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CLIMATE CHANGE ADAPTATION IN FISHERIES AND AQUACULTURE

Compilation of initial examples

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Compilation of initial examples

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ABSTRACT

This circular contains a selection of current and recent climate change adaptation activities and measures in the fisheries and aquaculture sector. These examples provide an overview of the types of adaptation activities and programmes rather than a comprehensive review of adaptation activities addressing fisheries and/or aquaculture. Some of the highlighted activities are specifically targeted at addressing climate change impacts in fisheries or aquaculture, and others address related areas (e.g. coastal management and capacity building activities) that also have benefits for fisheries or aquaculture. In addition to specific examples, the publication provides an overview of climate change impacts on global fisheries and aquaculture and potential adaptation and mitigation strategies. Descriptions for 26 current or recent activities and programmes focused specifically on or benefiting fisheries and/or aquaculture (and other sectors if relevant), primarily in developing countries, highlight the diversity of potential adaptation actions at the local to regional scales. This circular is intended to provide a starting point for planners, policy-makers and practitioners who are involved in sectors related to fisheries and aquaculture around the globe.

CONTENTS

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ABBREVIATIONS AND ACRONYMS

CCAI	Climate Change and Adaptation Initiative
EEZ	exclusive economic zone
ENSO	El Niño Southern Oscillation
GEF	Global Environment Facility
GHG	greenhouse gas
LME	large marine ecosystem
LSA	living shorelines approach
MPA	marine protected area
NAPA	national adaptation programme of action
NGO	non-governmental organization
PACC	Pacific Adaptation to Climate Change

1. INTRODUCTION

Climate change impacts on aquatic and marine ecosystems and associated livelihoods are growing, and the purpose of this circular is to provide a brief overview of potential impacts and details of ongoing and completed adaptation activities. Sharing examples will aid planning and development of adaptation in fisheries and aquaculture, and this compilation is intended to provide a starting point for planners, policy-makers and practitioners who are involved in sectors related to fisheries and aquaculture around the globe. This introduction provides an overview of climate change impacts on fisheries and aquaculture. The following chapter reviews potential mitigation and adaptation options for fisheries and aquaculture at various scales. This is followed by an overview of selected adaptation activities at various scales to demonstrate the types of activities under way or completed around the world, primarily in developing countries. This is not a comprehensive review of adaptation actions – there are other resources that provide more in-depth reviews of adaptation. However, this circular aims to provide examples of the kinds of adaptation activities specifically addressing fisheries and/or aquaculture.

FISH, FOOD SECURITY AND LIVELIHOODS

Fisheries and aquaculture are important contributors to food supply, food security and livelihoods at both the local and global levels. Aquatic foods have high nutritional value and are one of the most widely traded and exported food products for many developing countries. They account for at least 15 percent of animal protein for more than 4 billion people, most in developing countries (FAO, 2012). For some countries and communities, this number is much higher and accounts for up to 50 percent of animal protein in some small island States. The sector employs 43.5 million people, many of these in developing countries, and the processing, marketing, distribution and supply industries associated with fishing and aquaculture employ up to another 200 million people (Cochrane *et al*., 2009).

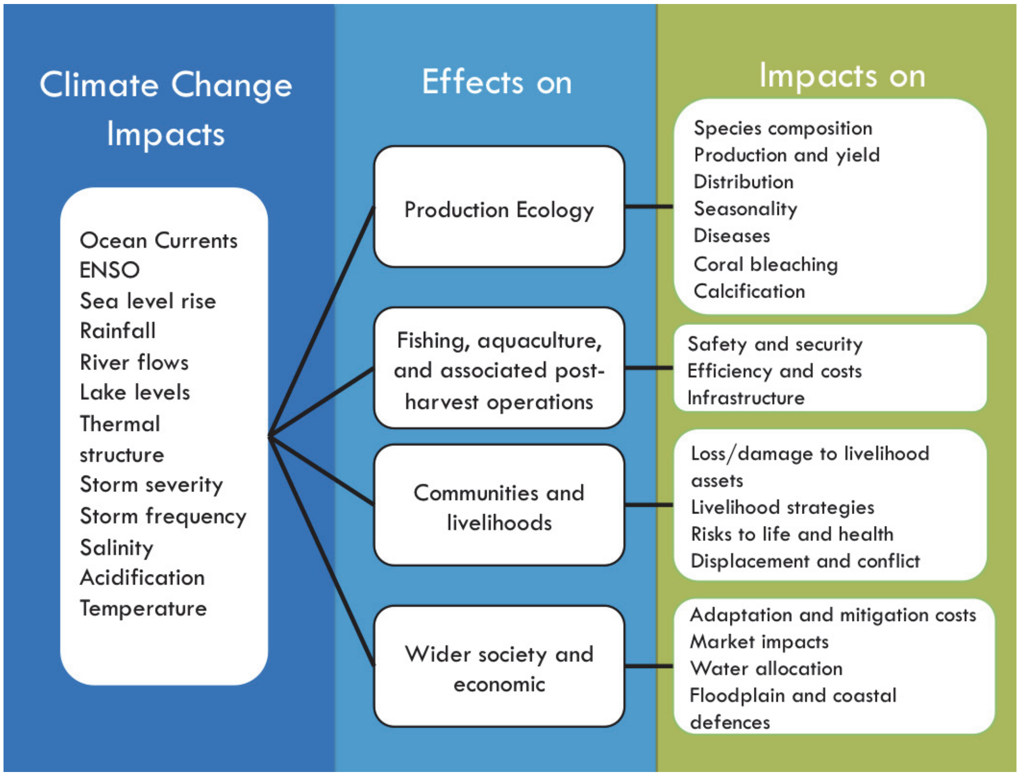
CLIMATE CHANGE IMPACTS

Climate change will affect fisheries and aquaculture via acidification, changes in sea temperatures and circulation patterns, the frequency and severity of extreme events, and sea-level rise and associated ecological changes. Both direct and indirect impacts (Figure 1) include impacts on targeted populations' range and productivity, habitats and food webs as well as impacts on fishery and aquaculture costs and productivity and fishing community livelihoods and safety (Daw *et al*., 2009; Badjeck *et al*., 2010).

Fish feeding, migration and breeding behaviour will be directly affected and changes in their physical environments will indirectly affect growth, mortality and reproduction (Brander, 2010). In addition, the species and ecosystems that fish rely on will be affected with uncertain impacts on fishery catch potential. Fish species will probably shift their distributions as warmer-water species and colder-water species are both expected to move polewards (Beare *et al*., 2004a, 2004b). Sea-level rise, storm surges and flooding can have negative and positive impacts on fish productivity, while human impacts to these will be negative. Coastal areas with coral reefs are particularly vulnerable to changes in temperature and acidity, with serious food security concerns for countries that rely on these resources for food and coastal protection. Inland aquaculture may provide an important animal protein source in the future. However, it will be affected by changing temperatures, water scarcity and salinization of coastal waters. Tropical and subtropical areas will experience more reduced ecosystem productivity than temperate and polar ecosystems, with impacts on fishery catch potential in the exclusive economic zones (EEZs) of those countries (Figure 2).

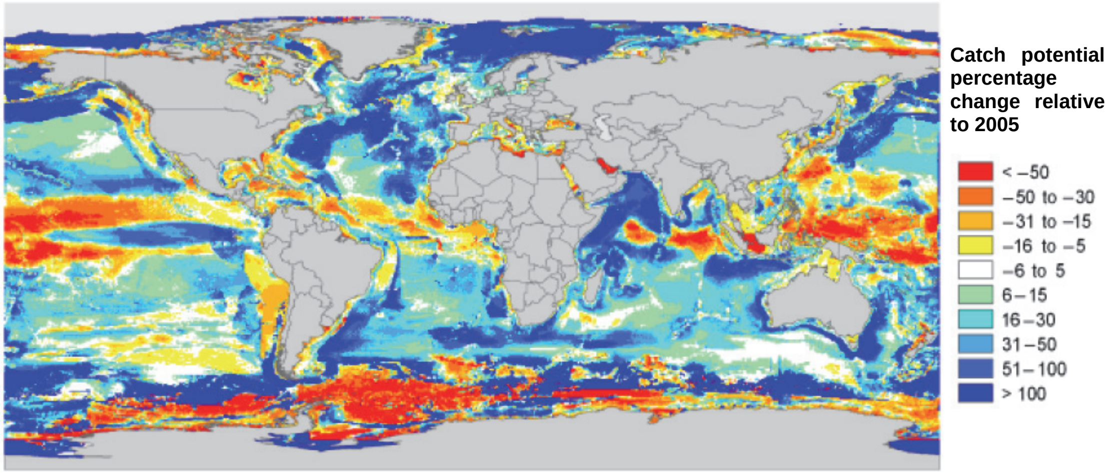
Some new opportunities and environments may be created with sea-level rise. New habitats may open up as polar ice melts (Easterling *et al*., 2007), and flooded coastal agricultural land may provide new areas for mangroves and aquaculture opportunities. New fisheries may become available as fish populations shift geographic distributions, and some ocean areas may experience increased productivity, which could increase the catch potential of some fisheries (Figure 2). Inland fishery productivity will also be affected by increased water temperatures, variability in water availability, eutrophication, stratification, and toxicity of pollutants. In addition, reduced habitat quality and availability of dissolved oxygen will affect productivity and the nutritional value of aquatic products.

FIGURE 1
Climate change impact pathways in fisheries and aquaculture



Source: From Badjeck *et al*. (2010).

FIGURE 2
Changes in catch potential in 2055 with a doubling of greenhouse gases in the atmosphere by 2100



Notes: Model predictions of catch potentials indicate that tropical countries are likely to experience large decreases in catch potential within their exclusive economic zones in 45 years, while some countries (e.g. Norway and Iceland) will see an increase. This is due to fish moving away from warmer waters and ice melt opening up new areas. Temperate countries do not see as extreme a decline in catch potential as, although species are moving away, new species are moving into those areas.
Source: Cheung *et al.* (2010).

GREENHOUSE GAS CONTRIBUTIONS

Fisheries and aquaculture contribute global greenhouse gas emissions (GHGs) during fish capture or growth, processing, transportation and storage. However, there are many different kinds of fisheries with many different fuel requirements. These range from small low-power single engines to larger vessels to fish factory ships. One of the primary differences between fuel use in developed- and developing-country fisheries is fuel efficiency, meaning the proportion of revenue spent on fuel, with developing countries spending up to 50 percent of total catch revenue on fuel (Daw *et al*., 2009). Fisheries management contributes to some of this inefficiency with policies that create a "race to fish". This refers to policies that inadvertently create incentives for more powerful engines to catch more fish, which can quickly lead to overfishing. Vessels then have to travel farther or to deeper waters and spend more to catch the same amount of fish as they have in the past.

