by all IFAD interventions in the fisheries and aquaculture sectors, regardless of location or context – are the ecosystem approach and co-management regimes.

The ecosystem approach

Many of the factors that make small-scale fisheries and aquaculture vulnerable to climate change, such as pollution and habitat degradation, originate from outside the sector. Therefore, an integrated and holistic approach to tackling these problems, including cross-sector collaboration, is needed in order to build resilience to climate change within fisheries and aquaculture communities. Implementing the "ecosystem approach" to fisheries and aquaculture management is essential to this.

As outlined in the Convention on Biological Diversity (CBD), the ecosystem approach consists of *"a strategy for the integrated management of land, water, and living resources that promotes conservation and sustainable use in an equitable way."*[5] Under the ecosystem approach, fisheries, aquaculture and

5. www.cbd.int/ecosystem/default.shtml

agriculture are seen as integrated activities within wider land and water management strategies, and as integrated elements of local livelihoods. FAO's Ecosystem Approach to Fisheries (EAF) and Ecosystem Approach to Aquaculture (EAA) are slightly narrower in scope compared with the CBD Ecosystem Approach, as they mainly focus on activities within the fisheries and aquaculture sectors, without strong links to activities and resource uses in other sectors. However, for IFAD, an approach that links fisheries and aquaculture with agriculture is particularly relevant.

Ecosystem services – defined as the benefits that people obtain from ecosystems – is a key concept within the ecosystem approach. Ecosystem services include *provisioning services* such as food, water, timber and fibre; *regulating services* that affect climate, floods, disease, wastes and water quality; *cultural services* that provide recreational, aesthetic and spiritual benefits; and *supporting services* such as soil formation, photosynthesis and nutrient cycling. Coastal ecosystem services have been estimated to be worth over US$25 trillion annually, ranking among the most economically valuable of all ecosystems (Nellemann et al. 2009). The human species, while buffered against environmental changes through culture and technology, is fundamentally dependent on the flow of ecosystem services (Millennium Ecosystem Assessment 2005; Anthony et al. 2009).

Healthy ecosystems provide both climate change adaptation and mitigation opportunities through their multiple ecosystem services. At the same time, they are prerequisites for healthy fisheries and aquaculture operations. Therefore, protecting and/or rehabilitating key freshwater, coastal and marine ecosystems can provide the multiple benefits of climate change adaptation, climate change mitigation, and support to fisheries and aquaculture in a cost-effective manner. Ecosystems of particular importance to small-scale fisheries and aquaculture are coral reefs, mangrove forests, wetlands and seagrass beds.

The concept of "Ecosystem-based Adaptation" to climate change (EbA) is another perspective of the ecosystem approach. EbA is a new concept, which capitalizes on the ability of natural systems to assist in human adaptation to climate change. In many cases, because natural systems provide multiple adaptation benefits, they are potentially more cost-effective than hard-engineered solutions.

FAO (2009d) defines the Ecosystem Approach as *"a strategy for the integration of the activity within the wider ecosystem in such a way that it promotes sustainable development, equity and resilience of interlinked social and ecological systems."* Some examples of the ecosystem approach to aquaculture include Integrated Multi-Trophic Aquaculture (IMTA), which is the cultivation of fed species together with extractive species that use the organic and inorganic wastes from aquaculture for their growth (Barrington 2009). One of the most important benefits of IMTA is that environmental costs of monoculture (i.e. externalities) are internalized to some extent. The scale of an IMTA can vary from a small operation suitable for poor communities to large commercial and capital-intensive initiatives. For the former, good models of marine-integrated systems in cages were piloted in Nha Trang Bay in Viet Nam by a DANIDA-supported project; the combination of species included snail, green mussel, seaweed, sandfish and fish (DANIDA 2005). An example of large commercial IMTA marine operation is located in the Bay of Fundy, Canada, and incorporates rows of salmon cages, mussel rafts and seaweed rafts (Chopin 2006; Barrington 2009). Another example of EAA includes integrated aquaculture (INTAQ), which is defined as *"the culture of aquatic species within or together with the undertaking of other productive activities which may include different types of aquaculture or capture fisheries"* (Angel and Freeman 2009). INTAQ can occur in the same farm or in closely situated operations, such as mussel and finfish farms located in proximity, or could result from enhanced productive opportunities

such as a combination of fish farming with artificial reefs that enhance local fish biomass around farms (Angel and Freeman 2009).

The value of conserving wetlands for flood protection in the city of Vientiane, Lao People's Democratic Republic, has been estimated at just under US$5 million, based on the value of flood damages avoided. The role of wetland ecosystems in flood protection will become increasingly important in many parts of the world. Wetland protection in Hail Haor, Bangladesh, contributed to an increase in fish catch of over 80 per cent (TEEB 2010), demonstrating the multiple benefits that such measures can deliver. Allison et al. (2007) call for the protection of African wetlands and deep sections of shallow lakes upon which inland fisheries depend, because they act as a refuge for fish populations during drought periods but are threatened by intensification of horticulture and rice cultivation. An ecosystem approach would ensure coordinated management of agricultural activities (i.e. horticulture and rice cultivation), the lake fisheries, and the wetland and water resources on which they both depend. For example, a United Nations Development Programme (UNDP) project in Samoa is helping a fishing community reduce its vulnerability to rising seas and flooding by reinforcing the resilience of the local ecosystem. The fragile wetlands around the community are being rehabilitated and replanted in order to become more resilient. Enhancement of water flow within the wetlands is helping protect homes and farms from flooding and allow fish breeding habitats to connect with the sea (UNDP 2010).

Shifting to more sustainable management regimes for a natural resource or ecosystem will normally involve costs, particularly in the short term, and these may be unevenly distributed, creating sources of tension, conflict and resistance to improved management. Payment for Environmental Services (PES) mechanisms provide a way to compensate people for income they might forego when their fishing, fish-farming or other natural resource exploitation practices are restricted and to reward them for contributing to the common good (Glover 2010).

The underlying premise of PES is that ecosystems, such as mangroves, provide useful services to people, including erosion control, climate stabilization and maintenance of biodiversity. However, these are public goods, or positive externalities, where benefits are spread widely, including to people living outside the mangrove area. People living in or nearby the mangroves may prefer to harvest the mangroves for fuel or building materials, but this will damage the flow of public goods. In order to encourage them to preserve the mangroves, they must be compensated for the lost income and other benefits they would have otherwise received – this is often a more effective means of preserving the mangroves than simply banning the practice of cutting them. The essence of PES, then, is a bargain between those who benefit from environmental services and those responsible for maintaining such services. Such arrangements can be complex to establish – the wider public may be reluctant to pay for something they have received for free in the past or had never considered paying for. Good PES examples in forest management can be found in Viet Nam (Bui and Hong 2006; Hawkins et al. 2010) and in Costa Rica (Glover 2010); with the increase in popularity of such schemes, positive examples are becoming more widespread.

In Viet Nam, a coastal zone management project being implemented by the German Society for International Cooperation (GIZ) is piloting mechanisms for the sustainable financing of ecosystem services provided by coastal wetlands. It strives to establish a benefit-sharing scheme, whereby members of the mangrove co-management group (poor and very poor) refrain from harvesting mangrove timber. In this way, the ecosystem services provided by the mangroves continue to benefit the community

and especially the clam farmers close to the mangrove area. In return, the members of the mangrove group are invited to join the clam cooperative and receive a part of the financial benefits gained from selling clams.

