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TECHNICAL REPORT

CLIMATE CHANGE AND COASTAL ZONES

AN ANNEX TO THE USAID CLIMATE-RESILIENT DEVELOPMENT FRAMEWORK

MARCH 2015
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ACRONYMS

ADIJ	Junquillal Development Association
CBP	Conservación – Baulas del Pacífico
CCRIF	Caribbean Catastrophe Risk Insurance Facility
CEBSE	Center for the Conservation and Eco-Development of Samaná Bay and its Surroundings
CO_2	carbon dioxide
EBFM	ecosystem-based fishery management
ECOWAS	Economic Community of West African States
FAO	Food and Agriculture Organization
FISH	Fisheries Improved for Sustainable Harvest
ICZM	integrated coastal zone management
IPCC	Intergovernmental Panel on Climate Change
MPA	marine protected area
NGO	nongovernmental organization
NOAA	National Oceanic and Atmospheric Administration
UNDP	United Nations Development Programme
USAID	United States Agency for International Development
USFWS	U.S. Fish and Wildlife Service
WWF	World Wildlife Fund

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EXECUTIVE SUMMARY

The coastal zone[1] is home to more than half of the world's population. The world's coasts are among the most productive economic zones, hosting much of the infrastructure that drives global economic output, supports critical ecosystems, and provides ecosystem services. Coastal areas throughout the world are home to important resources, industries, and significant population centers. Year-to-year variability in climate, such as droughts, intense precipitation events, storm surges, and sea-surface temperature anomalies, already affects the world's coastal zones. These stressors affect ecosystems, infrastructure, and communities in coastal zones; climate therefore has consequences for development practitioners working on coastal issues.

Climate change adds a new dimension to coastal zone planning and management. In the coming years, experts project additional stressors, including rising air- and sea-surface temperatures, changing precipitation regimes, intensifying storms, rising sea levels, and increasing ocean acidification. Scientists have already observed the rapid onset of some of these changes. As the climate changes, climate stressors will exacerbate many of the non-climate stressors that are already affecting the coastal zone, such as rapid population growth, increasing coastal development, pollution, poor governance, and poor management of coastal resources. Understanding the interaction of climate and non-climate stressors can help coastal managers choose adaptation actions that reduce vulnerability over the long term. In summary, coastal managers need to understand the implications of climate impacts to ensure long-term success in achieving development objectives.

The purpose of this document is to identify the stressors affecting the coastal zone and to provide an overview of the adaptation actions that can help development practitioners integrate climate concerns into strategies, programs, and projects in the coastal zone. For those managing, planning for, or funding projects in the coastal zone, understanding the implications of climate variability and climate change, collectively referred to here as "climate impacts," is important for long-term success. This document serves as a sector-specific elaboration of *Climate-Resilient Development: A Framework for Understanding and Addressing Climate Change* (USAID, 2014b).

Taking climate change into consideration does not always require a vastly different manner of thinking or doing business. Although some actions to address climate change may require new approaches, many will use existing methods that already address existing climate stressors such as coastal storms, as well as non-climate stressors, such as pollution and land-use change. To address climate vulnerability, planners and managers must understand how climate change might affect specific objectives for the coastal zone. Adaptation actions should be integrated into coastal development projects to make them more resilient to existing stressors and future climate impacts. Adaptation can ensure that climate impacts will not significantly impede projects that planners and managers are undertaking in an effort to help countries develop. This "development-first approach" maintains development priorities while also considering how climate may affect development (see USAID, 2014b).

1. For the purposes of this document, we define the coastal zone as the seaward and landward extent where coastal development and related economic activities occur, including, in some cases, marine environments and upland areas that influence or are influenced by the coast.

Several key strategies can help coastal managers incorporate climate impacts into coastal management. Section 5 discusses these strategies in more detail. The summary below identifies some of the best practices for integrating climate impacts; these actions have been successful in various sectors, regions, and levels of government.

- Mainstream the consideration of climate impacts into existing decision-making to avoid disruption, duplication, and resource waste
- Choose adaptation actions that are "no regrets" – actions that offer benefits regardless of what happens with future climate
- Address non-climate stressors to provide ecosystems with increased capacity to handle climate stressors
- Consider a variety of plausible future climate conditions to account for scientific uncertainty
- Explicitly address climate impacts in all coastal planning and management decisions
- Manage coastal resources adaptively, preserving the ability to adjust policy over time
- Examine best practices on climate adaptation from other sectors, levels of government, and regions to learn from related experience
- Work to remove barriers that discourage or prohibit adaptation to a changing climate or that increase climate vulnerability (e.g., laws, funding mechanisms, and management approaches that do not consider or that exacerbate potential climate impacts or stressors)
- Recognize the scales at which people make relevant decisions, so that one can implement suitable adaptations at the appropriate level of decision-making
- Look for the opportunities that climate change may present, instead of focusing exclusively on the negative impacts on coastal resources and development

This document provides those involved with the coastal zone with a comprehensive yet succinct summary of climate impacts and the challenges they pose for coastal resources and development. Following the main text, readers will find a short discussion of several adaptation actions that can reduce coastal vulnerabilities – not just to climate change, but to existing climate and non-climate stressors as well. Although this document is not prescriptive, it should help planners and managers identify options for adaptation in line with local development priorities and climate impacts. Finally, this document helps operationalize and provide the substantive detail necessary to effectively use the United States Agency for International Development's (USAID's) new climate-resilient development framework (USAID, 2014b) in the context of the coastal zone.