In addition to fuel emissions from fishing vessels, product transportation is the main source of emissions in the fisheries sector. Products are typically transported via freight on ships or plane, especially if they are moving from developing countries to developed-country markets. High-value species (e.g. tuna transported to Japan) are more likely to be shipped via airfreight, meaning their transport emissions are quite high.

STATUS OF THE WORLD'S FISHERIES

Although there is variation in the status of specific fisheries and populations, there is agreement that worldwide marine and freshwater species and habitats are at risk from human pressures, including overexploitation, pollution and habitat alteration (Hilborn *et al*., 2003; Allan *et al*., 2005; FAO, 2005). Destructive fishing practices, such as heavy bottom trawling gear, explosives and poisons, damage marine environments, while introduced species increase competition for native species. These destructive practices can lead to incidental losses for species and habitats, which in turn can lead to impacts on bioerosion (Bellwood, Hoey and Choat, 2003), predation (Myers *et al*., 2007), food for seabirds (Jahncke, Checkley and Hunt, 2004), and nutrient transport (Allan *et al*., 2005). In addition, fishing can inadvertently create genetic selection pressure on stocks (Hutchings, 2000), with consequences on growth rates and maturation age. Overcapacity and over investment in many industrialized fisheries (Hilborn *et al*., 2003) can lead to overfishing. Overfishing not only has impacts on fish populations, reducing stock resilience and potentially leading to stock collapse, but it also reduces the profitability and economic efficiency of fisheries (Hsieh *et al*., 2006).

On top of these pressures sit climate change impacts on fisheries and aquaculture. As discussed above, climate change impacts will vary but add an additional stressor to many already stressed systems. Although the pressures on marine and freshwater environments are considerable, protected areas (e.g. marine protected areas (MPAs), controls on land use and development, and ecosystem approaches to fishery management can reduce these pressures on species and habitats.

2. APPROACHES AND STRATEGIES

Approaching climate change typically involves actions that either reduce the amount of carbon dioxide and other greenhouse gases (GHGs) in the atmosphere or prepare society for the impacts associated with climate change via adaptation. How effective mitigation and adaptation activities are depend on the temporal and spatial scale of impacts and action goals, and the context of the activity. Not every activity will be applicable in every place and time, so success requires consideration of how activities are tailored to the local context and how they are implemented.

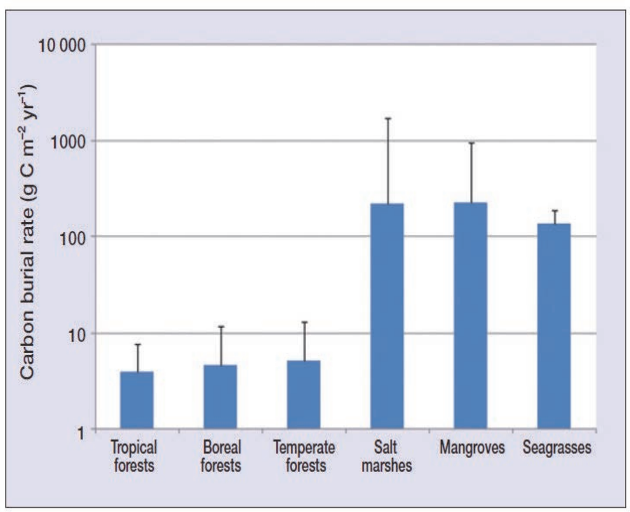
MITIGATION

Although fisheries and aquaculture do not emit large volumes of GHGs when compared with other industries, industry GHG emissions could be reduced. Improving fuel efficiency by switching to more efficient gear types or vessels, switching to sails or changing fishing practices would reduce emissions from fishing activities. This would also reduce fuel costs, although switching to more efficient vessels and/or gear may only reduce fuel use by 20 percent (FAO, 2007). Product transport is where more sectoral emissions come from, and emission reductions are possible. Using bulk sea freight rather than air freight or non-bulk sea freight, or increasing consumption closer to the source (reducing travel distance) would reduce fuel use. Even if international fishing continues to increase, including fish from developing countries travelling to developed country markets, these changes in product transportation can ensure that fishery contributions to GHGs do not increase at the same rate (Daw *et al*., 2009).

In addition to emissions reductions, there is the potential to store carbon in some coastal ecosystems (Box 1). Carbon storage, especially in these coastal ecosystems (mangroves, seagrass beds, salt marshes) has the potential to remove and store atmospheric carbon at much greater rates than terrestrial ecosystems (McLeod *et al*., 2011). Some of these systems, such as mangroves or salt marshes, also provide additional benefits to communities through flood control, buffering coastlines from storms, water quality, and provide habitat for juvenile fish.

Box 1
Blue Carbon

"Blue carbon" refers to carbon that is sequestered in coastal vegetation systems (e.g. mangrove forests, seagrass beds, salt marshes). These systems are better at removing and keeping carbon from the atmosphere than their terrestrial counterparts (e.g. rainforests) due to their high productivity and how well they trap sediments (and therefore carbon). These areas may even increase their potential as carbon sinks over time, unlike many terrestrial soils. The exact amount of carbon and how long it remains in these systems is uncertain, although this is currently being researched. Unfortunately these areas are being lost at a critical rate all over the globe due to rapid coastal development and mismanagement of coastal areas. (*from McLeod et al. 2011)*



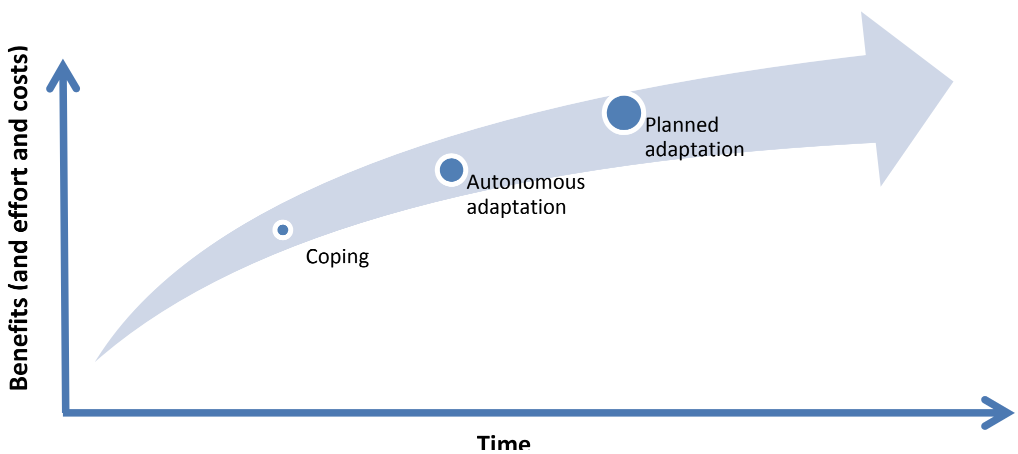
The amount of estimated carbon stored in major terrestrial forest systems and areas of "blue carbon" storage. Although there is uncertainty in the total amounts, "blue carbon" in salt marshes, mangroves and seagrass has much great storage potential than forests. Source: McLeod et al. 2011

ADAPTATION

Adaptation can be planned or autonomous (i.e. spontaneous reaction to environmental change or planned action based on climate-induced changes). **Autonomous adaptation** in fisheries may be changing the timing or locations of fishing as species arrive earlier/later or shift to new areas. **Planned adaptation** in fisheries may be research funding for finding species resistant to salinity and temperature fluctuations for aquaculture. A "**no regrets**" approach relies on building general resilience without a heavy reliance on specific climate impact projections, which is useful in areas with high impact uncertainty, which include many equatorial areas and developing countries without long-term historical climate data sets.

Adaptation in fisheries and aquaculture can include a variety of policy and governance actions, specific technical support or community capacity building activities that address multiple sectors, not just capture fisheries or aquaculture farmers. Adaptation activities may be addressing short- or long-term impacts, although coping can sometimes be confused with adaptation. **Coping** is a short-term response to an impact (e.g. responding to extreme storm impacts for a single season), and can result in undermining adaptation activities as the benefit time scale for coping activities is very short term (Figure 3).

FIGURE 3
Time scale and amount of benefits and costs required for various types of adaptation



Notes: Coping is focused on short-term benefits, often one season and usually with lower costs and requiring less effort than other adaptation. Planned adaptation typically requires the most effort and cost, but is focused on a much longer time scale (e.g. generations).

This section highlights adaptation actions with specific benefits to fisheries and aquaculture. Adaptation may address issues not specifically focused on fisheries or aquaculture, such as mangrove restoration for the primary purpose of buffering coastal communities from storm surge and coastal erosion. Although the primary purpose is not related to livelihoods, fisheries, biodiversity or water quality, ecosystem services from mangrove restoration will positively affect all of these. Mangroves provide important habitat for aquatic species, contributing to biodiversity and increased food product availability for household consumption and resources for local markets, as well as providing water filtration services. As with any development action, there is a potential for maladaptation leading to new or reinforcing inequalities if vulnerable landless groups used restoration areas, or resource extraction is not managed well and newly planted areas are overutilized, preventing full restoration and therefore full benefits.

For capture fisheries, adaptation involves adjusting fishing pressure to sustainable levels. Setting catch limits based on changes in recruitment, growth, survival and reproductive success can be done via adaptive management, monitoring and precautionary principles. This may also require changes in vessel or gear types if new fisheries opportunities become available. These may come with high costs (for new vessels and/or gear), but these changes may support the continuation of fishing communities. However, if these gear types are more efficient, this could lead to travelling farther (and spending more on fuel) or overcapacity may reduce fishery profitability. Other issues could include transboundary issues if populations move into other territorial waters. This will require cooperation and discussion between neighbouring countries and regions, including developing or modifying fishing agreements and collaborative management.