The adaptation measures in the following sections are all compatible with the ecosystem approach but must be implemented in a coordinated manner and engage all relevant stakeholders in order to meaningfully encourage the ecosystem approach. Extensive information on the ecosystem approach to fisheries and aquaculture is available on the FAO website.[6]

Co-management

Co-management is a participatory management process involving local communities, government entities at different levels and other stakeholders who agree to share benefits and responsibilities regarding the sustainable utilization of renewable natural resources.

Co-management approaches have numerous advantages. Co-management and farmers' group establishment can be potent mechanisms to increase advocacy and promote empowerment of fish farmers and fishers in a changing climate. They can help stakeholders adapt to climate change through more responsive governance and effective communication with the local and national authorities (Fezzardi 2001). Clustering farmers into groups is a first step towards obtaining certification of sustainability and traceability for aquaculture and fisheries operations. The establishment and strengthening of farmer organizations can improve dialogue and exchange among producers, and enable them to create early warning systems for diseases, share their successes and failures, techniques, and innovations in matters such as choice of fish species, feeding and nutrition, and farm management (ETC Foundation 2010). Farmers' organizations can also play a role in ensuring that farmers' voices are better heard in defining research agendas and in national policymaker. In Africa, Allison et al. (2007) point at co-management as a means to enhance the resilience of inland fisheries and aquaculture systems to climate change. Co-management initiatives may be closely associated with devolution of fishing rights to community level and community governance of fisheries. The design of such initiatives must be very carefully considered in any project.

Worldwide, governments are increasingly fostering co-management, and community-based management regimes for natural resources that involve groups and associations are seen as key entry points. In Viet Nam, co-management is increasingly seen as the way forward to improve fisheries and natural resource governance; several project-driven initiatives, as well as government national plans, promote co-management and community participation (Akester et al. 2004). Although past experience with project-driven initiatives, especially in Sub-Saharan Africa, has encountered sustainability problems after project termination, strengthening of producers' associations is still seen as an important strategy for fisheries and aquaculture development (ETC Foundation 2010).

Fishers' and fish farmers' groups are most sustainable when they offer clear financial benefits to members, even if they are also involved in co-management activities. In Uganda, the Walimi Fish Farmers' Cooperative Society (WAFICOS) is a good example of a sustainable fish farmers' association. Thanks to WAFICOS, fish farmers' private sector linkages have been strengthened, fostering aquaculture development; privately operated hatcheries have addressed problems of fish seed availability; markets have been created for farmed fish products; and members of WAFICOS have direct access to advisory services, appropriate technologies, farm inputs, markets and credit facilities (Walakira et al. 2010). In Malawi, the Zomba Fish Farmers Association,

6. www.fao.org/fishery/topic/13261/en

CASE STUDY

Poverty alleviation in the rural areas and improving market participation of the poor, Viet Nam

Geographic scope:	Ha Tinh and TraVinh Provinces, Viet Nam
Duration:	2007-2013
Funding agency:	GIZ and IFAD
Implementing agency:	GIZ and the Government of Viet Nam
References:	DRAGON Institute of Can Tho University
Links:	www.giz.de, www.ifad.org

Short description

The objective of the IFAD programme is to raise the incomes of poor rural people in Ha Tinh and Tra Vinh provinces by improving their access to labour, finance, commodities and service markets. Poverty rates are high in these communes, and most of the population live in rural areas and depend on subsistence farming. The programme focuses on the systematic removal of barriers that prevent the rural poor from market participation. To this end, the project: (i) supports local development planning; (ii) promotes market-oriented agriculture along value chains; (iii) contributes to improving the provision of relevant job skills training and fostering the local investment climate; (iv) creates off-farm employment; and (v) links market-based initiatives to the needs and priorities of poor communes. The project is implemented in cooperation with GIZ, which provides technical assistance.

Climate change adaptation focus

Although the programme does not focus primarily on climate change issues, it does address these by introducing a Climate-Proofing Tool to increase local development planning capacity. The probable consequences of climate change have not yet been addressed or fully implemented in local planning, and thus the Climate-Proofing Tool would make it possible to: (1) identify those activities or value chains that are at risk or under threat in some way from climate change; and (2) analyse whether additional measures are required in order to implement the value chain successfully. In particular, the programme has an aquaculture component focusing on pangasius and clam value chains, which are low-trophic species whose habitats can act as a carbon sink. With the support of the project, pangasius farmers are working in a public-private partnership initiative towards Global Good Agricultural Practices (GAP) certification. The aquaculture and fisheries component of the project is working in close collaboration with the provincial Department of Agriculture and Rural Development (DARD) and the provincial Cooperative Alliance. It also collaborates with DRAGON Institute of Can Tho University in a study that gathers farmers' and other key informants' perceptions on changes and impacts over time resulting from climate change and extreme weather events.

Approaches to building adaptive capacity

- Adopting a systematic approach in the use of the Climate-Proofing Tool to increase the chances of success of the planned and implemented value chains.
- Fostering farmers' groups, cooperatives and unions to increase adaptive capacity at the local level by enabling easier access to market information, technical expertise and aquaculture inputs.
- Promoting the clam industry as a potential alternative livelihood activity for fishing/agricultural households impacted by climate change.
- Creating fishery co-management regimes between clam cooperatives and DARD as a starting point towards establishing a progressive and lucrative clam fishery industry, eligible for an internationally recognized, sustainable fishery certification.

established in 2003 in six traditional areas in the Zomba District, receives technical and extension support from the District Fisheries Office, with assistance from the National Aquaculture Centre (ETC Foundation 2010).

The following are key steps that could be taken in IFAD-financed projects to promote co-management:

- *Promote the formation of farmers' groups, cooperatives and fisheries associations* as a first step towards co-management regimes and a key entry point for forging lasting partnerships between government authorities and fishers and fish farmers.
- *Foster the establishment and application of a robust legal framework for co-management and community-based management regimes* in fisheries, aquaculture, coastal wetlands and mangroves in order to create the necessary legal foundation for the development of such regimes.
- *Develop a practical manual for the organization of farmer groups and establishment of co-management regimes* for use at the community level, based on successful examples found in IFAD-financed projects and those of IFAD's partners.

All of the above efforts must take into consideration gender implications – that is, they must ensure that women's as well as men's priorities are represented in fisher organizations, relevant policy and legal frameworks, and that practical guidelines are developed based on a clear understanding of the roles of women and men in the fisheries and aquaculture sectors.

Detailed adaptation actions

Project programming and design

- **Stakeholder engagement and participation.** Ensure that target beneficiaries and stakeholders are involved in all steps of project development and that their needs and viewpoints are addressed through a participatory approach. Such involvement is necessary to identify issues, opportunities and priorities from the communities' perspective and key to ensuring ownership and long-term sustainability of interventions. During discussions, it will be necessary to improve stakeholder awareness of the nature of climate change and the distinction between climate variability and climate change. Small-scale fishery and aquaculture communities are often situated in areas prone to extreme climate events and climate variability, and therefore have long-term experience in dealing with climate issues. This local knowledge can help in identifying climate changes and appropriate adaptation measures; it should also be taken into consideration that it may have already initiated autonomous adaptation. Community participation should also be embedded in the implementation of the project, in monitoring its progress, and in evaluating its impact. A participatory monitoring and evaluation (M&E) framework for local and community-based adaptation to climate change – the Participatory, Monitoring, Evaluation, Reflection and Learning Tool (PMERL) – has been developed by CARE and the International Institute for Environment and Development (CARE and IIED 2012). A similar M&E framework has been developed by the Action Research for Community Adaptation in Bangladesh (ARCAB 2012).