This annex is structured as follows:

- ***Section 1*** introduces readers to the annex and explains its purpose and relationship to other USAID resources
- ***Section 2*** identifies climate stressors on coastal zones, such as sea level rise, projected changes in air and sea temperatures, and changes in the nature of extreme events
- ***Section 3*** identifies major non-climate stressors, such as changes in population, pollution, and environmental degradation
- ***Section 4*** projects the impacts that climate stressors may have on the coastal zone

- *Section 5* suggests principles of adaptation for thinking through climate impacts on the coastal zone
- *Section 6* identifies a set of possible adaptation actions, described in more detail in Appendix A to this document
- *Section 7* suggests resources for further reading; we cite many of these resources throughout this document, but also include additional resources of possible interest to development practitioners
- *Appendix A* provides detailed descriptions of the adaptation actions described in Section 7

1. INTRODUCTION

1.1 WHY SHOULD I CARE ABOUT CLIMATE CHANGE AMONG SO MANY OTHER IMPORTANT ISSUES?

Coastal areas throughout the world are home to important resources, industries, and significant population centers. These areas are under pressure from development challenges, such as population growth, urbanization, land degradation, pollution, poor management, ineffective regulatory frameworks, unplanned development, over-extraction of resources, and unsustainable resource harvesting practices (Small and Nicholls, 2003; McGranahan et al., 2007 in Nicholls et al., 2007; UNEP, 2007). Given the high degree of exposure and vulnerability of the coastal zone, climate change could have significant impacts on coastal ecosystems, infrastructure, and communities.

Coastal zones are the interface between land and ocean and are vulnerable to a range of climate stressors. Year-to-year variability in climate, such as drought, intense precipitation events, storm surges, and sea-surface temperature anomalies, already affects the world's coastal zones. Climate change adds a new dimension to coastal zone planning and management. Climate stressors, including rising air and sea-surface temperatures, changing precipitation regimes, intensifying storms, rising sea levels, and acidifying oceans already impact coastal ecosystems, infrastructure, and communities. Climate change will likely further increase the risks to coastal zones in the future (Nicholls et al., 2007).

Coastal planners and managers typically manage for average conditions within a historically defined range of variability, also taking into account occasional extreme events, such as hurricanes and typhoons; now, coastal planners and managers must plan for changes in average conditions, changes in the range of natural variability, and changes in the nature of extreme events. Furthermore, climate change might exacerbate many non-climate stressors that are already affecting the coastal zone, such as rapid population growth and urban development, livelihood activities, pollution and nutrient loading, extractive resource use, sediment delivery, and poor resource governance. In some cases, these existing non-climate stressors may present more severe or immediate threats than climate stressors.

Coastal zones provide goods and services, such as wild fish and foods; recreational, cultural, and religious experiences; and storm protection from natural buffers such as wetlands, mangrove forests, and barrier islands. By understanding how climate change might affect specific goods, services, or resources, planners and managers can incorporate adaptation actions alongside planned development activities. This "development-first approach" keeps development on track, while also considering how climate may affect development (see USAID, 2014b).

RESPONDING AFTER TYPHOON HAIYAN IN TACLOBAN CITY, PHILIPPINES

Typhoon Haiyan hit the Philippines on November 8, 2013, with sustained winds of more than 306 kilometers per hour (190 miles per hour). Haiyan was the strongest recorded typhoon ever to make landfall (Fischetti, 2013). It killed over 6,200 people, destroyed 1.1 million homes, and displaced 4.1 million people. Months after the storm, hundreds of thousands of individuals remained in shelters, with concern growing over food security since fishers' and farmers' crops or equipment had been destroyed (USAID, 2014c). Although scientists cannot directly attribute Typhoon Haiyan to climate change, the severity of extreme weather events such as Haiyan will likely increase with climate change. Recovering from Haiyan will take years, but presents an opportunity for Philippine residents to increase their understanding of climate risks and to improve their overall resiliency to climate impacts. Instead of managing for average conditions, coastal planners and managers in the Philippines must now plan for changes in average conditions, the range of natural variability, and the nature of extreme events. As a first step, the Philippine government is promoting mangrove reforestation and conservation as an adaptive option and as a first line of defense against future storms.

A relief camp established after Typhoon Haiyan in Tacloban City, the Philippines.

Photo source: U.S. State Department. Available: http://www.flickr.com/photos/usaid_images/11453947795/in/set-72157637814189514/.

A significant overlap exists between addressing vulnerability to climate variability – the day-to-day variations in current climate – and addressing vulnerability to climate change, the long-term shifts in future climate. Many adaptation measures can reduce vulnerability to both current and future climate stressors. Consequently, this document uses "climate vulnerability" to cover vulnerability to both climate variability and climate change. The phrase "climate impacts" refers both to the effects of current climate variability, as well as to the effects of projected climate change.

Many of the actions that follow are "no-regrets" options; coastal planners and managers can justify them based on current climate stressors alone and can justify them even more strongly when considering climate change and future climate stressors. Such no-regrets options may be sufficient to adapt to some climate impacts in coming years. However, over the longer-term, significant changes in climate are expected. These changes may require much more substantial adaptations than no-regrets options alone. In planning for climate impacts, coastal planners and managers should count on the need to design and implement significant adaptations, especially over longer timeframes. The positive aspect of integrating climate considerations into coastal zone planning and management is that such integration can help ensure the continued productivity of ecosystems, infrastructure, and communities in coastal zones.

1.2 WHAT DO WE MEAN BY THE COASTAL ZONE?

There are multiple definitions of what constitutes the coastal zone. For the purposes of this document, we have intentionally defined the coastal zone broadly, to include the seaward and landward extent of areas that directly influence the coast and that the coast influences. Under this definition, the coastal zone includes coastal waters and adjacent shore lands and ecosystems, as well as islands, transitional and intertidal areas, salt marshes, wetlands, beaches, and tidally influenced rivers. While this definition is intentionally broad compared to others, it encompasses three important components of coastal zones that are important for the development context of this document:

- Coastal and marine ecosystems such as forests, wetlands, salt marshes, mangrove forests, beaches, dunes, coral reefs, and estuaries
- Coastal infrastructure such as human settlements, transportation infrastructure, industrial and utility infrastructure, telecommunications networks, and water resources infrastructure
- Coastal communities and livelihoods such as fisheries, aquaculture, tourism, recreation, water resources, and human health

Throughout this document, we refer to a number of general statistics about population, livelihoods, economic activities, and ecosystems within the coastal zone. Some of the documents cited for these statistics use stricter definitions of the coastal zone than what have described above. Where possible, we try to clarify the definition for each cited document. However, the statistics we cite are meant only to underscore the global importance of coastal areas; the strict definitions used in each case are not necessarily relevant.