Although adaptation is context-specific, there are a number of adaptation activities that can be applied in most fisheries and aquaculture contexts. These include:

- **Reduce external stressors on natural systems.** Reduce land-based sources of pollution (e.g. agricultural and urban runoff) and destructive fishing practices (e.g. fishing with explosives and poisons).
- **Identify and protect valuable areas.** For example, deep pools in river systems, such as the Mekong River, provide sanctuary for fish during dry seasons, are important local fisheries themselves, and play an important role in upstream and downstream fisheries as they are also often spawning areas (MRC, 2005). These areas will be affected by both climate change impacts on the hydrologic cycle as well as upstream and downstream activities (e.g. dam building leading to siltation, or basin development leading to pollution runoff).
- **Investments in safer harbours and landings** and measures to improve safety at sea due to increased storm severity as well as **improved early warning and forecasting systems** for severe weather events. Adequate onshore storage facilities for boats and gear can prevent loss or damage from storms and extreme events.
- **Promote disaster risk management** in general (including disaster preparedness) and protective infrastructure (e.g. “hard” options such as seawalls and flood reservoirs, or “soft” options such as buffer zones via afforestation or reforestation of mangroves).
- **Mainstreaming**. Integrate fisheries and aquaculture sectors fully into climate change adaptation and food security policies at the national level (draft and enact where non-existent) to ensure incorporation into broader development planning. This will also involve trade-offs, compromises, and planning with other industries affecting fisheries and aquaculture (e.g. irrigation infrastructure, dams, and urban and agricultural runoff).
- **Capacity building**. Civil society, non-governmental organizations (NGOs), and government organizations need to be included in climate change planning, not just technically focused departments such as fisheries/interior agencies or science and meteorology departments. Partnerships between private, public, civil society and NGO sectors are vital for holistic climate change adaptation planning.
- **Financial mechanisms**. In addition to building capacity (above), the potential of new financial mechanisms as tools needs to be investigated. This can include insurance at national and international levels and other innovative instruments to create effective incentives and disincentives. These approaches are new and overall untested and there is an opportunity to test new approaches in the public sector, as the private sector will be controlled and integrated to some extent by the public sector via market mechanisms.
- **Recognition of opportunities.** New opportunities may become available, for example, the promotion of aquaculture-based livelihoods where delta areas have been inundated and agriculture is no longer possible.
- **Learning from the past**. What have people done and how have decision-making processes worked under highly variable and extreme events? How have people addressed a similar issue in the past? Can and how that be applied in a different context?
- **Identification of useful information** and where to obtain it (e.g. future fish production projections, decision-making tools under uncertainty).
- **Link local, national and regional policies and programmes.** Links will be required across both spatial and sectoral frameworks, plans and programmes. Climate change will affect poverty, food security, infrastructure and other sectors within and between countries. In addition, climate change

will probably cause spatial displacement of both aquatic resources and people, requiring strong regional structures to address these changes and their implications. At the international level, climate change will affect international trade, competition and policies at the same time as current development.

- **Spatial planning.** This comprises marine and terrestrial zoning for siting of aquaculture facilities (subtidal and terrestrial systems) and mangrove areas to balance aquaculture needs with terrestrial development and shoreline protection with rising sea level. In addition, the need to think long term about requirements for current coastal activities to shift landwards as shorelines retreat over time.
- **Monitoring**. This information will feed into adaptive management as well as contribute to understanding what impacts are occurring. As climate change will introduce changes outside the scope of experience for many people and species, it is important to collect information on what and when these changes are. As more is learned and understanding becomes more refined, people will be better able to make decisions that result in benefits for both the aquatic environment and the people who depend on it.
- **Policy and management considerations.** As some aquatic populations shift their range, probably polewards for many species, the fishery will follow. This may induce socio-economic changes as people migrate to follow populations, or as old fisheries become less profitable and new ones become available. Policies that are flexible and support easier entry and exit into new fisheries and out of those that are declining can ease both socio-economic impacts from changing fisheries and also prevent overfishing of the edges of stocks as they move away (Pinsky and Fogarty, 2012). Standard practice adoption for improved fisheries and aquaculture management (e.g. the FAO Code of Conduct for Responsible Fisheries, precautionary principles, adaptive and ecosystem management) and integrated coastal management for coastal and nearshore fisheries can improve resilience and increase system adaptability. Overall, capacity reductions and the removal of incentives for overfishing are vital to ensuring sustainable fisheries.
- **Safety at sea.** One potential to increase safety at sea could be to invest in larger vessels that are safer than smaller vessels in rough conditions. If these were capable of accessing seasonal pelagic species and small enough to also fish for demersal species in other seasons, safety during harvesting would be increased and year-round harvesting options made available. However, to prevent overcapacity, these vessels would have to replace smaller fishing vessels rather than add to the fleet.
- **Ghost fishing.** As storm severity increases, it is likely that more gear, such as lobster traps, will be lost. Such lost gear can cause mortality and habitat damage. However, there are some measures that can reduce their impacts. In addition to gear retrieval programmes, certain gear could be designed to minimize impacts if lost. For example, traps could have biodegradable escape panels (e.g. after a week) so trapped animals would be able to escape.
- **International trade.** Some trade measures and barriers such as tariff escalation, sanitary and phytosanitary measures and rules of origin requirements in export markets can work against increasing economic diversification of production and exports of high-value-added processed products. Other barriers include fishery subsidies in developed countries constraining the competitive stance of developing countries, and rapid trade liberalization in developing countries. This liberalization has limited the policy space available for a wide range of policies that could enhance supply-side fishery capacities. To address these obstacles, developing countries can support the elimination of distorting fisheries subsidies in developed countries and reduced tariff escalation and other trade barriers (ITCSD, 2009). At the national level, policies that discourage economically unviable fisheries can lead to economic diversification, leading to increased economic resilience. Other ways to create value-added fishery products include ecolabelling. Although fish products in developing countries may be travelling far to developed country markets, emissions from capture and processing in developing countries may be lower, and if product is shipped in bulk or within the region and it could meet ecolabelling criteria.

In addition to these more general adaptation measures, Table 1 lists adaptations to specific impacts such as reduced yields and profitability and increased risk.

TABLE 1
Potential adaptation measures in fisheries and aquaculture

Impact	**Adaptation measure**
Reduced yields	Access higher-value markets Increase fishing effort (risks overexploitation) Shift aquaculture to non-carnivorous commodities Selective breeding for increased resilience in aquaculture Moving/planning siting of cage aquaculture facilities Change aquaculture feed management: fishmeal and fish oil replacement; find more appropriate feeds Migration as fish distribution changes (risks overexploitation) Research and investments into predicting where fish populations will move to (risks overexploitation) Improve water-use efficiency and sharing efficacy (e.g. with rice paddy irrigators) in aquaculture Aquaculture infrastructure investments (e.g. nylon netting and raised dykes in flood-prone pond systems)
Increased yield variability	Diversify livelihood portfolio (e.g. algae cultivation for biofuels or engage in non-fishery economic activity such as ecotourism) Precautionary management Ecosystem approach to fisheries/aquaculture and adaptive management Shift to culture-based fisheries Shift to propagated seed for previously wild-caught seed stocks (higher cost)
Reduced profitability	Diversify livelihoods, markets and/or products Exit fishery Reduce costs to increase efficiency Change aquaculture feed management Shift to culture-based fisheries
Increased risk	Adjustments in insurance markets Insurance underwriting Weather warning systems Improved communication networks Workshops to teach data gathering and interpretation Monitoring of harmful algal blooms where molluscs farmed Improved vessel stability/safety Compensation for impacts
Increased vulnerability for those living near rivers and coasts	Hard defences (e.g. sea walls) (risks affecting local ecosystem processes and/or local livelihoods) Soft defences (e.g. wetland rehabilitation or managed retreat) (risks affecting local livelihoods) Early warning systems and education Rehabilitation and disaster response Infrastructure provision (e.g. harbour and landing site protection, building aquaculture facilities to withstand increased storm damage) Post-disaster recovery Encourage native aquaculture species to reduce impacts if fish escape damaged facility

Sources: Adapted from Daw *et al*. (2009) and De Silva and Soto (2009).

Coastal protection and the living shorelines approach

The living shorelines approach (LSA) uses natural vegetation, sand and some rock to protect shorelines and habitat. The LSA uses structural and organic materials to protect shorelines. These include wetland plants, oyster reefs, sand fill, some stone, fibre "logs" and submerged aquatic vegetation (Currin, Chappell and Deaton, 2010). This approach has many benefits compared with "hard" coastal protection approaches (e.g. seawalls, bulkheads and riprap):

- They are able to maintain sand movement and shoreline dynamics.
- They are able to rebuild eroded or maintain shorelines through trapped sand.
- They are able to reduce wave energy and absorb storm surge and flood waters.
- They are able to provide important habitats and maintain coastal ecosystem function.
- They are cheaper than many "hard" alternatives.
- They are able to filter nutrients and pollutants from water.
- Carbon sequestration (aquatic vegetation and wetlands absorb and store carbon dioxide).

Although the LSA has many benefits, there are some contexts where it may not be the most appropriate choice, and it may need to be used in conjunction with structural "hard" approaches. Drawbacks of the LSA include:

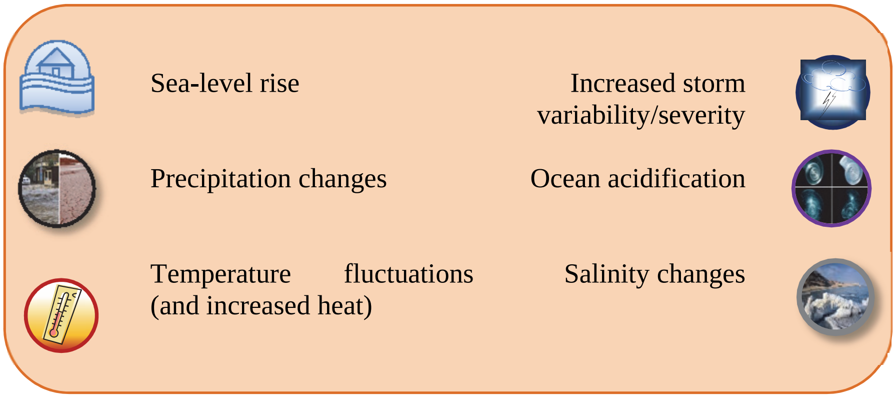
- It is less effective in areas where most of the shoreline is already hardened.
- It is less appropriate in high-wave energy environments.
- Being a new approach means it can be difficult to find experts for planning and installation.
- Limited information available on effectiveness for different types of shorelines and different coastal energy regimes and storm conditions

Coastal areas with vital infrastructure need to protect access to livelihoods, health care and education. However, "hard" approaches such as sea walls and riprap can have many negative ecological impacts and may even increase erosion elsewhere. Trade-offs between shoreline protection approaches may not be easy to make, and may involve costly alternatives (e.g. moving a road some distance inland or increasing erosion farther along the coastline).