- **Vulnerability assessment.** Undertake participatory vulnerability assessments of target communities susceptible to climate change and disaster using vulnerability mapping and scenario development. Climate change vulnerability assessment is a key process for identifying target areas and communities where adaptation needs are most urgent and severe. In recent years, many vulnerability assessment tools have been developed that can be used for small-scale

CASE STUDY

Programme to reduce vulnerability in coastal fishing areas (PRAREV), Djibouti

Geographic scope:	Arta, Loyada and Damerjog localities in Tadjourah and Obock regions, Djibouti
Duration:	2014-2019
Funding agency:	IFAD (loan and ASAP grant), Government of Djibouti, WFP, FAO, Caisses Populaires d'Épargne et de Crédit (CPEC), Centre d'Études et de recherche Djiboutien CERC)
Implementing agency:	Government of Djibouti
Implementing partners:	WFP, FAO, CPEC, CERD
References:	www.ifad.org

Short description

The aim of this recently designed IFAD programme is to implement and scale up climate change adaptation approaches in order to increase the resilience of coastal populations, improve income and promote co-management of marine resources.

The specific objectives are: (i) to increase the ownership by coastal populations of climate change resilient activities; (ii) to benefit a high proportion of target groups affected by climate change by strengthening cooperatives and associations; (iii) to increase incomes of programme beneficiaries; and (iv) to increase the landed value of fish catch without affecting the status of the resource.

The above objectives will be achieved through the implementation of three technical components:

- **Component 1- Support for resilience of habitats and coastlines.** Reduction of climate risks to the coastal ecosystem and restoration of the equilibrium of marine habitats, by means of participatory natural resource management that involves the beneficiaries in conservation works such as cleaning and planting, and sustainable coastal resource use. This will also include monitoring climate change impact on coastal ecosystems and restoring coastal habitats.
- **Component 2 - Promotion of fishery value chains.** Rehabilitation of pre- and post-production value chains affected by climate change, and provision of adequate equipment and infrastructure that will reduce the vulnerability to climate change impacts.
- **Component 3 - Capacity-strengthening.** Promotion of policy dialogue at the highest level to ensure that climate change adaptation considerations are mainstreamed into national strategies over the long term, and provision of vocational training for improving livelihood diversification.

Climate change adaptation focus

Under the combined effects of climate change and overuse of natural resources through deforestation and overgrazing, land degradation is worsening and biodiversity is undergoing a serious regression – both on land (with forests receding by 3 per cent a year) and in marine environments. Higher temperatures and rising sea levels resulting from climate change could exacerbate these processes, with dramatic consequences for the country.

The latest drought that afflicted the Horn of Africa has severely impacted the livelihoods of rural populations that depended on agriculture and livestock; as a result, the majority have migrated towards the coastal areas in search of livelihood opportunities within the fisheries value chain. In view of the impact of climate change on the coastal areas of Djibouti, the fisheries sector has become extremely vulnerable, with: (i) deteriorating fishing ecosystems and habitats; (ii) vulnerable infrastructure and coastlines; and (iii) insufficient capacity for climate change adaptation owing to the country's poor socio-economic development and recurrent natural catastrophes in the Horn of Africa. The programme approach is adapted to the situation of poverty of people living in coastal areas affected by climate change and lays the groundwork for sustainable development based on participatory natural resource management.

The programme will facilitate the development of mechanisms for livelihood improvement at the national and local levels that incorporate the priorities of small-scale fishers and smallholders in adapting to climate change. Responses to these changes will be based on the strengthening of capacities for adaptation and resilience of both communities and the ecosystems on which they depend. The value added by IFAD's ASAP financing will enable affected populations to acquire the knowledge they need to guard against climate change risks and access more resilient means of addressing them. Examples of climate-relevant activities include: the restoration of 50 per cent of mangroves identified for rehabilitation (200 hectares) and preservation of 100 kilometres of coral reefs, which are vital to fish stocks; investment in more climate change resilient equipment and infrastructure in the fishing sector (including equipment based on renewable energy); innovative micro-projects that promote diversification, based on the sustainable use of coastal resources; and a system of co-management for fish resources that also combats illegal fishing. In addition, IFAD will finance two major studies that would enable the set up of a sustainable M&E system for fish resources (including determining the maximum sustainable yield) and a long-term monitoring system for coastal ecosystems.

Approaches to building adaptive capacity

The project is a comprehensive response to the challenges of climate change and poverty in rural coastal areas, with an overall approach that is intended to strengthen the resilience of rural coastal populations to climate change and adopt innovative approaches to sustainable use of natural resources and promotion of renewable energies, while developing infrastructure and equipment for more climate change resilient value chains in fisheries. It builds adaptive capacity by:

- Identifying multi-risk areas affected by climate change for programme targeting, based on the results of the vulnerability assessment undertaken by UNEP Risø Centre.
- Adopting innovative diversification activities – for example, promoting the cultivation and sale of red algae as an income-generating activity for women, and salting and drying of fish that has not been sold, etc. as potential alternative livelihood strategies.
- Providing technical and financial support needed to scale up innovations and allow for replication and adoption of best practices.
- Climate proofing the fisheries value chain and building capacity for sustainable management and use of resources.
- Developing a solid knowledge management network at the national level with countries in the sub-region and United Nations organizations on climate adaptation-related innovations and natural resource management.
- Building on the results of the vulnerability assessment to develop a comprehensive and effective M&E system and knowledge sharing.

fisheries and aquaculture sectors, including: the Community Vulnerability Assessment Tool (CVAT), which can be downloaded from the UNFCCC website;[7] the Climate Vulnerability and Capacity Analysis (CVCA) Handbook by CARE;[8] the Training Guide for Gender and Climate Change Research in Agriculture and Food Security for Rural Development by the FAO; and the Research Program on Climate Change, Agriculture and Food Security (CCAFS)[9] developed by the Consultative Group on International Agricultural Research (CGIAR). Vulnerability assessments ask questions such as: To what extent will climate change have an impact on target communities and their livelihoods? What is the economic status of these communities? Are fisheries' resources depleted? Is the area prone to frequent disasters or extreme weather events? Is there any viable and autonomous coping strategy to learn from? Do farmers understand the concept of climate change? Are they aware about the associated risks? Assessments should collect specific information about past and recent history of events related to climate

7. www.unfccc.int/adaptation/
8. www.careclimatechange.org/cvca/CARE_CVCAHandbook.pdf
9. www.fao.org/docrep/018/i3385e/i3385e.pdf

change that had drastic consequences for the local economy and livelihoods, and which might occur again in the future and jeopardize project implementation and/or outcomes. Relevant tools include climate change and disaster scenario development, which examine both current and future climate risks and document current coping strategies that address these impacts, leading to the development of participatory needs-based adaptation strategies. Climate Change Country Profiles for 52 of the world's poorest countries, available on the UNDP website[10] and the World Bank Climate Change Data Portal,[11] can provide preliminary information for this purpose. Previous comprehensive assessments, such as that recently completed for the IFAD-financed Programme to Reduce Vulnerability in Coastal Fishing Areas[12] in Djibouti, can also serve as examples.

- **Participatory monitoring and evaluation** (PM&E). Establish a monitoring and evaluation system to assess the success of adapting to climate change. Select site-specific, impact-oriented and easily verifiable indicators to measure progress and achievements, including outputs, outcomes and impact; ASAP is a useful reference for this purpose. Ensure that your system is actually measuring the real impact of your project on the community, going further than the achievement of the logframe's initial outcomes and indicators. The ARCAB PM&E framework for Community Based Adaptation (CBA) and CARE's PMERL mentioned above are newly developed tools with that specific aim. The PM&E strategy should be designed at the very early stages of the project with the active participation of the targeted communities. M&E systems should generate lessons learned and inform management decisions.