COASTAL ZONES AS AN ECONOMIC DRIVER

Globally, coastal zones are home to large and growing numbers of people, resulting in high concentrations of economic activity and critical infrastructure (Nicholls and Cazenave, 2010). Seventy-five percent of the world's population is expected to live within 160.9 kilometers (100 miles) of the coast by 2025 (The National Academies, 2007). Many coastal industries such as tourism, transportation, fisheries, and aquaculture are economic drivers. For example, marine fisheries and aquaculture produced 89.1 million metric tons (98.2 million U.S. tons) of products in 2011, worth roughly US$144 billion (FAO, 2012). These zones also harbor coastal and marine ecosystems that support the health and livelihoods of coastal and inland communities, contribute significantly to gross domestic product, and support global biodiversity. However, the high concentration of populations and economic activities in the coastal zone add many non-climate stressors that can degrade the very coastal resources that drive these economies.

1.3 WHY SHOULD I READ THIS DOCUMENT?

The United States Agency for International Development (USAID) developed this document to help people who care about the coastal zone – municipal planners, natural resource managers, emergency planners, and development practitioners including USAID staff – understand and address climate impacts on coastal zones. We refer to these people collectively as "planners and managers" throughout the rest of this document.

For those with a role in managing, planning, or funding projects in the coastal zone, understanding possible climate impacts is important for long-term success. This document should help coastal planners and managers as they update and implement national coastal strategies, coastal zone management plans, and development plans and strategies, as well as specific development projects. Although we do not provide an exhaustive discussion of the science, we do synthesize and condense the relevant science to make it useful for coastal planners and managers.

Coastal planners and managers will need to integrate climate impacts into decision-making processes at regional, national, and local levels to promote approaches and practices that lead to climate-resilient coastal planning and management. Funding institutions need to factor climate considerations into their development assistance programs to ensure that their interventions effectively safeguard coastal ecosystems, infrastructure, and communities to achieve their objectives. It is important to address climate vulnerability through a sound methodology that considers climate impacts in the context of development, such as the "development-first" approach described in *Climate-Resilient Development: A Framework for Understanding and Addressing Climate Change* (USAID, 2014b).

Coastal planners and managers need to consider climate vulnerability as a fundamental constraint on development success in the coastal zone. In many cases, planners and managers in coastal areas already consider climate impacts. However, many countries lack adequate coastal management plans, governance processes, and institutional and human capacity to address climate impacts. They may need to revise their understanding of the nature and management of threats in coastal zones, consider new actions, revisit goals and objectives, and adjust existing regulatory and management frameworks to accommodate different options. This document will help planners and managers identify options for adaptation in line with local development priorities.

1.4 HOW DOES THIS DOCUMENT RELATE TO THE CLIMATE-RESILIENT DEVELOPMENT FRAMEWORK?

The USAID (2014b) climate-resilient development framework can help planners and managers integrate climate concerns into strategies, programs, and projects using a structured step-by-step process. This framework complements USAID's 2012–2016 *Climate Change & Development Strategy*, which identifies adaptation as one of USAID's three strategic objectives on climate change (USAID, 2012).[2] The framework builds upon a conventional project cycle management framework, which development institutions use to manage their projects and programs. Exhibit 1 illustrates the framework, which consists of five stages: (a) scope, (b) assess, (c) design, (d) implement and manage, and (e) evaluate and adjust. This document provides interested practitioners and policymakers with more specific information tailored to the coastal zone, and the substance necessary to apply the process outlined in *Climate-Resilient Development: A Framework for Understanding and Addressing Climate Change* (USAID, 2014b) to the coastal zone. However, any specific

2. The other two objectives are integration and mitigation.

strategy, program, or project under consideration will require more detailed information than this document contains. Note that this document updates and complements USAID's document, *Adapting to Coastal Climate Change: A Guidebook for Development Planners* (USAID, 2009).

EXHIBIT 1. USAID'S CLIMATE-RESILIENT DEVELOPMENT FRAMEWORK.

This document focuses on a limited subset of the tasks in the scope, assess, and design stages of the framework. The "scope" tasks highlighted in this coastal annex include *framing the planning process* and *identifying climate and non-climate stressors*. We highlight the *exposure assessment* task under "assess." The "design" task in this document focuses on *identifying adaptation options* to increase the resilience of the coastal zone to climate stressors. However, to fully understand the proposed framework and approach, we recommend reading *Climate-Resilient Development: A Framework for Understanding and Addressing Climate Change* (USAID, 2014b) and the other supporting annexes.[3] In particular, for information on climate impacts to freshwater resources, see *Climate Change and Water: An Annex to the USAID Climate-Resilient Development Framework* (USAID, 2014a).

3. In addition to the climate-resilient development framework and this coastal annex, USAID provides other companion annexes that address critical issues and sectors. The water annex (USAID, 2014a), like the coastal annex, is a sector-specific application of the climate-resilient development framework (USAID, 2014b). The vulnerability assessment annex [USAID, Forthcoming (a)] focuses in greater detail on how to conduct a vulnerability assessment. USAID developed the governance annex [USAID, Forthcoming (b)], and marginal populations annex [USAID, Forthcoming (c)] because these two issues are considered critical for climate-resilient development.

2. CLIMATE STRESSORS ON COASTAL ZONES

Climate stressors are climate factors that can affect the functioning of a system and are driven by variability in climate as well as climate change. Planners and managers in the coastal zone have a history of managing for climate variability and extreme events in conjunction with the non-climate stressors discussed in Section 3. Climate conditions, such as sea-surface temperature or precipitation, can vary – sometimes dramatically – from expected average conditions. Furthermore, severe storms generate storm surges, high winds, and flooding in the coastal zone. Because of the coastal zone's natural variability and extreme events, planners and managers frequently prepare for uncertainties such as drought years, flooding events, delays in the onset of the rainy season, hurricanes or typhoons, and other conditions that are perhaps rare, but anticipated. We suggest that planners and managers consider both seasonal and inter-annual variability when thinking about climate-resilient development; however, the methods of dealing with each type of variability can be quite different.