3. EXAMPLES OF ADAPTATION ACTIVITY

The following section lists specific examples of adaptation actions and strategies such as those found in Table 1. These are activities that have been implemented or are in the process of implementation, and they are organized by large marine ecosystem (LME). This list is not exhaustive but a sample of the types of activities currently addressing climate change impacts in fisheries. Many of the projects are multifaceted so the activities below are a selection of project components related to fisheries and aquaculture. Further information and sources for these examples may be found in the Appendix.

Each of the following activities and projects addresses climate change impact pathways, and the pathways are indicated by the following symbols:



BAY OF BENGAL COUNTRIES

Aquaculture

Bangladesh

In coastal areas, one project administered by Caritas in Bangladesh focused on enhancing the coping and adaptive capacities of coastal communities (Caritas, undated). Selected project activities included:

- **Pond excavation and land shaping**. A pond was built in the middle of fallow coastal land. This was then used for irrigation and fish farming while the surrounding land was raised with the excavated material and used for growing vegetables. To enhance local management capacity and ownership, a village committee manages the pond and surrounding land. This system also provides short-term employment (during construction) and long-term provision of foodstuff for lean times.
- **Introduction of locally available fish species.** Mullet and tilapia were introduced, including providing fingerlings for pond stocking. The project also provided training and technology support for farmers raising these fish. This component will reduce nutritional deficiencies, provide additional income and food sources and reduce vulnerability to lean periods and climate variability.
- **Individual loan support**. Loans were provided to support individuals creating employment/self employment with a focus on applications for crab fattening, fish processing, kitchen gardening, apiculture, mangrove plant nurseries and integrated fish farming. Other learning and awareness activities (e.g. climate change and environmental health) that were part of this project also contributed to increasing household and community adaptive capacity.

Another project in Bangladesh focused on creating opportunities for flood-friendly fisheries in coastal areas that are flooded for up to 4–5 months of the year. The project's goal was to increase knowledge about various fishery management techniques and to mitigate losses in flood-prone areas (Disaster Mitigation Programme ITDG-Bangladesh, undated).

- **Small-scale homestead pens.** Bamboo pens with trap doors were built next to homes. These were stocked with some fish, and then when seasonal floods came the fish were not washed away, and new fish were introduced via floodwater. Households ate the larger fish, and the smaller fish washed in restocked the pens.
- **Trap pond management.** On seasonally flooded land, bushes and branches were used to build traps for flood periods and traditional bamboo traps were modified to reduce catch per unit effort. The traps also provide habitat for young native species. As this cultivated land is unavailable for several months of the year, this increased catch provides additional food and income sources.

Plate 1
Fencing a pond for flood management in Bangladesh.
COURTESY OF ITDG-B.

Nepal

An inland project created livelihoods for communities displaced by dam building (Gurung *et al*. 2010). Although this project took place before climate change had moved to the forefront of development and environmental concerns, its context is relevant for other communities that may be displaced by dam building activity. With growing populations and climate change impacts on water, dams are one method to provide energy and water reservoirs, although with other social and environmental costs.

- **Cage aquaculture.** Cage aquaculture using plankton-feeding fish (e.g. bighead and silver carp) was introduced in the reservoir. There was no need for external inputs as the fish feed on naturally occurring plankton. The government initially supported individual farmers with fingerlings, and now escapees have mixed with naturally occurring species (the reservoir is 30 years old) to create a capture fishery as well. There currently are 60 farmers operating in the reservoir, with production leaping from zero in 1988–89 to 165 tonnes in 2005–06. Almost 81 percent of displaced families are involved in cage or capture fisheries. One aspect that may have been responsible for the easy transition from farming to aquaculture was that fishing in local rivers was common prior to displacement so communities were familiar with local aquatic species and fishing.

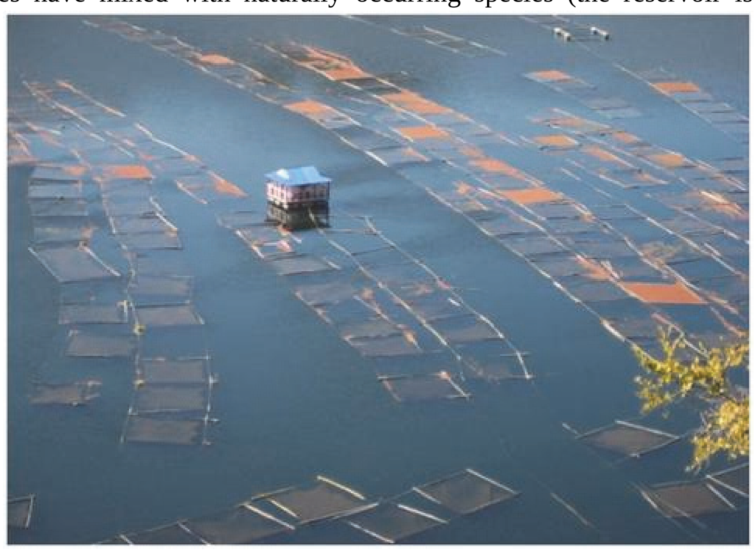
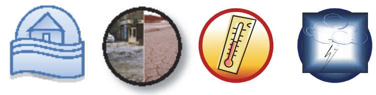


Plate 2
Cage aquaculture in Kulekhani Reservoir, Nepal.
COURTESY OF FISH CONSULTING GROUP.



Multicountry

The **AquaClimate** project includes India, Viet Nam, Sri Lanka, and the Philippines and focuses on increasing adaptive capacity of small-scale aquaculture through assessment of adaptive capacity, perceptions and an evaluation of potential adaptation options and proposed guidelines (NACA, undated; Muralidhar *et al*., 2010). Although present in several LMEs, this project is described in the Bay of Bengal LME.

- **Participatory assessment of fish farmer vulnerabilities** (India)**.** One output from this assessment was the realization that men were more tied to the land than women, meaning they were less likely to change their livelihoods than women. Based on this, approaches that account for different attitudes to diversifying livelihoods between men and women are recommended. Participants also noted that river mouth siltation due to natural processes and upstream activities was reducing water quality and that dredging was needed to increase water flows.
- **Aquaculture practice recommendations**. Multiple recommendations were made, including:
  - deepening ponds and strengthening and raising dyke height to account for higher water temperatures and more frequent flooding;
  - adding nursery areas to ponds to increase survival in early life stages;
  - adjusting crop calendars to account for higher temperatures (i.e. moving practices to earlier/later to avoid temperature peaks);
  - planting shade plants and trees in and around ponds to reduce thermal stress.
- **Training workshops and publications.** Materials and resources have been shared between the group, in addition to workshops and training sessions to discuss methods and implementation of assessments.

SOUTH CHINA SEA COUNTRIES

Aquaculture

Viet Nam

A project focused on mud crab farming to address rural food security involved improving local capacity to farm mud crabs and provide support for transitioning away from shrimp farming. The project is part of a multiyear project to increase mud crab farming capacity in rural Viet Nam in general (Linder, 2005).

- **Extension and hatchery capabilities strengthened.** Hatchery facilities and staff capabilities were upgraded at selected mud crab centres. Mud crabs are more resistant to common aquaculture diseases and more tolerant of salinity and oxygen changes than cultured shrimp. These crabs will respond better to rising sea level than the current commonly grown cultured shrimp.
- **Technology and methods adapted and transferred to local conditions and species.** There are variations in local conditions, and the centres are modifying technology to local conditions. Mud crabs also work well in polyculture systems, which means farmers can diversify – which provides both increased income and a buffer from external shocks. The centres noticed that mud crab farming required an initial capital (land and cash) investment unavailable to most except wealthier landowners, so without support for entry this could reinforce existing inequalities. In addition, without appropriate policies, changing to a system with different labour needs could negatively affect landless people's employment opportunities.

Another project in Viet Nam focused on building local stakeholder resilience to climate change with a focus on natural resource management in coastal areas (GEF, 2012):

- **Integrated resource management planning.** Stakeholders participated in the creation of local resource mapping and plan formation. Local ownership and awareness of environmental issues, local resources and their distribution was increased.
- **Salinity-tolerant rice varieties and rice-fish cultivation.** Testing and development of salt-tolerant rice varieties to reduce variability to sea-level rise and storm surge. Fish were grown in

household rice–fish systems for household consumption and income, and when rice and fish are grown together overall water needs are reduced. Although not mentioned in the project documents, brackish-water and salinity-tolerant fish species can be introduced in conjunction with salt-tolerant rice varieties. This system and the participatory resource management planning increased and provided more stable incomes as well as increasing community resilience to incoming brackish water.

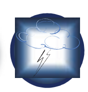
China

An inland project in China promotes a traditional farming technique to increase production and reduce environmental degradation (Weimin, 2010).

- **Rice–fish farming system.** The traditional farming system involves fish (and sometimes ducks) raised in rice paddies. They provide pest control and fertilization, reducing the need for external inputs (and costs), increasing profitability and reducing environmental impacts. It also reduces competition for water and other resources and provides additional income and food sources, which provides a small buffer against climate variability. There are about 1.55 million ha of rice–fish culture in China and it has grown to be one of the most important Chinese aquaculture systems, promoting food security, rural livelihoods and an ecosystem approach to aquaculture.

Plate 3
Dong rice-fish farming system in China.
COURTESY OF LIANG QUANKANG / MDG ACHIEVEMENT FUND.

GULF OF THAILAND COUNTRIES



Fisheries

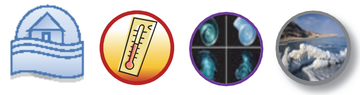
Multicountry

In the Gulf of Thailand, the Mekong River Commission is part of the **Climate Change and Adaptation Initiative (CCAI**). This initiative is a collaborative effort between Cambodia, the Lao People’s Democratic Republic, Thailand and Viet Nam to develop and share adaptation strategies. There is an emphasis on applying efforts at priority sites while also integrating planning with other efforts at local, national and basin-wide scales (MRC, 2011).

- **Demonstration sites.** The CCAI is choosing demonstration sites to pilot activities based on local knowledge in the four member countries. Adaptive management and scaling up of activities will be emphasized.
- **Awareness raising.** Key climate change messages are communicated via posters, cartoons and grassroots comics in riparian languages. In addition, the CCAI provides support for adaptation plan development to each member country, such as learning-exchange visits, mentoring, and training manuals.