Policy Strategy, and Capacity-Building

- **Increase the awareness of local authorities, communities and other resource user groups about climate change and the irreversible nature of some impacts.** This is a necessary first step to ensure a common understanding and commitment to take action. Information on risks, vulnerability and threats posed by climate change, as well as on lessons learned and insights gained on adaptation to climate change from global, country and sector-level analyses enables stakeholders to prioritize actions and develop a robust, integrated approach that leads to greater resilience to climate risks (Daw et al. 2009; World Bank 2010b).

- **Support mainstreaming of climate change adaptation and mitigation in fisheries and aquaculture sector development planning.** Climate change risks must be considered systematically in development planning at all levels. In particular, when estimating returns from investments, the costs of adaptation, mitigation, and potential losses and gains from climate impacts need to be factored in (Kam et al. 2010). In addition to the sector perspective, planning processes need to take account of plans and decision-making processes at the level of administrative districts and at the level of ecosystem units, such as bays, river basins, lakes or estuaries. The extent to which planning processes already do this should be considered in the policy analysis stage during COSOP or Concept Note development. This process should include a review of existing plans, budgets and investments from a climate change perspective.

- **Build capacity and promote the use of scenario-building methodologies for policymakers** as a robust framework and an iterative process to identify key features of fisheries and aquaculture production, and

10. http://country-profiles.geog.ox.ac.uk
11. http://sdwebx.worldbank.org/climateportal
12. http://operations.ifad.org/web/ifad/operations/country/project/tags/djibouti/1671/project_overview

the drivers of change, and to understand vulnerability to climate change and climate variability. This helps to create responsive planning scenarios and design evidence-based and coherent adaptation policies at both the national and regional level.

- **Support disaster risk reduction and preparedness.** Include elements of disaster risk reduction and preparedness into development planning. This is imperative for reducing the vulnerability of fishing and fish farming communities to natural disasters and extreme weather events. Given that livelihoods, hazards and climate change are closely interconnected, it is suggested that disaster risk management, climate change adaptation and mitigation measures should be integrated into a single strategy, which would increase efficiency, reduce costs, and increase effectiveness and sustainability of actions (FAO 2010c). Such a strategy, focusing on both current and future impacts, should systematically be included in development projects to ensure long-term sustainability.

- **Promote Integrated Coastal Zone Management (ICZM) and Integrated Watershed Management (IWM)** as tools for planning across land and water-based sectors, and administrative units. ICZM has been widely proposed as a more comprehensive approach to coastal zone management that addresses the limitations and difficulties associated with sectoral and enhanced sectoral approaches, particularly in relation to coastal aquaculture, fisheries, other natural resources and industries. Thus, ICZM could be the most appropriate approach to deal with climate change, sea level rise, and other current and long-term coastal challenges. Enhancing adaptive capacity is an important part of this approach (Nicholls et al. 2007). Furthermore, recommendations on adaptation and mitigation from individual sectors should be aligned with national projects and programmes, and should take account of potential conflicts or synergies between adaptation actions in different sectors.

- **Strengthen regional cooperation and partnerships** among relevant agencies and implement bilateral and multilateral agreements on shared rivers, lakes, seas and fish stocks. Strong cooperation is needed to improve management of shared resources and exchange knowledge and experiences on climate change impacts and adaptation/mitigation measures, as well as create a stronger presence and united front in international fora concerned with climate change.

- **Strengthen the knowledge base and climate change advisory capacity of fisheries and aquaculture extension workers.** Extension services play a crucial role in disseminating knowledge and best practices, even in remote fishing and aquaculture communities. Climate change adaptation calls for a different approach to development, including building markets for alternative products, climate-proofing farming and fishing facilities to make them resilient to climate risks, and accounting for the inherent uncertainty in future climate projections. Well-trained extension workers and climate-proof extension material will be key in addressing climate change challenges.

- **Organize and deliver training to target vulnerable fishing and farming communities on climate change and adaptation.** This would include basic concepts of climate change, adaptation in fisheries and aquaculture, vulnerability of livelihoods, business planning and marketing, and improved safety and security at sea.

- **Encourage knowledge-sharing.** Several regional and international platforms are

BOX

The Phuket consensus supports women's empowerment

Recommendation 5 of the Phuket consensus of the Global Conference on Aquaculture 2010:
Support gender-sensitive policies and implement programmes that facilitate economic, social and political empowerment of women through their active participation in aquaculture development, in line with the globally accepted principles of gender equality and women's empowerment.

available for knowledge-sharing, including communication about projects and relevant research. For example, Africa Adapt (www.africa-adapt.net/themes/4/) has a specific theme on agriculture, fisheries and food security and their interconnection with climate change. Weadapt (weadapt.org/subject/aquaculture) offers a research tool with dedicated tags for aquaculture and fisheries, as well as vulnerability assessment tools, among others. The UN-sponsored "Adaptation Learning Mechanism" (www.adaptationlearning.net) provides a search engine, whereby information can be retrieved using a key word, or by selecting a theme or type of document. Some organizations have developed national web portals to share information about country-level initiatives – for example, the International Centre for Climate Change and Development (ICCCAD), which operates a web portal for Bangladesh (http://ccresearchbangladesh.org/); such portals also can serve as sources of information about best practices.

- **Sponsor action research to fill the critical knowledge gaps** on adaptation to climate change impacts, community and national assessments of fisheries and aquaculture-related vulnerability, and development of prediction models for different scenarios. Other topics may include research on cost-effectiveness of different project interventions, as well as on how intra-household gender roles influence household adaptation decisions. The research by WorldFish and CCAFS referred to earlier in this publication is an example of good practice.

- **Mainstream gender concerns** throughout all of the above, building on an understanding of the different capacities and vulnerabilities of men and women in project areas. Priority actions to address women's lack of voice include strengthening women's leadership in fishery organizations, ensuring new sectoral legislation and budgets reflect the priorities of both men and women in line with the provisions in the "Voluntary Guidelines on the Responsible Governance of Tenure of Land, Fisheries, and Forests in the Context of National Food Security" (FAO 2012) and "Good Practice Policies to Eliminate Gender Inequalities in Fish Value Chains" (FAO 2013). IUCN has useful case studies on how gender has been addressed in national climate change policies; the case study for Tanzania specifically focuses on fisheries.[13]

Management measures

- **Implement the ecosystem approach to management.** The ecosystem approach is a holistic, integrated and participatory method to improve fisheries management and move fishing practices towards sustainability and equity, and away from the risky maximum sustainable yield approach (Daw et al. 2009). Fisheries co-management and community participation in resource utilization are also very effective ways to improve fisheries governance and the local management of fish stocks, as well as build the resilience of fishing communities.

- **Reduce overfishing and excess capacity.** This involves adjusting fleet composition by supporting small-scale fisheries and discouraging industrial fisheries, especially in countries where there are fully or

13. www.iucn.org/dbtw-wpd/edocs/2012-086.pdf

overexploited stocks. Where data on fish stocks is limited or of poor quality, it should be assumed that stocks are fully or overexploited. Project activities that might increase fishing pressure should only be undertaken if there is very clear evidence that they could be carried out sustainably. While small-scale fisheries can also overexploit stocks and harm the environment, and may generate only marginal profit levels, they often offer advantages over industrial fisheries in terms of efficiency (lower fuel use, better targeting resulting in less waste and discarding) and lesser impacts on the environment (use of less destructive gear, longer time taken to deplete a stock, which gives time to policymakers to react). In addition, small-scale fisheries can provide more employment and contribute to reducing poverty and food insecurity (FAO 2008g).