Despite substantial experience in managing natural climate variability, some developing countries have significant development and infrastructure deficits that prevent them from adequately addressing future risks. Climate-resilient development is an opportunity to address these deficits, as well as to consider changes in development initiatives to accommodate climate change.

The consequences of climate change for the coastal zone are likely to be profound (Nicholls et al., 2007). For example, global mean sea levels are projected to increase 0.28–0.98 meters (0.92–3.2 feet) above 1986–2005 levels by 2100 (Church et al., 2013).[4] This sea level rise, alone, will have profound effects on the coastal zone through the loss of land area, the destruction of ecosystems, and impacts on cities and villages. Below, we describe a number of climate change-related climate stressors that affect coastal zones. Although we do not emphasize this point in each section below, the nature of these stressors is inherently uncertain. Uncertainty relates to a number of important factors, including how much the climate will actually change and the difficulty of modeling how environmental parameters will change at the local scale. We have drawn the

4. These numbers span various scenarios of economic development, population growth, consequent greenhouse gas emissions, as well as scientific uncertainties.

information below from the Intergovernmental Panel on Climate Change (IPCC) state-of-the-science reports (Church et al, 2013; Field et al., 2014).

In summary, this section addresses the following climate stressors:

- Increases in air and sea-surface temperatures
- Changes in average and extreme precipitation
- Changes in storm frequency and intensity
- Sea level rise
- Ocean acidification

We anticipate that coastal planners and managers already have a good understanding of stressors associated with natural climate variability. The focus of this document is on climate change, so rather than detailing the climate stressors associated with natural climate variability, we focus instead on how those climate stressors are projected to change.

2.1 INCREASES IN AIR AND SEA-SURFACE TEMPERATURES

The IPCC Fifth Assessment Report projects that global average surface air temperatures will increase by more than 1.5°C (2.7°F) by the end of the century; some scenarios suggest increases of up to 4.8°C (8.6°F) over the same timeframe (Church et al., 2013). Because of the moderating effects of oceans on air temperature, coastal zones will likely see smaller increases in temperature than inland areas (Christensen et al., 2007). However, changing global air and ocean temperatures could alter ocean currents and upwelling zones, which may create localized effects in many coastal zones. Ocean temperatures will very likely continue increasing as the climate changes, with projected upper-ocean temperature increases of 0.6 to 2.0°C (1.1 to 3.6°F) by the end of the 21st century (Church et al., 2013). In addition to direct impacts on coastal resources, this rise in sea-surface temperature will likely lead to increases in storm intensity and sea level rise, as described below.

2.2 CHANGES IN AVERAGE AND EXTREME PRECIPITATION

Although the specific projections of different climate models vary considerably, they all show an increase in global average water vapor, evaporation, and precipitation over the 21st century. However, this global average does not describe individualized projections for regional precipitation change. In coastal areas, this may include changes in annual total and average rainfall, shifts in the timing and amount of seasonal rainfall, fewer days with rain, and increases in rainfall intensity (Parry et al., 2007). In coastal zones, climate models generally project precipitation increases over the tropical oceans and in areas with monsoon regimes (e.g., South Asia, Australia, parts of East Asia). In contrast, widespread decreases in average precipitation are projected during June, July, and August for many mid- and low-latitude locations (e.g., Central America, the Mediterranean, North Africa). In coastal zones, such precipitation changes may lead to changes in freshwater input into coastal waters. For a better understanding of how precipitation changes impact other water resources, see the USAID Water Annex (USAID, 2014a).

Climate change is likely to make extreme precipitation events more frequent and intense, particularly in mid-latitudes and wet tropical regions (Church et al., 2013). The IPCC has determined that it is very likely that heavy precipitation events will become more frequent. In most areas projected to get wetter on average, extreme precipitation events likely will increase at a faster rate than total precipitation increases. Even in areas projected to get drier on average, precipitation likely will be concentrated in more intense events with longer

dry periods in-between. More intense severe storms, discussed below, will also lead to an increased intensity of precipitation events.

2.3 CHANGES IN STORM FREQUENCY AND INTENSITY

Coastal zones experience severe storms, such as tropical and extratropical cyclones (e.g., hurricanes, typhoons, nor'easters), which can generate strong winds, heavy precipitation, and storm surges along the coastal zone. Changing climate conditions will likely lead to intensification of tropical and extra-tropical storms, including heavier precipitation, stronger winds, larger extreme waves, and bigger storm surges that may exacerbate flooding in coastal zones (Nicholls et al., 2007). A changing climate may also lead to shifts in the seasonality and latitude range of tropical storms and to changes in the frequency of the most intense storm events (Church et al., 2013; Emanuel, 2013).

2.4 SEA LEVEL RISE

Church et al. (2013) project a rise in global mean sea level of 0.28–0.98 meters (0.92–3.2 feet) above 1986–2005 levels by 2100. This *global mean* sea level rise will occur because thermal expansion as the oceans warm will coincide with inputs of additional water from melting ice sheets, icecaps, and glaciers. The actual sea level rise experienced at any specific location is known as *relative* sea level rise and varies regionally because of plate tectonic movement, land subsidence or uplift, ocean circulation patterns, and modes of climate variability, such as the El Niño Southern Oscillation. Although sea level rise will not be uniform, approximately 95% of the world's oceans are expected to see a rise in sea levels, with 70% of the world's coastlines experiencing a sea level rise within 20% of the global mean (Church et al., 2013). In other words, the global mean sea level rise projection is a good approximation for the general level of impact expected for most coastal areas. The relative rate of sea level rise along coastlines is higher on average than the oceans in some locations because of subsidence (Nicholls and Cazenave, 2010). Additionally, planning for sea level rise must take into account that the rate of rise might change because the rate of sea level rise is likely to increase over the next century (Church et al., 2013). Catastrophic events, such as rapid melting of the Greenland ice sheet or collapse of the Antarctic ice sheet, could cause sea levels to rise significantly more than Church et al. (2013) describe.