Another lower Mekong capacity building project is the **“sister river”** project. The Lower Mekong is partnered with the Mississippi River in the United States of America to share lessons learned, planning efforts and technical capacities focused primarily on floodplain management and basin development (USDS, undated). Although not directly related to fisheries or aquaculture, both rivers provide important fisheries and livelihoods for thousands both along the river and in the marine environments that these rivers drain into.

SULU-CELEBES SEA COUNTRIES



Fisheries

Multicountry

A multicountry, multiple LME project is focused on building capacity in the Asia-Pacific region for those involved in MPAs to create, conduct and implement monitoring programmes in MPAs (de Guzman and Suwandi, undated). Protected areas are one method to set aside part of the marine environment and provide marine species and habitats with opportunities to recover from human impacts.

- **MPA monitoring training.** Participants who already had some familiarity with marine environments, MPAs and scuba were trained on marine species identification, monitoring techniques and protocols. Baseline information for marine areas, especially in developing countries and remote locations, is often sparse. Having at least some data points will permit future decision-makers to make more informed choices and is vital for assessing an area's vulnerability. The training increased technical capacity for participants, and this training and the training handbook creates the potential for participants to create and implement programme in their own setting and further train others. This could result in further education for and employment in MPAs.

PACIFIC ISLANDS COUNTRIES

Fisheries

Fiji

The Rural Community Climate Change Adaptation project aimed to assist rural communities to identify current and future issues affected by climate change and to support local adaptation planning process and implementation (PACE-SD, undated). Six communities were part of the project, and most identified water shortages as the area of most concern. One village identified coastal erosion and developed both short- and long-term adaptation strategies.

- **Coastal protection:** Construct series of perpendicular and parallel groynes to protect shorelines (short term). Plant mangroves along foreshore, with the community involved in planting and also groyne construction (long term). The long-term strategy, mangrove planting, will also provide habitat for juvenile aquatic species as well as protect the shoreline as the groynes will slowly erode with time. Other benefits from the project include the outreach and awareness building that occurred. Communities learned about climate change impacts and were able to incorporate this with other priority areas (e.g. food security or water). Local capacity to understand changes and uncertainty and think about long-term solutions was increased.

Multicountry

The **Vessel Day Scheme for Pacific tuna** is an agreement between nine countries to limit the number of vessel days for tuna fishing and constrain large catches of Pacific tuna (Aqorau, 2009). Tuna currently respond to El Niño Southern Oscillation (ENSO) events, with catch distributions shifting east or west during El Niño or La Niña events. Fishing vessels can purchase fishing days, and the limited number of days available limits the capacity of the fishery and helps maintain Pacific tuna populations. This demonstrates that regional governments have the capacity to manage resources in a variable environment, which will only become more variable with climate change.

Aquaculture

Multicountry/Palau

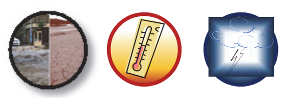
The **Pacific Adaptation to Climate Change (PACC)** project involves 14 countries: the Cook Islands, Fiji, the Marshall Islands, Micronesia (Federated States of), Nauru, Niue, Palau, Papua New Guinea, Samoa, Solomon Islands, Tokelau, Tonga, Tuvalu and Vanuatu. The project aims to aid implementation of long-term adaptation strategies to increase resilience in key development sectors (water resources, food production and security, and coastal zone management). Each country is asked to choose one focal area for initial adaptation activity implementation in consultation with government agencies, relevant NGOs, and PACC staff. Projects address sectors related to fisheries and aquaculture (e.g. coastal management), but only one project in Palau is also targeting aquaculture (SPREP, 2013).

Plate 4
Aquaculture in Palau.
COURTESY OF PACC PALAU.

- **Food security in Palau.** New varieties of salt-tolerant taro and traditional management techniques are being tested in Palau. In addition, monitoring programmes in aquaculture are being developed, and improved clam and crab farming techniques will be implemented. This increases food security and provides some additional income (SPREP, 2012).

HUMBOLDT CURRENT COUNTRIES

Fisheries



Peru

In a project focused on coastal community risk, an alternative insurance scheme is part of an on going project to support adaptation (GlobalAgRisk, 2012).

- **Innovative insurance scheme.** Farmers in the coastal region are able to purchase an insurance that uses index-based instruments based on the occurrence of previously established climate data parameters proven to predict damaging events rather than measurement of actual damage (e.g. rise in sea surface temperatures near Peru, which are correlated with El Niño onset)**.** Although not directly related to fisheries or aquaculture, fishing and aquaculture sectors share many similarities with agriculture in terms of profit vulnerability to climate variability**.**

GULF OF MEXICO COUNTRIES

Fisheries

Mexico

Coastal wetlands are important habitats and at risk from development and climate change impacts. Mexico has chosen four coastal wetland areas for a coastal adaptation project (Zuleta, 2012).

- **Coastal restoration and rehabilitation.** Native vegetation will be used to restore and rehabilitate biological corridors within the wetland and around the lagoon. Sandbars protecting the lagoon will be strengthened. This will maintain ecosystem functioning and provide habitats for aquatic species.
- **Wetland conservation management strategy.** A conservation management strategy will be developed, including updating land zoning regulations and enhancing local area governance. This will build local capacity as well as continue benefits from ecosystem services provided by the wetland (e.g. erosion buffering, water filtration, potential carbon sequestration).

In addition, since 2006 the Ministry of the Marine has been producing **specialized weather forecasts** for fishers (coast to 10 nautical miles, twice daily), navigators (coast to 200 nautical miles, once daily) and coastal populations (coast to 10 km inland, once daily) (SEMARNAT, 2007). These forecasts promote safety and permit planning for both those at sea and coastal infrastructure such as marinas and processing facilities.

MEDITERRANEAN SEA COUNTRIES

Fisheries

Egypt

Incorporating sea-level rise considerations into coastal zone management in the lower Nile delta is part of the Adaptation to Climate Change in the Nile Delta through Integrated Coastal Zone Management project (GEF, 2009a). Selected project activities include:

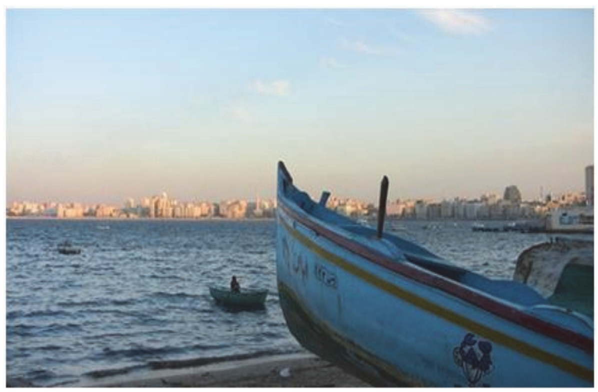


Plate 5
Alexandria, Egypt.
COURTESY OF M. FUCHS.

- **A living shorelines approach**. To maintain ecosystem functioning and productivity in coastal lagoons, this approach includes "soft" shore protection measures (innovative bank stabilization and habitat restoration techniques). Pilot adaptation sites were chosen for project implementation with participation from local villagers and fishers. These potentially include marsh plantings, beach nourishment and strategically placed structural organic materials (e.g. oyster reefs). The living shorelines provide space for ecosystem functioning to continue as hard defences are removed and "soft" defences are constructed in coastal areas. "Hard" defences often disrupt natural processes, affecting habitats and fisheries, while living shorelines permit natural ecosystem processes. This project is part of a larger integrated coastal zone management plan that includes local participation and long-term climate change adaptation, building local capacity to adapt.
- **Climate risk assessment.** Risk assessments introduced for integrated coastal zone management initiate controls on coastal development that may negatively affects fisheries or habitats. All future and ongoing coastal development will be evaluated to identify short-term measures that can be linked to long-term adaptation.

GUINEA CURRENT COUNTRIES

Fisheries

Guinea

Building on its national adaptation programme of action (NAPA), Guinea is currently implementing the Increasing Resilience and Adaptation to Adverse Impacts of Climate Change in Guinea's Vulnerable Coastal Zones project (GEF, 2009b). Selected project activities include:

- **Solar salt production techniques.** Alternative production techniques for solar salt production to reduce mangrove clearing in coastal areas. In addition to preventing further mangrove clearing, this provides livelihood alternatives in an area with heavy reliance on rice cultivation, which is vulnerable to rising sea level and saltwater intrusion.
- **Oyster-growing technique dissemination.** New techniques are disseminated to either introduce or strengthen (if existing) oyster fisheries. This also reduces mangrove clearing and provides additional incomes and livelihood opportunities. Community stakeholders participated in identifying issues and learning about climate change impacts and will participate in implementation of adaptation measures and sharing lessons learned with other communities.

Senegal

Three communities in Senegal (Rufisque, Saly and Joal) are the focus of a project addressing littoral zone management, including protecting people and economic and cultural resources (Centre de Suivi Ecologique, 2010). Specific activities vary in the three communities and include:

- **Coastal protection.** Updating and validating feasibility studies for coastal protection facilities, cleaning of canals and clearing connections with the sea. Protection facilities in vulnerable areas (hotels, poor villages and docks) are being set up, waste management systems are being developed, and impact assessments and environmental and social management plans are being developed and implemented (in Joal).
- **Livelihoods**. Protecting against salinization in rice-growing areas as well as protecting and renovating coastal infrastructure for processing (e.g. smoke fish kilns), with a focus on strong involvement from local women. As beach erosion has negatively affected local tourism and associated livelihoods, community training to increase awareness of adaptation options and good coastal management practices.

Plate 6
Senegalese project sites and activities.
COURTESY OF KEMO/CENTRE DE SUIVI ECOLOGIQUE.

Democratic Republic of the Congo

A project funded by the Global Environment Facility (GEF), "Building the resilience and ability to adapt of women and children to changing climate in Democratic Republic of Congo" (GEF, 2013) aims to address the resilience and capacity of rural communities in the Democratic Republic of the Congo with a focus on women and children. Although not focused on fisheries or aquaculture specifically, project activities include livelihood diversification including developing fish conservation units and aquaculture to promote livelihoods and food security. These activities are intended to address wider issues of climate change and variability impacts on vulnerable rural communities and women rather than impacts specific to fisheries. Diversifying livelihoods and food production will increase socio-economic resilience of the target communities.