Ecosystem services

- **Rehabilitate/protect essential freshwater, marine and coastal ecosystems and the services they provide** through conservation and rehabilitation of coral reefs, seagrass beds and mangroves and restoration of wetlands, marshes, and known nursery and spawning areas. This could include interventions to reduce coastal erosion and increase sedimentation, such as the installation of wave-breaking barriers.

- **Introduce sustainable financing of ecosystem services** through PES. Opportunities for promoting carbon offsets on international voluntary carbon markets should be explored.

- **Support the establishment of Marine Protected Areas (MPAs) and Inland Waters Protection Areas.** MPAs may include zones where no fishing is allowed, zones demarcated for recreational fishing, or zones where only artisanal and small-scale fishers have the right to exploit resources by using selective, non-destructive gear. Fishery management measures outside protected areas are necessary to complement the protection offered by MPAs (Salayo et al. 2008). Protected areas in inland waters are also effective fishery management tools, in particular when fishing communities are proactively engaged in their establishment and enforcement. Climate change may cause shifts in the range of ecosystems and species occurrences, which in turn may result in the need for range changes and shifts of some protected areas. Again, it is important that such changes take into account local knowledge. Where they have been implemented, MPAs have been largely accepted once fishers understood their significance in both habitat conservation and rehabilitation of fishery resources – for example, in the Philippines and Thailand. The Philippines has some long-standing MPAs with demonstrated positive effects on fisheries, including well-documented situations in adjacent non-MPA marine areas. In Laos, so-called "fish conservation zones" have been established in the Mekong River, largely based on local fishers' knowledge (Baird and Flaherty 2005). In Cambodia, fishers are also amenable to the establishment of some form of protected areas – for example, by converting some fishing lots and fishing grounds into conservation areas (Salayo et al. 2008). West Africa has developed a Regional Network of Marine Protected Areas (RAMPAO).[14]

- **Promote culture-based fisheries (CBF) and stock enhancement practices** in suitable water bodies, including reservoirs and irrigation infrastructures, floodplains and coastal lagoons. CBF can be developed as a community-based activity that uses a common property water resource either in perennial or seasonal water bodies. CBF uses aquaculture techniques to increase production

14. www.rampao.org/view/eng/accueil.php

in natural environments by controlling the early life stages of fish. Seed/larvae/fingerlings can be sourced from the wild and/or from hatcheries, grown to a size where they have a higher rate of survival in the wild, and then transplanted or released in open waters. Through non-consumptive water use, CBF improves the efficacy of water usage, and therefore conservation for irrigation, domestic use and aquaculture will be balanced. There are good examples of successful establishment of CBFs in newly impounded reservoirs and large water bodies for the benefit of displaced communities in need of a new means of livelihood (De Silva and Soto 2009). CBF can play a key role in those regions of Asia and Africa where longer drought periods are predicted and where natural survival rates may decrease (De Silva and Soto 2009). Another strategy to preserve fish population is the installation of fish sanctuaries in water bodies in order to shelter fish during periods of low water level, as well as from predators such as birds and from fishers. Seasonal sanctuaries provide shelter during the early and late rainy season in order to increase seasonal fish survival.

- **Identify and invest in key infrastructure and ecosystem rehabilitation projects, favouring a "no-regrets" approach**, composed of actions that generate net social benefits under all future scenarios of climate change and impacts. In consultation with national authorities and communities, explore opportunities for investing in innovative infrastructure that could counteract the impacts of climate change, such as coastal dike systems and freshwater supply systems for aquaculture. Examine existing plans and projects for infrastructure development and their funding status. Such interventions should include investments in ecosystem-based adaptation – for example, ecosystem rehabilitation to increase the provision of ecosystem services, such as storm protection, erosion prevention and water retention. For instance, a GIZ-supported project in Viet Nam is currently testing wave breakers made of bamboo to facilitate coastal sedimentation that, in turn, would allow mangrove rehabilitation. Bamboo fences are both flexible and permeable and can be installed in a T-shape pattern to create polders on which mangroves can be planted. A similar method has already been used in Thailand, highlighting the value of regional learning.

Livelihood measures

- **Livelihood diversification.** Diversification of income in order to maintain a fishery-based livelihood is an essential adaptation measure, especially among the small-scale fishers in areas where stocks are overexploited. A common way to diversify activities within the fisheries sector is to engage in some form of aquaculture and/or artisanal post-harvest processing, though this is not always feasible. SPC is promoting small-pond aquaculture to help fishers in the Pacific Islands build on their natural resilience to handle the uncertainty of climate change (SPC 2008). Alternatives can include the tourism sector, wage employment or other microenterprises. Such interventions are often readily taken up by women. Interventions should focus on creating an enabling environment for the establishment of business activities and creation of employment opportunities. In areas where agricultural land is threatened by salinity and sea level rise, aquaculture or integrated farming could provide a valid alternative to agriculture.

- **Improve early warning systems and increase safety at sea.** Introduce and/or improve weather early warning systems to inform fishers in a timely manner of bad weather. Improve safety at sea through better-built boats, improved communication systems and health/life and equipment insurance.

- **Temporary or permanent migration.** In extreme cases, where few or no other options are available – for example, due to sea level

rise, salinization of groundwater or increased frequency of storms – the only option may be the relocation of vulnerable communities (IFAD 2010b). Some forms of temporary migration linked to fluctuation and shifting of catch are well-known adaptation options for many fishers around the world – as is the case with the Peruvian scallop fishers (Daw et al. 2009), as well as fishers along the coasts of western Africa and the Gulf of Guinea. Migration for work may also be a means of livelihood diversification.

- **Financial services.** Small-scale aquaculture and fisheries are considered risky activities for which financial credit and insurance products are rarely available. In aquaculture, the availability of credit from lending institutions is closely linked to the perceived risk of the sector. Nevertheless, the provision of financial services is an effective way of boosting the resilience of poor and marginalized communities to climate change. Options include micro-credit schemes, such as community-based revolving funds, and simplified lending mechanisms within formal and semi-formal credit organizations for fishers and aquaculture farmers. In aquaculture, adoption of best management practices (BMPs) increases creditworthiness by making the crop outcome more safe and predictable (Secretan et al. 2007).

- **Promote Marine Stewardship Council (MSC) certification scheme** to certify sustainable and well-managed fisheries – effectively rewarding adaptation efforts and environmental services financially. MSC is arguably the "gold-standard" certification scheme for sustainable capture fisheries worldwide, which helps generate market demand and thus encourages sustained improvements in fishery management. A successful example is the MSC-certified Ben Tre Clam Fishery in Viet Nam: as a result of MSC certification, the farm-gate price for clams produced in Ben Tre increased by 156 per cent between 2007 and 2010; the branded clams are known globally and the current production is not enough to satisfy market demand (ICAFIS 2010b).

- **Insurance.** Availability of traditional or index-based insurance products tailored for small-scale fishers and fish farmers, and covering against losses due to natural calamities – such as dyke breaking, floods and storms – would greatly enhance their resilience. Consider the development of weather index-based insurance schemes, which cover against weather-related hazards and pay out once a predefined index is crossed, regardless of the level of damages. This could be pursued through a partnership between governments, insurers, and private- and public-sector organizations, and linked to the adoption of BMPs, GlobalGAP,[15] ASC and MSC certification schemes.

Technical measures – Fisheries

- **Introduce new fishing gear, and identify and promote fisheries that target underexploited species.** Small-scale fishers usually do not have the necessary resources or equipment to go fishing in areas far from their homes and, consequently, are forced to harvest local species. Fishers may have to adapt their fishing habits – for example, gear, methods or species fished – in order to continue catching fish if the composition of species in their fishing grounds changes due to climate change (Roessig et al. 2004). This would require adequate extension backstopping, as well as input support in procuring new fishing equipment. However, such assistance should seek to build on existing local knowledge and capacity for adapting to change – ecological, seasonal, environmental, etc. It should only be provided in cases where there is clear evidence that stocks can support additional fishing pressure.