2.5 OCEAN ACIDIFICATION

Ocean acidification refers to changes in the carbonate chemistry of the oceans that occur when atmospheric carbon dioxide (CO_2) dissolves in sea water; higher CO_2 concentrations cause water to become more acidic. As more CO_2 fills the atmosphere through human activities, such as the use of fossil fuels, oceans absorb more CO_2 and become more acidic (Bindoff et al., 2007). Over the next several decades, oceans will likely absorb a greater amount of CO_2, leading to more-acidic oceans.[5] Note that because of variable processes in the coastal zone, such as nutrient and organic matter inputs, coastal seawater acidity exhibits much larger spatial and temporal variability compared to the open ocean (Field et al., 2014). Ocean acidification can slow the formation of calcium carbonate skeletons and shells in marine organisms such as corals and bivalves, which can impair the health of many organisms at the foundation of the oceanic food web.

5. The amount of CO_2 that oceans can absorb depends on both the atmospheric concentration of CO_2 and the ocean temperature; increasing atmospheric CO_2 will tend to increase the amount of CO_2 absorbed by the oceans, but increasing water temperatures will tend to decrease it. The rate of ocean acidification driven by climate change will depend on the relative rates of atmospheric CO_2 increases and ocean warming.

3. NON-CLIMATE STRESSORS ON COASTAL ZONES

Coastal zones in many areas are already under pressure from non-climate stressors, such as extractive resource use, urban development, pollution, and governance frameworks that do not adequately protect coastal resources. Non-climate stressors have led to adverse effects on coastal communities' physical health and well-being; on livelihoods in sectors such as agriculture, fisheries, aquaculture, and forestry; on settlement and infrastructure vulnerability; on water availability and quality; and on ecosystem health. We describe non-climate stressors here because they are significant determinants of the sustainability and resilience of coastal zones. Although a distinction is often drawn between non-climate stressors such as pollution and extractive resource use, and enabling conditions such as population growth and poverty, here we use the term "non-climate stressors" to refer collectively to all of these stressors that might make natural systems less resilient to climate stressors. In many cases, these non-climate stressors pose more immediate and severe threats than climate stressors do. However, climate stressors may exacerbate these non-climate stressors, increasing the vulnerability of coastal and marine ecosystems, coastal infrastructure, and human communities and livelihoods in the coastal zone. Furthermore, effective management of non-climate stressors can facilitate preparedness and reduce the effects of climate stressors. This section addresses the following non-climate stressors:

- Population growth and urban development
- Unsustainable livelihood activities
- Pollution and nutrient loading
- Extractive resource use
- Sediment delivery
- Poor resource governance

The non-climate stressors in this section represent only a selected sample of the full array of non-climate stressors in the coastal zone. Furthermore, many non-climate stressors are interrelated, such as population growth and pollution, and we do not intend for the discussions below to suggest that these categories are mutually exclusive.

3.1 POPULATION GROWTH AND URBAN DEVELOPMENT

The low-elevation coastal zone, defined as contiguous coastal land that is less than 10 meters (32.8 feet) in altitude, constitutes only 2% of the world's land area. However, it contains some 10% of the world's population – an estimated 600 million people.[6] More than half of these people live in coastal cities (McGranahan et al., 2007). Additionally, global population growth is leading to coastal migration (de Sherbinin et al., 2011), the development of coastal megacities (McGranahan et al., 2007; Satterthwaite, 2007), and peri-urban populations living in informal coastal-urban settlements (Handmer et al., 2012). Although experts expect these trends to continue, confidently projecting the complex drivers of population growth and urban development in the coastal zone is difficult. Experts estimate that 75% of the world's population will live within 160.9 kilometers (100 miles) of the coast by 2025 (The National Academies, 2007), with consequent implications for climate vulnerability and impacts on the coastal zone.

Population growth and urban development in the coastal zone will place greater numbers of people at direct risk from coastal storms, storm surges, flooding, and sea level rise, particularly as land-use changes associated with development and urbanization can result in the loss of coastal and upland forests, mangrove forests, coral reefs, and other natural buffers to climate impacts. Coastal population growth and urban development can also increase pressure on coastal and marine ecosystems, communities, and livelihoods, exacerbating other non-climate stressors such as pollution, nutrient loading, and extractive resource use.

3.2 UNSUSTAINABLE LIVELIHOOD ACTIVITIES

Human livelihood activities in the coastal zone, such as agriculture, fishing, aquaculture, and tourism, depend on coastal and marine ecosystems such as dunes, seagrass meadows, coral reefs, and mangrove forests. When people, governments, or industries use unsustainable practices, the effects on these ecosystems can be significant. Affected marine ecosystems may be less able to provide livelihood resources or to act as natural buffers that mitigate climate impacts. Therefore, ecosystem degradation can lead to more vulnerable coastal ecosystems, infrastructure, and communities, as well as less-resilient ecosystems. For example, inappropriate siting of aquaculture through the removal of mangrove forests can reduce coastal protection and increase the vulnerability of communities to storms. Similarly, onshore practices such as agriculture, if mismanaged, can lead to nutrient or sediment loading in coastal waters, harming ecosystems such as coral reefs and the livelihoods and communities that depend on them. Such unsustainable activities place the long-term viability of coastal ecosystems, infrastructure, and communities – and the associated livelihoods themselves – at greater risk to climate stressors.

3.3 POLLUTION AND NUTRIENT LOADING

Pollution threatens natural resources and ecosystems in coastal and marine areas and is particularly problematic around coastal urban centers in developing countries. Sources of pollution include fertilizers, pesticides, chemicals, oil spills, untreated sewage, agricultural waste, heavy metals, radioactive substances, and trash. In some cases, pollution provides surplus nutrients to the environment, degrading coastal ecosystems by altering the chemical balance of coastal and marine waters. Hypoxia, or decreased dissolved oxygen content in water bodies, occurs when excessive nutrients from untreated sewage, agricultural waste, or runoff from livestock operations cause phytoplankton or bacteria to grow and consume oxygen. Marine life depends

6. Note that the coastal zone, as defined in this document, includes more than the low-elevation coastal zone. See Section 1.2.

on dissolved oxygen; its reduction could be devastating. The effect of hypoxia can be observed in the many "dead zones" in the world's coastal waters, where ecosystem productivity and fishery catches are low (Breitburg et al., 2009). In the future, pollution and nutrient loading may interact with climate stressors, such as increased sea-surface temperatures and altered hydrologic cycles, to further impair coastal ecosystems and fisheries (Rabalais et al., 2010; Meire et al., 2013).