Benin

The Support Programme to the Participatory Development of Artisanal Fisheries targeted artisanal fishing communities and poverty alleviation to the poorest households relying on fishing (including production, processing and marketing). The four main project components were: strengthening institutional capacities; rehabilitating waterbodies, including erosion control and management plans; rationalizing fishery value chains with technology to support marine and inland fisheries and/or aquaculture and encouraging livelihood diversification (e.g. growing vegetables or rabbits); and programme management (IFAD, 2012).

SOMALI CURRENT COUNTRIES

Fisheries

Kenya

In coastal Kenyan communities, the project Livelihood Sustainability through Raising Community Capacity for Fisheries/Coastal Management in Lamu Archipelago aims to use participatory planning and management of coastal fisheries resource utilization and conservation to enhance livelihood sustainability (Kareko *et al*., 2011).

- **Strengthen local community-driven institutions.** Institutions responsible for fisheries management (e.g. beach management units and collaborative fisheries management areas) are strengthened via increased understanding of resources and impacts. Co-management has led to fishery management implementation (where before there had been none or weak enforcement), including reduction in destructive fishing practices, increased trust in management authorities, self-policing of the fishery. Formal co-management has increased national funding for fisheries management at the local level.
- **Participatory fisheries data collection.** Local fishers collect data, and these are used to inform management and policies. Policies influenced locally include fishing ground zoning and short- and long-term closures for stock recovery. Both local data collection and strengthened local institutions have increased local capacity for management and understanding. Locals have already noticed potential climate change impacts, and this activity contributes to sustainable and adaptive management of the fishery, increasing management resilience and local adaptive capacity.

United Republic of Tanzania

The project Adaptation Strategies and Challenges Associated with Climate and Ecological Changes to the Lake Victoria Community in Tanzania aims to implement sustainable adaptation alternatives in the fishing communities of the Lake Victoria region to bolster food and income-generation activities. Initial assessments and consultations with district-level government officials and three communities dealing with the scarcity of clean drinking-water and poor crop yields revealed current adaptation and coping measures. Building on these, sustainable methods to cope with fish shortages and fish farming techniques were introduced to address food security in addition to new groundwater sources and irrigation schemes (Unitar, 2009).

AGULHAS CURRENT COUNTRIES

Fisheries

Mozambique

In Mozambique's coastal zone, an ongoing project is providing financing for local communities to transition to climate-resilient higher-income livelihoods (UNDP, 2011).

- **Start-up support.** Support will be provided for associations, business plans, and professional association development in local communities. Financing and other support will be used to assist people to transition to alternative livelihoods. This will help develop local markets and the linkages between locally produced aquatic and other goods and other markets.
- **Training in agricultural and fishing practices.** Training in practices that are viable in high climate variability scenarios will be provided, including extension service packages tailored to village needs. This will lead to more resilient food production practices, which increase community resilience, especially when combined with new linkages to markets for additional income and diversification opportunities.

Lake Malawi

Around Lake Malawi, actions addressing post-harvest loss have been introduced in the form of smoking kilns to dry fish. As climate change reduces the quantity and quality of fish harvested from the lake, reducing post-harvest loss increases in importance. In addition to reducing these losses, the smoking kilns also reduce deforestation and improve water quality, improving habitat quality for aquatic species and removing an additional stressor for fish (Jamu, 2011).

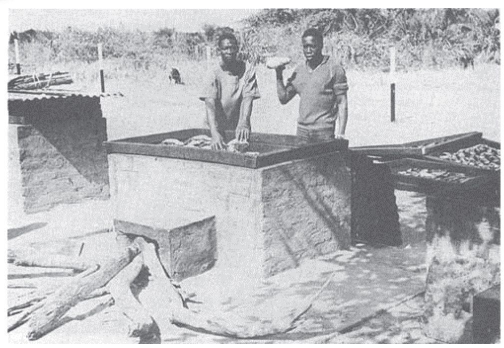


Plate 7
Smoking kilns at Lake Malawi.
Courtesy of D. Jamu.

INDIAN OCEAN ISLANDS COUNTRIES

Fisheries

Seychelles

In a small island developing State, coastal flooding and water scarcity are two climate change concerns addressed by an ongoing project. The project goal is to contribute to sustainable development overall in Seychelles, using ecosystem-based adaptation to climate change (Adaptation Fund, 2011).

- **Ecosystem-based climate change adaptation.** To address coastal flooding from an ecosystem approach, coastal erosion will be addressed via active mangrove management and restoration, sand dune rehabilitation using native species, wetland restoration and alien species removal and agricultural land reclamation, and construction and rehabilitation of fringing coral reefs. These habitats will provide important coastal habitats, reduce erosion and maintain other ecosystem services important to Seychelles.
- **Local management.** A local-level coordinating body will be established to oversee vulnerability assessments, implementation and monitoring of adaptation activities. Local capacity will be built via this coordinating body and associated training for participation in this group.

4. COSTS

Costs for adaptation will be variable and depend on the local context and type of adaptation action. There will also be variability in the benefits, although these may outweigh the costs, and there is high variability in the economic impact climate change will have on different regions and sectors.

In an economic study of adaptation costs and benefits in catfish and shrimp farms of the Vietnamese Mekong Delta, planned adaptation funded by the government was found to provide more benefits than if farmers were left to adapt for themselves via reducing or offsetting farmers' autonomous adaptation costs (Kam *et al*., 2012). However, the economic analysis also revealed that catfish farming was operating close to the edge of economic viability and profits could be significantly affected by climate change without industry restructuring (e.g. reducing input costs or moving profit margins down the value chain to producers). The shrimp industry was able to tolerate adaptation costs longer than catfish, and improved extensive farming was found to be more environmentally and economically sustainable, especially for small-scale farmers, despite lower profitability compared with semi-intensive and intensive shrimp farms.

Costs were estimated at the farm level and based on farmer interviews and expert advice, and scenarios with no climate change and with climate change were compared. Growth in both catfish and shrimp sales until 2050 was based on current and recent market trends. Income and yields were based on 2010 stakeholder interviews and price changes were estimated based on expert advice taking into account the last ten years of price fluctuations. Public investment in river and sea dyke construction to prevent flooding and tidal intrusion was used to consider the benefit provided to farmers of planned adaptation measures. This government-funded measure offset or reduced on-farm costs of dyke upgrading and increased electricity and fuel costs in response to increased salinity and flooding at the farm level.

Autonomous adaptation at the farm level would result in reduced profits for farmers and probably drive out those farmers unable to cover these extra costs. Adaptation activities included in this study were dyke upgrading for flood protection and increased electricity and fuel costs for water pumping for increased pond aeration. Planned and government-funded adaptation activities included constructing sea dykes to prevent tidal flooding and reduce salinization and river dykes for seasonal flooding, as well as support for increased electricity and/or fuel costs. The total cost of these planned adaptations over ten years was projected at USD 191 million, while the catfish and shrimp exports bring in USD2.7 billion. The cost for the government was only 0.7 percent of the total money brought in from exports from these two aquaculture businesses (Kam *et al*., 2012). Although this study only looked at one kind of adaptation, it is an example of the kind of benefit that public-funded adaptation can have on small-scale producers as well as highlighting the role government can play in facilitating adaptation and linking adaptation to wider regional and local development.

5. TRADE-OFFS AND MALADAPTATION CONCERNS

Adaptation activities in one sector can affect other sectors or have unintended consequences in the fisheries and aquaculture sector. Trade-offs (negative or positive effects resulting from activities in the fisheries and aquaculture sector or other sectors) occur where there may be tight competition for resources. Common in climate change is competition between sectors for water resources, for example, between agriculture, domestic use and other sectors such as aquaculture. Certain groups (e.g. agriculture) may be more powerful in some contexts and able to divert water away from systems. This could cause further degradation in addition to climate change impacts on aquatic systems. Trade-offs are not entirely unavoidable, but they can be minimized and their effects mitigated if sectoral cooperation and communication leads to a conversation between stakeholders about resource allocations.

Long-term planning and scenario analysis can address some unintended consequences of adaptation, as far as scenarios are able to include future alternatives. Although not specific to fisheries, the following example demonstrates long-term unintended consequences of technology installed to prevent a climate-induced disaster later changing power dynamics and social relations, resulting in conflict over water decades before hydrologic models predicted changes in water volumes to induce conflict. Drainage tunnels and floodgates installed at Peru's Lake Parón demonstrate the long-term nature of unintended consequences of adaptation (Carey, French and O'Brien, 2012). A drainage tunnel and floodgates were installed to prevent catastrophic outburst flooding and use the lake as a reservoir and for hydroelectric generation in the 1980s. The following decades brought changes in economic opportunities, neoliberal reforms and privatizations, changes to governance structures and environmental changes that led to local groups taking control of the reservoir from a transnational in 2008. Although taking into consideration changes in international political-economic trends and changing public perception of climate change and hazards when planning adaptation projects is difficult to impossible, when these kinds of changes occur an adaptation plan or project can engage in shorter-term scenario analysis or other exercises to reconsider new unintended consequences.

Maladaptations (where adaptation increases vulnerability within a sector or system rather than decreasing vulnerability) result from adaptation activities that are not planned or implemented properly. Effects to communities outside of the immediate community need to be considered as well as local impacts. For example, a community that decides to build a sea wall to prevent further erosion will alter the coastal dynamic of the area, affecting their coastline and also potentially causing more intense erosion or affected ecosystem functions farther down the coastline. Maladaptations may also be trade-offs. An activity that provides a benefit for one group (e.g. a dam for agriculture) may negatively affect another sector (e.g. aquatic systems and fisheries). Strong institutions, collaborative decision-making and holistic planning can prevent maladaptations or at least provide all sectors a voice when making decisions that may involve trade-offs. Most adaptation decisions will involve some kind of negative impact on a system (e.g. using soft coastal erosion controls such as the LSA may involve relocation of some buildings or infrastructure). However, there will also be positive impacts and it is important that stakeholders be involved in decision-making to ensure that impacts are understood and agreed upon. Maladaptations can also occur over time, as in the example from Lake Parón (above). Initially, the adaptation was focused on mitigating impacts from a single climate-induced event type (catastrophic flooding). However, over two decades, wider political and economic changes shifted the balance of power and resulted in a decade-long struggle from the 1990s to 2008 (Carey, French and O'Brien, 2012). Building in flexibility for managing adaptations that, for example, involve changing local power balances or installing new technologies that may initiate struggles in the future, can help mitigate potential future maladaptations.