15. www.globalgap.org/uk_en/

BOX 1

Inland fisheries in Africa

Ovie and Belel (2010) have recently reviewed current and potential adaptation measures adopted by the riparian communities living around the Lake Chad Basin (LCB), where severe droughts are causing the "shrinking" of the lake and – consequently - catch reduction, and where future climate change will further reduce fish catches and make communities that are dependent on fisheries very vulnerable.

Current coping/adapting strategies include: (i) multiple/alternative sources of income; (ii) mass storage and local preservation of agricultural products as a safety net for lean periods; (iii) migration and mobility in response to annual and inter-annual variation in lake water area, fish distribution and catch; (iv) adoption of different patterns of fishing strategies, including species exploited, location of fishing grounds and types of gear used; (v) fisheries co-management arrangements in place; and (vi) small-scale aquaculture as a viable adaptive strategy to climate change impacts. Additional opportunities are coming from the reservoirs created by damming rivers; the negative effects they cause – such as loss of habitat, biodiversity and fisheries' production – are counterbalanced by an increased population of important commercial species and the creation of suitable locations for cage-culture.

The review calls for a series of policy actions to support the current adaptive strategies, including: conducting an assessment and building scenarios of future potential impacts due to climate change; strengthening the management of LCB at the regional level; fostering co-management regimes and conducting awareness campaigns about climate change; establishing new and/or supporting existing community-based organizations to strengthen resilience and enhance livelihoods of the fishing communities.

- **Install and maintain low-cost fish aggregating devices (FADs) for subsistence fishers.** Pacific Island countries, which rely heavily on capture fisheries, have benefited from an expanded deployment of low-cost inshore FADs (SPC 2008). FADs are also a key feature of the tuna fisheries in the Maldives. An IFAD project in Mauritius has also successfully introduced the use of FADs, whereas financing of FADs is included in an IFAD project in Indonesia. This technique helps reduce costs and days at sea, as fishers do not need to travel widely in search of fish but can instead travel directly to FADs.

- **Improve harvest and post-harvest technology**, including improved fish storage, handling and processing in order to maximize catch value and ensure that fish reach markets in good condition and obtain the best available price. Reduction of waste can help buffer the effects of legislation that limits fishing efforts to prevent overfishing.

Technical measures – Aquaculture

- **Strengthen the capacity of relevant and competent agencies and authorities** to monitor and inform regarding the occurrence of disease in fish farms and harmful algal blooms (HABs), including red tides and ciguatera, which may increase due to climate change – especially in areas known to be vulnerable to eutrophication (De Silva and Soto 2009). For aquaculture, prevention systems must rely on an effective monitoring of water bodies and cultured organisms, in addition to good risk communication strategies and early warning.

- **Promote best management practices (BMPs), biosecurity and climate-proof aquaculture production models.** Disease susceptibility is predicted to increase due to the impact of climate change. The dissemination and voluntary adoption of BMPs and aquaculture

biosecurity measures are a very effective way to reduce the risk of disease, especially when farmers are organized in groups (Secretan et al. 2007). Furthermore, BMPs play a key role in increasing farmers' creditworthiness and access to insurance by making the crop outcome more predictable and safe (Secretan et al., 2007). In designing aquaculture facilities, it is important to consider technical solutions that can minimize mass escapes and create coping mechanisms in the face of more irregular and extreme weather events, especially in disaster-prone areas – for example, upgrading pond dykes with nylon netting (or alternatives such as cheap saris in South Asia) and dyke raising. Extension training material must be revised to take into consideration the effects of climate change, and extension workers must be trained in the subject. Action research should be embraced to identify adaptation best practices, drawing on both scientific and local community knowledge, and with the involvement of key stakeholders in the aquaculture sector.

- **Promote the Aquaculture Stewardship Council (ASC) certification scheme** to certify aquaculture operations and offer financial reward for sustainable production. ASC seeks to use market forces to transform the aquaculture sector by certifying the output of aquaculture operations as sustainable production if it is in compliance with specific standards at the farm level, as well as social and environmental criteria. ASC's strategy is to: (i) create a standard holding entity (the ASC) and consumer label; (ii) develop and implement an outreach and marketing programme that creates demand for ASC products in the marketplace; and (iii) institute a certification process that uses independent third-party entities to certify farms. The initial standards – which are being developed through a multi-stakeholder process – are for 12 aquaculture commodities[16] and have already been established for products such as tilapia and pangasius.

- **Invest in research to develop/identify new commercially viable strains of aquaculture species**, particularly those more tolerant of low water quality, high levels of salinity, and a broader range of temperature and disease. Worldwide, there are already examples of aquaculture operations that have shifted to such species, as an autonomous adaptation measure in response to a changed water environment. However, aquaculture diversification may require educating consumers about new species and products, and may depend on the successful transfer of the technologies to farmers (De Silva and Soto 2009). In the deltaic area of the Mekong, where salinity intrusion episodes are increasingly frequent, farmers are now diversifying their production to more salt-resistant yet commercially viable species. However, this requires further in-depth research and market study to assess the economic and technical efficiency of such conversions, especially with respect to those species that show slower growth or higher production costs. In such situations, a possible adaptation measure could also be that of moving aquaculture operations upstream to avoid salinity intrusion – although this may not always be feasible because of the costs, land/site availability issues and possible environmental problems associated with abandoned ponds. Shrimp farming is a lucrative adaptation solution for saline environments but requires implementation in a regulated, sustainable manner. For example, in Bangladesh, where intensive shrimp farmers bring saline water inside the polders (cultivable lands surrounded by high dykes), the saline water contaminates surrounding lands and stays in the soil, making agriculture almost impossible. In view of such harmful practices,

16. The 12 species are: abalone, clams, mussels, scallops, oysters, cobia, freshwater trout, pangasius, salmon, seriola, shrimp and tilapia (www.ascworldwide.org).

it is important to promote seasonal shrimp/rice farming as the most sustainable option, although some stakeholders also point to the viability of closed clusters, which concentrate intensive shrimp farming in only one place, protecting other areas from salinity ingress.

- **Engage farmers in fish nursing activity as an additional/alternative income option and to facilitate restocking after disasters.** Many small-scale farmers are increasingly shifting from the lengthy full grow-out approach to a shorter model of nursing fry to fingerlings – for example, in Indonesia and Viet Nam. This business model may be more appropriate for small-scale farmers than the low-profit traditional grow-out approach, because: (i) it requires less skills than hatchery; and (ii) a short production cycle involves less risk, lower investment and better cash flow (Peter Edwards, Asian Institute of Technology, pers. comm.). Nursing is therefore a valid alternative income option for some small-scale farmers, especially where there are seasonal ponds, and in water-stressed and disaster-prone areas. However, this requires investment in hatchery management to improve brood stock and seed quality and ensure supply of quality fry.

- **Stock larger fingerlings and post-larvae (PLs), and culture fast-growing species in disaster-prone areas**. Stocking bigger seed and fast-growing species would shorten the farming period, and thus reduce the risk of losing the crop. This strategy was successfully introduced by WorldFish in Bangladesh in the aftermath of Cyclone *Sidr*, which hit the country in November 2007, causing loss of life and livelihoods and destroying many aquaculture facilities. The rehabilitation programme re-established lost livelihoods and built resilience for the battered communities, introducing innovative measures in aquaculture, in addition to various other activities.