3.4 EXTRACTIVE RESOURCE USE

People rely on coastal resources for a variety of extractive uses. For example, people mine coral for material to construct roads and buildings; cut down mangrove or upland forests for building materials, firewood, and charcoal; clear land for agriculture, aquaculture, and development; and mine beaches and dunes for sand. While resources can be extracted sustainably, over-exploitation can occur in areas where governance is weak and enforcement is lax. When climate stressors affect coastal resources, people may either intensify resource use, further degrading the resource, or turn to other natural resources to provide for basic needs. Furthermore, when non-climate stressors – poverty, disease, or social conflict – strain populations, people may have even fewer options. To survive, people may have to choose short-term gains and over-exploitation of natural resources, rather than choosing long-term sustainable methods.

MANGROVE USE AND MANAGEMENT IN GHANA

In many coastal communities, people have destroyed mangrove forests, using the wood as fuel for cooking and to provide materials for construction, and using the sites for aquaculture ponds. For example, in the 1960s in the community of Anyanui, Ghana, a newly constructed dam reduced water availability for crops and threatened residents' livelihoods. The community began to harvest mangroves more intensively as a source of income. Over time, the mangrove forest began to dwindle. In 1991, Anyanui formed the Mangrove Planters and Fishmongers Association to support the restoration of the mangrove forests. The association purchases acreage on 12-year leases to harvest and replant mangroves. It encourages members of the association to do the same. Members are offered financial incentives for collecting seedlings and replanting mangrove forests; members have access to the association's trade market. Currently the association and its members manage approximately 32 hectares (79 acres) of mangrove forest. While such acreage may seem small by some standards, it represents a significant change in mindset and valuation of mangrove forests.

Source: Torell and Tobey, 2012.

Planting mangrove cuttings in West Africa.

Photo credit: Peace Corps.

3.5 SEDIMENT DELIVERY

Human activities in coastal zones and in river basins that empty into the ocean can substantially alter the sediment dynamics of coastal zones. Deforestation, poor agricultural soil management, and other land-use changes increase sediment loads in rivers that empty into the ocean; whereas constructing dams and dikes, channeling rivers, and mining sand and gravel in rivers can decrease sediment loads. The use of coastal resources, such as beach mining; the elimination of natural coastal vegetation, such as mangroves; and the development of infrastructure, such as dikes and levees; all alter the sediment dynamics along a coastline as well. The overall sediment dynamics of a coastal area are location and circumstance dependent, and are influenced by local dynamics, dynamics in upland areas, and dynamics in neighboring coastal areas. Changing the sediment dynamics of coastal zones can have significant impacts on coastal and marine ecosystems, and can increase the vulnerability of infrastructure to erosion, endangering coastal communities and livelihoods.

CONTROLLING EROSION IN MOZAMBIQUE

In Nacala, Mozambique, erosion of uplands during severe storm events has created a large fan of sediment emptying into the adjacent harbor. In addition to its effects on the ecosystem, this sedimentation presents a potential threat to the sustainability of the port facilities, which is a major economic driver for this part of Mozambique. Climate change may exacerbate sedimentation concerns, if future storm events become more frequent or more severe, further increasing the rates of erosion and sediment delivery to the harbor. USAID is currently helping to understand the conditions leading to these extreme erosion events, evaluating the potential effects of climate change on erosion and sedimentation, and identifying appropriate adaptation actions to reduce these impacts (Ferm et al., 2013).

3.6 POOR RESOURCE GOVERNANCE

Policies and practices, including laws, regulations, institutional activities, and enforcement mechanisms, often fail to protect or promote a sustainable and climate-resilient coastal zone. For example, national policies may fail to regulate and sometimes may even promote development in coastal flood zones, increasing community vulnerability and harming coastal resources and ecosystems. In many cases, policies and regulations have been developed without consideration of shoreline processes, coastal hazards, and down shore and upland watershed impacts on the coastal zone. Coastal planners and managers, as well as political leaders, must update ineffective government policies and practices to encourage integrated coastal management, disaster risk reduction, conservation of critical coastal habitats, and adaptation to climate impacts. When effective policies and practices exist to regulate coastal development and the use of coastal resources, enforcement is critical. If enforcement mechanisms or capacity are weak or inefficient, unsustainable resource use or development may persist, exacerbating vulnerability (Exhibit 2). See USAID's document, *Governing for Resilience: An Annex*

EXHIBIT 2. INFORMAL SETTLEMENT. A lack of effective regulation of coastal development is associated with the establishment of informal settlements on marginal land, such as this house and seawall on a barely emergent island in the Pohnpei Lagoon in the Federated States of Micronesia. This small island is regularly inundated during storms.

Photo credit: M. Haws.

to the USAID Climate-Resilient Development Framework [USAID, Forthcoming (b)], for more detail on good and poor resource governance.

The coastal zone is one of the most difficult areas to manage because of overlapping or conflicting jurisdictions and authorities; varying management regimes, laws, and policies; and the dynamic nature of the coastal zone itself. These problems can lead to degradation of coastal resources, ecosystems, and associated ecosystem services. For example, the coastal zone has often suffered from open access to its resources, which has contributed to overfishing and other resource overuse.

Management approaches that support effective cross-sectoral or cross-jurisdictional coordination can decrease the vulnerability of coastal communities, ecosystems, and resources to climate and non-climate stressors. Clear delineations of jurisdictional responsibilities and secure access to resource use, including working with communities and governments to decide who has access to resources and when, can help address the lack of management, thereby enhancing stewardship. Adaptation Action 9 in Appendix A includes information on improving coastal resource governance to increase the resilience of coastal and marine ecosystems, coastal infrastructure, and human communities and livelihoods. Also see USAID's document *Governing for Resilience: An Annex to the USAID Climate-Resilient Development Framework* [USAID, Forthcoming (b)].