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GLOSSARY

Adaptation: Any adjustment in a natural or human system in response to expected or actual climate stimuli or their impacts. This includes behaviour changes that prevent, or prepare communities for, the consequences of climatic events.

Aquaculture: Farming of aquatic organisms, can be freshwater or saltwater. Fish, crustaceans, molluscs and aquatic plants are commonly farmed aquaculture products.

Autonomous adaptation: Adaptation that is in response to changes in ecological or human systems, but is not a conscious response to these stimuli.

Ecosystem services: Services provided by natural systems that benefit humans. These include water filtration, forest and fishery products, clean air, and nutrient cycling.

ENSO: El Niño Southern Oscillation. A phenomenon associated with sea surface temperatures and atmospheric circulation. It affects global temperatures and weather, and is most noticeable in the Pacific Ocean. Sea surface temperature and precipitation impacts are felt globally.

Fishery: An entity raising or harvesting fish or other aquatic species. It is often defined by the type of animal, gear, area, social community, class of boats, or a combination of these. It can refer to both wild captured fish and aquaculture.

Mitigation: Any action that reduces the amount of carbon dioxide or other greenhouse gases in the atmosphere.

Mariculture: Branch of aquaculture involving cultivation of marine organisms (rather than freshwater). Often involves open-ocean cage systems, or tanks, ponds or raceways filled with seawater. In addition to food, fishmeal, nutrient agar and jewellery are produced by mariculture.

Maladaptation: Action that increases vulnerability to climate change, often via unintended consequences and may be due to poor planning. This may occur outside the system or sector of focus, or to certain groups within the system.

Mainstreaming: The refers to the process of integrating climate change impact and adaptation objectives and strategies into policies and measures implemented at various scales (e.g. local, national, international).

Polyculture: Agriculture using multiple crops in the same location to more closely mimic natural systems and reduce need for external inputs or increase farm efficiency or productivity.

Stock: A subpopulation of a particular fish species where population dynamics are determined by intrinsic parameters (growth, fishing mortality, etc.) and extrinsic factors (immigration) are considered unimportant to population dynamics.

DETAILS OF SELECTED ADAPTATION EXAMPLES IN FISHERIES AND AQUACULTURE

Where	Project goals	Selected activities	How these address fisheries/aquaculture	Other benefits	Source
Bay of Bengal countries					
Bangladesh Enhancing coping and adaptation capacity of the community to reduce vulnerability to climate change.	Project will initiate actions for local-level community and stakeholders to enhance adaptive capacity, resilience and livelihood due to impact of climate change by involving directly 250 households (based on SSN Project Design Document) focusing on key areas of environmental education, agriculture, fisheries, alternative livelihoods, water, and disaster risk reduction activities.	– Pond excavation / land shaping. – Promote brackish-water fish species. – Livelihood diversification, promoting aqua-agro.	– A pond built in the middle of fallow coastal land will be used for irrigation and fish farming while the surrounding land will be raised using the excavated soil and vegetables grown. One per village, managed by local committee. – Locally available species (e.g. mullet, tilapia) introduced, and fingerlings; technology and training provided by the project. – Project provides loan support to individuals creating employment/self-employment with a focus on applications for crab fattening, fish processing, kitchen gardening, apiculture, mangrove plant nurseries and integrated fish farming.	– Short-term local employment, food (vegetables and fish), long-term provision of food for lean periods. – Reduce nutritional deficiencies, provide additional income opportunities and food sources, reducing vulnerability to lean periods and climate variability. – Other learning and awareness activities (climate change and environmental health) that are part of this project will also contribute to increasing household and community adaptive capacity.	Caritas, undated
Bangladesh Creating opportunities for flood-friendly fisheries.	Increase knowledge of various fisheries management techniques to address issues with losses in flood-prone areas.	– Small-scale homestead pens. – Trap pond management (on land that is under water for 4–5 months). – Upgrading traditional fishing gear.	– Bamboo pens with trap doors keep stocked fish in during floods as well as trapping wild fish – larger ones are eaten and smaller contribute to restocking. – Wild-caught fish catch enhanced via use of bushes and branches to build traps. – Traditional bamboo traps are modified to reduce catch per unit effort.	– Also provides habitat for young native species. – Cultivated land is unavailable for long periods, increased catch provides additional food and income sources.	ITDG-B, undated
Nepal Post-dam building displacement in Kulekhani reservoir.	Alternative livelihoods for communities displaced by hydroelectric dam.	– Introduced cage aquaculture in reservoir.	– Plankton-feeding fish (e.g. bighead and silver carp) were used; therefore, no external feed input needed. Government supported individual farmers with fingerling provisioning.	– Over time, escapees combined with naturally recruited species (reservoir is almost 30 years old) have provided a capture fishery. Total production went from 0 in 1988/1989 to almost 165 tonnes in	Gurung *et al.*, 2010

Where	Project goals	Selected activities	How these address fisheries/aquaculture	Other benefits	Source
				2005/2006, and 60 farmers are involved in capture operations. Up to 81 percent of displaced families now involved in cage or capture fisheries. (Fishing in local rivers was common before displacement, so local familiarity assisted implementation.)	
AquaClimate Strengthening adaptive capacities to the impacts of climate change in resource-poor small-scale aquaculture and aquatic resources-dependent sectors in the south and south east Asian region. India, Sri Lanka, Viet Nam and the Philippines	Increase adaptive capacity of small-scale aquaculture through assessment of adaptive capacity, perceptions and an evaluation of potential adaptation options / propose guidelines.	– India: participatory assessment of fish famer vulnerabilities and adaptive capacity. – Viet Nam: recommendations include deepen ponds and use soil to increase dyke height, add nursery areas to ponds adjust crop calendar to changing climate conditions, strengthen and raise dyke perimeter height, stock high-quality seed, plant shade trees and plants in and around ponds to reduce thermal stress, polyculture systems.	– India: Assessment outcomes included understanding gendered relationships to land and livelihood: men are more tied to land, meaning they are less likely to change livelihoods than women. Other recommendations include dredging to clear silt at river mouths. – Viet Nam: aquaculture recommendations included: deepening ponds and strengthening and raising dyke height to account for higher water temperatures and more frequent flooding; adding nursery areas to increase survival in early life stages; adjusting crop calendars to account for higher temperatures (i.e. moving practices to earlier/later to avoid temperature peaks); and planting shade plants and trees in and around ponds to reduce thermal stress. – Training workshops and publications. Materials and resources have been shared between the group, in addition to workshops and trainings to discuss methods and implementation of assessments.		Muralidhar *et al*., 2010 NACA, undated

South China Sea countries					
Viet Nam Community-level climate change resilience building.	Build local stakeholder capacity to increase resilience to climate change with a focus on natural resource management.	– Integrated resource management plan, including resource maps developed with stakeholder participation. – Testing and development of salinity-resistant rice varieties, and integration of these with rice–fish cultivation.	– Overall increased awareness of environmental issues, local resources and their distribution. – Grow fish for household consumption and income, when combined with rice reduces water needs (no mention of introducing brackish-water species with salinity-tolerant rice varieties).	– Increased and more stable income from fish–rice farms, as well as increased resilience to incoming brackish-water (from sea-level rise or inundation from storms, etc.)	GEF, 2012
Viet Nam Development of leading centres for mud crab aquaculture in Viet Nam in Hai Phong Province.	Improve local capacity for mud crab farming in rural Viet Nam.	– Strengthened extension capabilities and upgraded hatchery and facility and staff capabilities at selected centres. – Adapted and transferred technology to local conditions and species.	– Mud crabs are more resistant to some common aquaculture diseases and more tolerant of changing salinity and oxygen levels than cultured shrimp, meaning mud crabs will respond better to sea-level rise than shrimp. – Mud crabs also work well with polyculture systems so can allow farmers to diversify and buffer against shocks / increase income.	– Although are chances for increased income, in this case more of the benefits went to wealthier landowners (requires land and investment capital), with potential negative impacts on landless people's employment opportunities.	Linder, 2005
China Rice–fish farming systems.	Increase farm productivity and reduce environmental degradation via promotion of traditional farming system.	– Farmers plant rice paddies where they also raise fish (and sometimes ducks), which provide both pest control and fertilization.	– Aquaculture system not in competition for water or resources.	– Provides additional income and reduces costs for either pest control and fertiliser or via reduced profits from a lack of those. Additional products and income provide small buffer from climate variability.	Weimin, 2010
Gulf of Thailand					
Lower Mekong Basin Climate Change Adaptation Initiative (CCAI). Cambodia, Lao People's Democratic Republic, Thailand, Viet Nam	Overall goals include achieving Millennium Development Goals, poverty eradication and improved food security, guiding climate change adaptation planning and implementation through improved strategies and plans at a variety levels in the basin.	– Demonstration sites to pilot adaptation activities based on local knowledge in member countries. – Awareness raising and capacity building via key climate change messages communicated simply in local languages. Support for adaptation plan development, learning exchanges and training manuals.	– Adaptation plans include focus on food security, including aquaculture and fisheries. This project is not specifically focused on fisheries, but many communities in the Lower Mekong Basin heavily rely on fisheries and aquaculture and it recognizes potentially significant climate impacts on regional fisheries and aquaculture and will address those via adaptation plans and increased communication and coordination.	– Overall capacity building and increased communication in vulnerable region at variety of stakeholder levels (local, national and regional).	MRC, 2011