- **Promote integrated aquaculture and agriculture systems** – for example, in irrigation systems such as reservoirs and canals. Aquaculture systems such as rice-fish farming and poultry-fish farming have traditionally been common in Asia and South-East Asia. Generally, the fish species farmed in such systems feed low in the trophic chain (phytoplankton, zooplankton and benthos) and external feed is usually not provided. In Bangladesh, two popular

BOX 2

Post-tsunami fisheries and aquaculture rehabilitation project in Aceh Province, Indonesia

In the aftermath of the tsunami that hit Indonesia in December 2004, FAO led the effort to rehabilitate the aquaculture and fisheries in tsunami-affected areas, in cooperation with a wide range of partners. The project supported the sustainable development of Aceh's fisheries and aquaculture sectors through four major components: (i) coordination and planning, (ii) fisheries co-management, (iii) aquaculture, and (iv) post-harvest handling and marketing. Through the planning component, and in coordination with key partners, the project strengthened the government's capacity to coordinate, promote and plan sustainable fisheries and aquaculture practices. Within the co-management component, the focus was on fostering the partnership between local fishers, the community and the state, aimed at sharing responsibility and authority for fishery management. Key elements in the aquaculture component included: the dissemination and promotion of BMPs for shrimp farming and fish cage culture through an efficient extension service; promotion of integrated aquaculture systems such as shrimp-milkfish-seaweed polyculture; and special support to women-headed households dependent on aquaculture. The post-harvest and marketing component looked at: strengthening policy and planning; improving the fish handling and processing methods used by fishermen, traders and processors; improving market access for existing and new products; and developing business skills (FAO 2010g).

strategies allow people to combine agriculture and aquaculture in low-lying flooded or water-logged areas. One is the "Ghers" system, consisting of a square, flat, seasonally flooded land area surrounded on the four sides by canals and dykes. The flat central area is used to grow rice, the canals are used for fish and prawn culture, and the dykes are used for vegetables (WorldFish 2010b). The combination of rice-freshwater prawn and Nile tilapia, followed by a shrimp crop, can be very rewarding; net returns from the rice-integrated aquaculture system are 330-422 per cent higher than from the locally adopted rice monoculture (Joffre et al. 2010). The second strategy pursued in Bangladesh is called Sorjan, which consists of several rows of raised beds upon which farmers plant vegetables or timber/fruit trees, surrounded by a network of canals in which fish can be cultivated. However, the latter can only take place if the water level is well regulated, which is not always the case (WorldFish 2010b). In the Mekong Delta, specifically in areas where the freshwater period exceeds six months, rice-shrimp rotation farming achieves more sustainable results than shrimp monoculture, with a lower percentage of disease outbreaks.

- **Promote the use of flooded and/or salinized land and water bodies** by agriculture-based communities, whose land has been lost, to develop brackish water aquaculture systems, including the cultivation of aquatic plants for consumption and for production of useful products, such as biofuel, plant protein and alcohols. In the longer term, such systems can rehabilitate the soil. Promising results were obtained in salinized areas in the Mekong Delta, where more than 100 species of seaweed were tested (Algen Sustainables 2009), though production may need to be undertaken at very large scale to be commercially viable due to high investment costs and economies of scale. Governments should encourage this shift by providing economic incentives, infrastructure, production facilities (e.g. hatcheries, etc.) and an effective extension service (De Silva and Soto 2009). As mentioned in the section "Impacts by ecosystem/acquatic habit", caution should be exercised to prevent possible collateral damages and local power relation conflicts, such as the conflict in south-western Bangladesh between rice cultivators and shrimp farmers.

- **Promote the development of aquaponics**, which combines hydroponics (soilless gardening) with fish production. After the fish are fed, their waste products are transformed by bacteria into absorbable feed for plants (the ammonium is first converted into nitrites, then nitrates), which in turn clean the water for the fish. Aquaponics offers many advantages compared to hydroponics or traditional farming, as it doesn't require pesticides, conserves water, provides higher revenue for a limited investment and reduces risks by diversifying sources of income. The species and varieties for aquaponic systems must be chosen carefully. The presence of the right bacteria is crucial for the system to work. The plant varieties must be selected depending on the type of aquaponic system. Plants with low to medium nutrition requirements, such as green leafy vegetables, are very suitable. Fish species that tolerate some fluctuations in water quality are preferable, such as pangasius and tilapia. In Bangladesh, the Bangladesh Agriculture University developed a simple aquaponics model using racks and rafts in ponds. Another inspiring example from Bangladesh is the floating gardens, observed in some flooded areas and consisting of a floating bed made of water hyacinths, on which farmers cultivate vegetables without using any other inputs (Salam et al. 2013). Following this model,

trials have also been conducted in Thailand on catfish and tilapia ponds, as well as in rivers, using manure, rice husk ash and composted water weeds as a growing media. The trials have demonstrated promising results, particularly in catfish ponds, where plants benefitted for the very high nitrogen level present in the water (Pantanella 2008).

- **Improve aquaculture development planning and zoning**. While aquaculture in fresh water, brackish water and open marine environments represents an excellent opportunity for sustainable development of vulnerable communities, it must be carefully planned and take into consideration the climate change aspect in order to maximize productivity and prevent detrimental environmental effects. Poor and uncoordinated planning may result in improper site selection, inappropriate species or technology choice, negative environmental impact, lack of long-term considerations, increased risks and likelihood of disease, and mismatched long-term regional objectives. All of these factors could decrease productivity and affect the financial viability of the aquaculture projects and the livelihoods of those who depend on them. Ideally, an improved national aquaculture planning process would have a capacity-building component relying on a solid knowledge-based analysis of suitable sites for aquaculture development. Furthermore, implementing the ecosystem approach requires a focus at different spatial scales and a shift from planning within institutional and administrative boundaries to planning within natural or ecosystem boundaries, such as watershed or water bodies, and across institutional boundaries. This type of approach would require political commitment and inter-sectoral integration through – for example – the adoption of an Integrated Coastal Zone Management framework in collaboration with river basin authorities and hydroelectricity producers.

Specific mitigation measures

Fisheries mitigation measures

Many adaptation measures also provide mitigation benefits – for example, the rehabilitation of wetland and mangrove ecosystems – and as such should be prioritised. Mitigation measures that could be adopted to reduce the impact of fishery operations on climate change include the following (FAO 2008e; SPC 2008; Daw et al. 2009; MAB 2009).

- **Rehabilitate/protect ecosystems, such as mangrove forests, wetlands, seagrass beds and salt marshes** by limiting fishing therein and banning the use of damaging fishing techniques. In addition to their roles as natural barriers to cyclones, and habitat and breeding ground for fish, as well as their role in the absorption of salinity, these vegetated ecosystems also act as a carbon sink, absorbing CO_2 from the atmosphere two to four times faster than mature tropical forests, and storing it in the soil in a quantity three to five times higher (Murray et al. 2011). Improved watershed and land management to reduce run-off of soil, nutrients and chemicals would also protect these ecosystems.

- **Use of more fuel-efficient boats**, made with innovative material and hull shape, and equipped with more efficient engines and storage capacity to reduce the consumption of fuel.

- **Reducing overfishing and excess capacity**, including adjusting fleet composition, by supporting small-scale fisheries and discouraging industrial fisheries, especially in countries where fish stocks have been fully or partially overexploited. Such measures would also reduce fuel use as a result of the reduction in the number of vessels at sea and increase in the catch per unit effort (CPUE).

- **Introduce new fishing gear** to achieve higher CPUE and by-catch reduction, with preference given to more selective and less damaging passive gear, such as well-designed traps/gillnets.