4. CLIMATE IMPACTS ON THE COASTAL ZONE

Climate stressors, including climate variability (e.g., hurricanes and the timing of monsoonal rains) and climate change (e.g., sea level rise and increased average sea-surface temperatures), will affect coastal and marine ecosystems, coastal infrastructure, and coastal communities and livelihoods in significant ways. Because we anticipate that coastal planners and managers already have a good understanding of existing impacts from climate variability, the discussion below focuses on impacts from climate change. Although these impacts on coastal zones will likely be negative (Parry et al., 2007), some positive changes may occur. For example, some areas may experience a needed increase in precipitation. All of these impacts – both positive and negative – will be location-specific, depending on the nature of climate stressors and how they interact with non-climate stressors. In this section, we look at some of the key climate impacts on coastal zones, focusing on coastal and marine ecosystems, infrastructure, and communities and livelihoods. Exhibit 3 summarizes some of the key climate change impacts on the coastal zone, as well as the vulnerability of different coastal resources to these impacts. Section 6 and Appendix A describe specific adaptation actions to reduce these impacts on coastal zones.

4.1 COASTAL AND MARINE ECOSYSTEMS

Climate change presents a number of risks to marine and coastal ecosystems, including coral reefs, mangrove forests, seagrass meadows, dunes, and beaches. Sea level rise, along with non-climate stressors such as subsidence and altered sediment delivery, will cause coastal ecosystems to migrate inland over time. Or, if natural or artificial barriers block their migration path or if the rate of sea level rise exceeds the rate of ecosystem migration, these coastal ecosystems may be inundated or destroyed. Higher temperatures and ocean acidity will shift ecosystems for many species and threaten coral reefs. Additionally, more frequent or intense storms may damage ecosystems. These impacts can impair ecosystem function, cause irreversible ecosystem changes, and lead to species extinction.

Coastal and marine ecosystems supply many of the natural resources and ecosystem services that coastal communities rely on, including fisheries, shoreline protection, and important areas for tourism and recreation. For example, coastal and marine areas are largely responsible for fisheries production, which is a global industry worth more than US$100 billion a year (FAO, 2012). The productivity of coastal and marine ecosystems has great importance beyond communities situated directly along the coast. Many of these ecosystems are already under pressure from non-climate stressors, such as population growth, increased development, and extractive resource use, such as overfishing or coral mining. Actions that reduce non-climate stressors to improve the health of these ecosystems will make them better able to adapt to climate stressors and continue to provide key ecosystem services. Climate impacts on wetlands, seagrass meadows, and mangrove forests; beaches and dunes; coral reefs; and estuaries and lagoons are discussed below.

EXHIBIT 3. SUMMARY OF CLIMATE IMPACTS ON THE COASTAL ZONE.

Coastal zone element	Climate impacts	Exposure	Sensitivity	Adaptive capacity
Coastal and marine ecosystems	• Changes in precipitation could lead to flooding, drought, or more-polluted runoff into coastal ecosystems • Higher sea levels could lead to loss of land and salinization of waterways • More intense storms could damage critical resources • Higher sea-surface temperatures and severe storm events could lead to coral bleaching or migration of species • Ocean acidification could slow the formation of calcium carbonate skeletons and shells in marine organisms, such as corals and bivalves	Exposure varies depending on the ecosystem. In general, coastal ecosystems are highly exposed to climate impacts because their location is close to sea level where storm surge, flooding, sea level rise, and other impacts are common.	Sensitivity varies by ecosystem. For example, corals are very sensitive to rising sea-surface temperatures, increasing ocean acidity, and impaired water quality. On the other hand, mangrove forests and wetlands are sensitive to salinity and rising sea levels.	Adaptive capacity can vary by ecosystem and in relation to non-climate stressors. For example, individual coral species can survive only in a narrow range of sea-surface temperatures, and ocean acidity and water quality levels. They cannot adapt well once parameters fall outside of that range. Mangrove forests and wetlands might be able to adjust over time to varying levels of salinity; they need space to migrate to adjust to rising sea levels.
Infrastructure	• Increased precipitation could lead to flooding • Higher sea levels could lead to inundation • Fewer natural buffers could worsen the effects of storms on infrastructure	Simply being located on the coast exposes coastal infrastructure to many climate stressors.	Sensitivity can vary depending on current infrastructure design and natural buffers. In many developing countries, the sensitivity is quite high.	Adaptive capacity can vary based on resource availability, governance capacity, political will, and other factors.
Communities and livelihoods	• Changes in precipitation could lead to flooding, drought, or more-polluted runoff into coastal ecosystems • Higher sea levels could lead to loss of productive land and salinization of water sources • More intense storms could damage critical resources • Higher sea-surface temperatures could lead to the migration of fisheries species • Higher air temperatures could expand the range of disease-carrying vectors or the suitability of regions to harmful bacteria	Coastal livelihoods are highly exposed to climate stressors because they are low lying and influenced by upstream flooding as well as coastal storm surge and sea level rise.	Sensitivity can vary depending on particulars, but many livelihoods are highly sensitive because of large human populations, sensitive species, and many non-climate stressors.	Adaptive capacity can vary by community and livelihood based on non-climate stressors such as upstream resource management practices and local development patterns, but it is generally low. Alternative livelihoods might be available in those regions that experience the appearance of new fishery species because of migration, or in regions where warmer temperatures improve tourism opportunities.

4.1.1 WETLANDS, SEAGRASS MEADOWS, AND MANGROVE FORESTS

Coastal wetlands, including seagrass meadows and mangrove forests, are among the most important coastal ecosystems, and many are currently under threat from human activities. Wetlands not only support key economic activities such as fisheries (by serving as nurseries); they also serve as natural infrastructure by protecting shorelines from erosion, flooding, and storm surge. Coastal wetlands and mangrove forests also provide habitat for wildlife; economic resources such as firewood; game, edible plants, and agricultural areas; and natural protection from severe storms. Seagrass meadows in intertidal and subtidal areas also provide important habitat for a number of marine species.