Lower Mekong / United States of America Sister Rivers Project. Cambodia, Lao People's Democratic Republic, Thailand, Viet Nam, Myanmar, United States of America	"Sister-River" partnership shares technologies and lessons learned between the two basins, primarily on floodplain management and basin development.	– Increasing communication and capacity via sharing lessons learned and plans.	– Not directly related, but the Mekong River is an important fishery source for thousands (as is the Mississippi river).	– Capacity building (new technologies, plans, and relationships built).	USDS, undated
Sulu-Celebes Sea					
Asia-Pacific MPA monitoring training. Indonesia, Philippines, Timor-Leste, Thailand and Viet Nam	Building capacity in the region for those involved in MPAs to create, conduct and implement monitoring programmes in MPAs.	– Trained participants (already had some familiarity with environments, MPAs and scuba) on marine species identification, monitoring techniques and protocols.	– Baseline information for marine areas, especially in developing countries is often sparse and having at least some data points will permit future decision-makers to make more informed choices.	– Increased technical capacity for participants, as well as training handbook and ability for participants to create and implement programme in own setting, which could result in further education for others and potentially employment (if more are needed to do monitoring)	de Guzman and Suwandi, undated
Pacific Island countries					
Fiji Rural community climate change adaptation.	– Assist rural communities to identify current and future issues affected by climate change and support local adaptation planning process and implementation of plan/activities. – 6 communities, most identified issues with water shortages. Navukailagi village identified coastal erosion.	– Short-term action: construct series of perpendicular and parallel groynes. – Long-term action: planting mangroves along foreshore with community involvement.	– Protecting shoreline from erosion and inundation prevents washing away of village buildings. A long-term fishery benefit is the habitat mangroves provide for juveniles.	– Community learned about climate change impacts and was able to incorporate other actions into community climate adaptation plan. Not all have been implemented, but built local capacity to understand changes, uncertainty and think about long-term solutions.	PACE-SD, undated
Multicountry Vessel day scheme for tuna. Marshall Islands, Micronesia (Federated States of), Nauru, Papua	Constrain large catches of Pacific tuna.	– Is a "cap and trade" on number of tuna vessel days in countries participating in the scheme where vessels purchase fishing days.	– Limiting number of vessel days targeting migratory species limits fishing capacity and helps to maintain Pacific tuna populations.	– Permits some flexibility with east–west variations in tuna locations during ENSO events, and this flexibility may be beneficial long term with climate-induced changes in variation in tuna locations.	Aqorau, 2009

New Guinea, Palau, Solomon Islands, Tuvalu, and Kiribati					
Multicountry PACC [Pacific Adaptation to Climate Change] Palau, Vanuatu, Tonga, Nauru, Solomon Islands, Samoa, Tuvalu, Cook Islands, Fiji, Papua New Guinea, Tokelau, Micronesia (Federated States of), Marshall Islands and Niue	Aid implementation of long-term adaptation strategies to increase resilience in key development sectors (water resources, food production and security and coastal zone management).	– Palau: monitoring programmes and improved techniques for mud crab and clam aquaculture.	– Improved techniques and guidelines will lead to more climate-resilient aquaculture practices.	– Capacity building and communication sharing at local and regional levels facilitated by individual projects and PACC project. Other benefits included more resilient livelihoods and increased food security.	SPREP, 2012
Humboldt Current countries					
Peru Insurance for agricultural microcredit schemes to support adaptation to climate change.	Reduce risk to farmers and producer associations along Peru's northern coast to negative effects of extreme climate phenomena (e.g. ENSO) to contribute to regional economic stability.	– Innovative insurance scheme for farmers in the coastal region.	– Project not directly related to fisheries/aquaculture, but similar could be applied for aquaculture producers.	– Insurance uses index-based instruments based on the occurrence of previously established climate data parameters proven to predict damaging events rather than measurement of actual damage e.g. rise is sea surface temperature near Peru– correlated with El Niño onset.	GlobalAg-Risk, 2012
Gulf of Mexico countries					
Mexico Adaptation to climate change in coastal wetlands in the Gulf of Mexico	Promote adaptation in coastal wetlands in pilot sites, with lessons learned used to scale up and/or reproduce efforts elsewhere.	– Coastal restoration and revegetation. – Wetland conservation management strategy.	– Maintain and improve coastal and wetland habitats for aquatic species.	– Increased water filtration, potential carbon storage (via blue carbon), and enhanced local area governance.	Zuleta, 2012
Mexico This is also relevant for the Pacific coast	Provide weather information to marine/coastal users.	– Since 2006, twice daily forecasts for fishers (coast to 30 nautical miles), once daily for navigators (coast to	– Accurate and frequent marine and coastal weather forecasts protect fishers at sea and permit planning	– Coastal/marine weather forecasts also benefit other industries, such as shipping, transport and tourism.	SEMARNAT, 2007

of Mexico, in the California Current and Pacific Central-American LMEs		200 nautical miles) and once daily for coastal populations (coast to 10 km inland).	for weather events to protect facilities and infrastructure on land.		
Mediterranean Sea countries					
Egypt Adaptation to climate change in the Nile Delta through integrated coastal zone management.	Incorporate sea-level rise into coastal management.	– Climate risk assessment for integrated coastal management activities. – Living shorelines approach for shoreline protection.	– Coastal and wetland ecosystems maintain or increase productivity, which benefits local fisheries.	– Long-term planning is enhanced via climate risk assessments and local participation builds capacity.	GEF, 2009a
Guinea Current countries					
Guinea Increasing Resilience and Adaptation to Adverse Impacts of Climate Change in Guinea's Coastal Zones Project.	Builds on NAPA.	– Alternative solar salt production techniques. – Oyster-growing technique dissemination to new and existing oyster fisheries.	– Reduced pressure to clear mangroves as alternative livelihoods in area with high reliance on rice cultivation.	– Additional income and livelihood alternatives can also reduce vulnerability as rice cultivation is sensitive to sea-level rise and saltwater intrusion. – Community stakeholders participated in workshops to learn about climate impacts, identify important local issues, aid in project implementation and sharing lessons learned with other communities.	GEF, 2009b
Senegal Adaptation to coastal erosion in vulnerable areas.	Littoral zone management and protection of people and economic and cultural resources. In three communities: Rufisque, Saly and Joal.	– Coastal protection is enhanced via updating and validating coastal protection feasibility studies. Protection targets include hotels, poor villages and docks in addition to developing waste management systems. – Community trainings to raise awareness of climate issues (e.g. beach erosion), adaptation options and good coastal management practice.	– Coastal infrastructure for processing fish (e.g. smoke fish kilns) is vulnerable to beach erosion and sea-level rise as it takes place along the shoreline. Enhancing coastal protection protects processing areas. – Coastal management practices, including developing waste management systems, will enhance the resilience of coastal and estuarine ecosystems.	– Many women are involved in fish processing and the project is focused on bringing in high levels of women's involvement. In addition, protecting valuable coastal area (e.g. poor villages, rice-growing areas and other areas of economic importance such as hotels, docks and fish processing) can enhance resilience of local communities to climate shocks.	Centre de Suivi Ecologique, 2010

Benin Support Programme to the Participatory Development of Artisanal Fisheries.	Aims to address overfishing concerns and poverty alleviation of artisanal fishing communities.	– Livelihood diversification and promotion of fisheries/aquaculture (including processing/marketing). – Waterbody and coastal management plans.	– Promotion and training for fisheries and aquaculture facilities as well as other aspects of the fisheries sector, including processing. – Management plans are a first step to increase the health and productivity of coastal and aquatic systems.	– Enhanced economic resilience via more diversified livelihoods (e.g. promoting growing vegetables or rabbits). – Enhanced environmental management via management plans.	IFAD, 2012
Democratic Republic of Congo Building the resilience and ability to adapt of women and children to changing climate in the Democratic Republic of the Congo.	Aims to address the resilience and capacity of rural communities in the Democratic Republic of the Congo, focusing on women and children.	– Promote climate-resilient livelihoods via training and support – Unsophisticated food processing units, including support for fish conservation units managed by women's groups.	– Developing aquaculture and fish processing units, using fisheries and aquaculture sector as an alternative to more climate-sensitive rainfed agriculture.	– These activities are intend to address wider issues of climate change and variability impacts on vulnerable rural communities and women rather than impacts specific to fisheries. Women are the primary farmers / agricultural labourers in the Democratic Republic of the Congo and this project will reduce dependence on rainfed agriculture.	GEF, 2013
Somali Current countries					
United Republic of Tanzania Advancing capacity to support climate change adaptation (ACCCA).	Implement sustainable adaptation strategies to improve food and income generation.	– Sustainable fish shortage coping mechanisms and fish farming techniques introduced, building on participatory assessment of current coping and adaption.	– Methods for addressing fish shortages and improved/introduced fish farming.	– Improved access to higher quantity/quality water via other project activities as well as fish farming and shortage coping techniques improve food security and provide additional income sources.	Unitar, 2009 http://weadapt.org/placemarks/maps/view/804
Kenya Livelihood sustainability through raising community capacity for fisheries/coastal management (RaCCCoM) in Lamu Archipelago, Lamu District.	Enhance livelihood sustainability through participatory planning and management of coastal fisheries recourse utilization and conservation.	– Strengthening local community-driven institutions responsible for fisheries management (beach management units, and collaborative fisheries management areas). –Introduce participatory data collection for fisheries.	– Increased understanding of resources and impacts, as well as co-management led to fishery management implementation including reduction in destructive fishing practices, trust in management authority, self-policing of fishery, and formal co-management has increased funding for fisheries management at the local level. – Policies influenced locally	– Increased local capacity for management and understanding. Locals have already noticed potential climate change impacts, and this activity contributes to sustainable and adaptive management of the fishery, increasing management resilience and local adaptive capacity.	Kareko, Muriuki & Kanyange, 2011

			include fishing ground zoning and short- and long-term closures for stock recovery.		
Agulhas Current countries					
Mozambique	Financing for local communities to transition of climate-resilient higher-income livelihoods.	– Support for start-up businesses, association and business plans. – Agricultural and fishing practice training.	– Potentially open new markets for aquatic products. – Training focused on practices that are viable in high climate variability scenarios and extension packages tailored to local village needs.	– Transitioning to alternative livelihoods will provide increased resilience to livelihoods vulnerable to climate impacts. This will also develop and enhance linkages between locally produced aquatic (and other) goods and new markets. – Enhanced local food production.	UNDP, 2011
Lake Malawi	Address post-harvest loss issues.	– Smoke kilns to dry fish.	– Reduced quantity and quality fish caught means more important to reduce post-harvest loss.	– Reduce deforestation as pressure on forest resources for burning is reduced, which also improves habitat quality for aquatic species and removes additional stressor for fish.	Jamu, 2011
Indian Ocean Island countries					
Seychelles Ecosystem-based adaptation to climate change in Seychelles.	Sustainable development in Seychelles using ecosystem-based adaptation to climate change.	– Ecosystem-based adaptation via active mangrove management and restoration, sand dune rehabilitation with native species, wetland restoration, alien species removal, agricultural land reclamation and construction/rehabilitation of fringing coral reefs.	– Enhanced coastal, wetland and mangrove habitats for aquatic species.	– Reduce erosion and maintain important ecosystem services (e.g. water filtration in wetlands). – Local capacity built via local management coordinating bodies to oversee assessment, implementation and monitoring of activities.	Adaptation Fund, 2011