- **Install and maintain low-cost inshore FADs** for subsistence fishers (see also the section Technical measures - Fisheries). Appropriate agreements should be established between fishers and fisheries' managers on installation, use and maintenance of FADs. By providing specific points where fishers know they would be able to find fish consistently, significant reductions in fuel use also can be achieved.

Aquaculture mitigation measures

Aquaculture mitigation measures include interventions that aim at reducing the carbon footprint of production by using certain species, farming methods and activities that actually sequester carbon (Bunting and Pretty 2007; De Silva and Soto 2009; MAB 2009; Davies 2010), such as the following:

- **Culture of low-trophic-level species**, including herbivorous or planktivorous species, such as Indian major carps (catla, rohu, mrigal), Chinese carps (grass carp, silver carp, bighead carp, common carp), tilapia, and sea cucumber (scavenger echinoderms feeding on debris). These species do not require fish oil or fish meal and have a low carbon footprint – for example, only 1.67 kilograms of CO_2 are released per 1 kilogram of tilapia produced. Cultured molluscs and bivalves, such as clams, mussels and oysters, can remove substantial amounts of carbon from coastal oceans and also do not need fish oil or fish meal. The carbon footprint for mussels and oysters is 0.01 kilogram of CO_2 per 1 kilogram of production; moreover, it was estimated that mussels could assimilate and remove up to 80 metric tons of carbon per hectare per year. However, the role of shellfish as a carbon sink is the subject of ongoing scientific debate, in particular with respect to the fate and sequestration of the removed carbon.

Blue carbon

Defined as *"the carbon stored, sequestered, or released from coastal ecosystems of tidal marshes, mangroves, and seagrass meadows"* (Herr et al. 2012, in Murray et al. 2012), blue carbon is yet to be integrated in the UNFCCC process. First discussed in June 2011 within the subsidiary Body for Scientific and Technological Advice (SBSTA) on the request of Papua New Guinea, the issue was considered "not mature enough" and referred for consideration under the Reducing Emissions from Deforestation and Forest Degradation Programme (REDD+).

As of today, blue carbon has still not emerged as a specific, separate agenda in the negotiations. However, at its thirty-seventh session, the SBSTA requested the secretariat to organize a workshop at the thirty-ninth session to address technical and scientific aspects of ecosystems with high-carbon reservoirs that are not covered by any other agenda of the Convention (Murray et al. 2012).

- **Culture of aquatic plants**, including seaweed (for example, the genera *Eucheuma* and *Kappaphycus*), which can contribute to carbon sequestration. Having a relatively short farming period – about three months per crop – and yields of over 2,500 metric tons per hectare, the carbon extractive capacity of seaweed far exceeds that of any other agricultural activity for a comparable area. Seaweed farming is common along the coasts of the Philippines, Indonesia, China and other Asian countries, as well as in Tanzania, Madagascar and Mozambique.

- **Integrated Multi-Trophic Aquaculture (IMTA)** was defined earlier as the cultivation of fed species together with extractive species that use the organic and inorganic wastes from aquaculture for their growth. Thus, integrated aquaculture may increase bio-mitigation and absorb excess nutrition in the environment, providing important environmental waste processing services

(Angel and Freeman 2009; Barrington et al. 2009; Troell 2009). IMTA is also a good example of the ecosystem approach. There are ongoing discussions on whether a nutrient-trading credit scheme focusing on nitrogen, carbon and phosphorus – similar to the carbon credit scheme for forests – could actually be established to take advantage of the IMTA extractive capacity. Low-intensity traditional multi-trophic aquaculture also includes: freshwater polyculture systems, which are very common in Asia – particularly South-East Asia – with carp as major farmed species that occupy multiple niches within the same pond; and integrated agriculture-aquaculture systems – for example, rice-fish and rice-shrimp culture in Viet Nam.

- **Energy efficiency.** Support viable energy-efficient technologies and facilitate the replacement of low-efficiency equipment and technologies. Fossil fuel consumption and, consequently, carbon emissions could be reduced significantly through substitution and improved energy efficiency – for example, by introducing gravity-fed ponds, investing in on-site micro-generation of power, electricity or heat from renewable sources, sourcing inputs (feed, seed, fertilizer, etc.) locally, and using energy-efficient lighting, equipment and vehicles, as well as machinery run on renewable bio-fuels (Bunting and Pretty 2007). Energy-efficient aquaculture initiatives in Tunisia are currently piloting the use of solar energy to run farms (Luigi Negroni, ALVEO S.c.r.l., pers. comm.). In Thailand, there are ongoing activities supported by GIZ to promote energy and eco-efficiency in shrimp farming, which involves the replacement of low-efficiency motors and the adoption of good energy management practices. Preliminary results show that there is potential to improve energy efficiency up to 30-40 per cent, which would have a considerable cost-reduction dividend.

- **Identify opportunities to access carbon finance.** Financial mechanisms linked to ecosystem-based mitigation include the sale of carbon credits, referred to as Reducing Emissions from Deforestation and Forest Degradation (REDD). REDD is an international financing mechanism, the purpose of which is to create a financial value for carbon stored in forests and generate substantial revenues for rural communities that engage in forest conservation (TEEB 2010). REDD+ is the extension of REDD and focuses on the role of conservation, sustainable management of forests and enhancement of forest carbon stocks. The project "Poverty Alleviation, Mangrove Conservation and Climate Change: Carbon offsets as payments for mangrove ecosystem services in Solomon Islands", implemented by WorldFish, has been exploring options for the registration of small areas of mangroves on international voluntary carbon credit markets. Payments for mangrove ecosystem services through mechanisms like REDD+ could give rural communities a direct economic stake in the protection and sustainable use of mangrove forests, while enabling them to reduce their vulnerability under certain conditions. A similar project has been established in Trinidad by the Biocarbon Fund. Carbon is also stored, or sequestered, and sometimes released from coastal ecosystems such as tidal marshes and seagrass beds (Murray et al. 2012).

Conclusions

Climate change is a growing global concern that has implications not only for every aspect of human life but for all living organisms. Climate changes already being witnessed include warming of the atmosphere and the oceans, changes in rainfall patterns, and increased frequency of extreme weather events. The oceans are also becoming increasingly saline and acid, affecting the physiology and behaviour of many aquatic species, and altering productivity, habitats and migration patterns. Sea level rise, combined with stronger storms, severely threatens coastal communities and ecosystems. The world's coral reefs are under threat of destruction over the coming century. Some inland lakes and water bodies are drying up, while in other areas destructive flooding is becoming a regular occurrence. In many instances, it is the poorest communities in the poorest countries that are most vulnerable to these changes.

IFAD has long recognized the necessity, urgency and feasibility of addressing climate change and associated impacts through its country-level operations. Concrete steps in this regard have been taken with the formulation of the Climate Change Strategy in 2010, the Environment and Natural Resource Management Policy in 2011, and the launch of the ASAP in 2012. These latest guidelines take these efforts further by offering a range of multiple-benefit options and best practices for integrating climate change adaptation and mitigation into IFAD interventions in the fisheries and aquaculture sectors. The proposed measures have been identified by means of a detailed study of relevant literature on climate change, the fisheries and aquaculture sectors, and relevant activities of other international organisations. In line with the ASAP's first principle of scaling up tried and trusted approaches, most of the proposed measures are not new concepts or ideas but have been proven time and again in practice to provide a range of benefits to and increase the resilience of small-scale fishers and fish farmers, as well as the ecosystems on which they rely.

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International Fund for Agricultural Developmen
Via Paolo di Dono, 44 - 00142 Rome, Italy
Tel: +39 06 54591 - Fax: +39 06 5043463
E-mail: ifad@ifad.org
www.ifad.org
www.ruralpovertyportal.org
ifad-un.blogspot.com
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