Of climate change's expected impacts, those that affect freshwater quantity and water chemistry may cause the most direct effects on coastal wetlands and mangrove forests. For example, an increase in salinity caused by altered precipitation patterns or rising sea levels may shrink suitable ecosystem areas for wetland and mangrove species, many of which have narrow salinity tolerances. Rising sea levels might also shrink the area of mangrove forests or wetlands as the shoreline migrates landward. In severe droughts, reduced freshwater inflows could cause some freshwater wetlands to dry up completely. In addition to these slow-onset changes, increases in the frequency or magnitude of extreme events, like storm surges and high winds, could accelerate erosion of coastal wetlands, marshes, and mangrove forests.

4.1.2 BEACHES AND DUNES

Non-climate stressors already threaten beaches and dunes in most parts of the world; climate impacts will increase this pressure. Non-climate stressors include occupation of beach areas for tourism and human settlements, as well as the construction of dams, jetties, docks, or other hard structures. These hard structures can alter along-shore currents and sediment transport patterns, starving some beaches of sand. Removal or loss of vegetation from shoreline areas, as well as extractive resource use, can also lead to loss of sand and dune structures. Loss of beaches and dunes not only affects activities such as tourism; it also represents a loss of ecosystems and reduced natural protection from storm surge.

The most significant effects to beaches and dunes from climate change will likely come from sea level rise and increased storm intensity. However, separating climate-induced shoreline changes from changes caused by a variety of non-climate stressors will be difficult. Sea level rise can result in "coastal squeeze," in which beaches and dunes become trapped between rising seas and hard inland structures (UNFCCC, 2006). More intense storms can erode beaches and dunes, particularly in areas where sand is not naturally replenished because of dams or hard shoreline structures.

4.1.3 CORAL REEFS

Coral reefs are tropical and sub-tropical ecosystems that corals and algae build when they secrete calcium carbonate. Coral reefs provide shoreline protection, as well as habitat for fish and a large variety of other marine organisms. Other types of reefs also exist; for example, oysters form extensive reefs that perform the same function as coral reefs, but in temperate areas.

Many coastal residents, particularly those who rely on associated fisheries and tourism, depend on the health of reefs. Decades of pollution, sedimentation, coral mining, and destructive fishing practices have already severely degraded the world's reefs; approximately 20% of reefs have already been destroyed and another 40% are considered to be seriously damaged (NOAA, 2010). Given the key role of coral reefs as the primary habitat for up to 25% of all marine species, reef decline is a global issue (Buddemeier et al., 2004).

Of the major climate change stressors on the coastal zone, changes in sea-surface temperatures and acidity are the most likely to affect corals. Corals have a narrow temperature tolerance; prolonged periods of warm temperatures can lead to episodic mortality events, known as "coral bleaching" (e.g., Buddemeier et al., 2011). In addition, corals build their skeletons from calcium carbonate, whose stability depends on low-acidity water. Increases in atmospheric CO_2 levels, however, are increasing the acidity of the oceans, potentially undermining coral stability. Increasing water temperatures and ocean acidification are therefore adding new stresses to coral reefs. Terrestrial impacts from intense storms and runoff could also affect reefs because coral reefs can be sensitive to changes in water quality and sediment load.

Widespread coral reef bleaching and mortality events witnessed over the past few decades suggest that coral reef ecosystems generally have limited adaptive capacity in the face of changing ocean conditions (Baker et al., 2008). Protecting coral reefs from rising water temperatures, acidity, or extreme events ultimately will require global coordination to reduce greenhouse gas emissions and the resulting climate impacts. However, several medium-term options can protect reefs; such options include local and regional approaches to reducing non-climate stressors by improving environmental management practices. In particular, the improved management of reef fish, particularly to protect them from over-exploitation, is a promising approach to helping coral reefs recover from disturbances (Hoegh-Guldberg et al., 2007).

4.1.4 ESTUARIES AND LAGOONS

Estuaries are areas where fresh water and saltwater mix; they are typically found at river deltas. Coastal lagoons are shallow coastal water bodies that connect to the ocean intermittently. Estuaries and lagoons provide important habitat, especially for the reproductive purposes of some organisms. Estuaries are also the primary conduit for all pollution, nutrients, and sediments that flow from upland areas. People tend to settle near lagoons and estuaries, and so these areas experience the effects of many non-climate stressors.

Many of the species that inhabit lagoons and estuaries have adapted to the intermediate salinity conditions found in these areas. As with coastal wetlands, changes in salinity driven by sea level rise or reduced freshwater inputs could reduce suitable habitat in these areas. Other climate change impacts could result from the increased intensity of extreme events, which may destroy the barriers that protect lagoons from the open ocean. Sea level rise can also fundamentally alter estuaries and lagoons over longer timeframes.

4.2 INFRASTRUCTURE

Coastal zones often provide a home for human settlements, sea- and land-based transportation infrastructure, industrial and utility infrastructure, communications technology infrastructure, and water resources infrastructure that are of critical regional or national importance. For example, much of the world's food, fuel, and material goods move in and out of coastal ports. Coastal infrastructure typically appears as dense clustering around water bodies, such as bays or estuaries, and near freshwater sources such as rivers or lakes. Nearly all coastal infrastructure periodically experiences significant climate impacts.

Climate impacts on infrastructure are location-specific; however, some of the most direct climate change impacts to coastal infrastructure will come from sea level rise and from more intense or frequent storms and floods. Coastal infrastructure that might be at risk includes housing, industrial and commercial structures, and public buildings, such as health centers. Sea level rise and storm surges can corrode information and communications technology infrastructure, as well as inundate roads, railroads, airports, and ports with both seawater and debris. Sea level rise and storm surges can affect water and wastewater treatment infrastructure, causing water supply shortages, water quality issues through combined sewer overflows, and human health concerns because of increases in water-borne diseases. Rising groundwater levels in landfills or septic tank

systems can also allow contaminants to leach into groundwater supplies. Storms and rising sea levels threaten protective structures, such as dikes, levees, and seawalls, which redirect water and often serve as the first line of defense in protecting coastal communities. Coastal areas prone to subsidence will be more vulnerable to the effects of sea level rise, and increased groundwater withdrawals could exacerbate subsidence in some areas, particularly if average climate conditions become drier.

BUILDING A CLIMATE-SMART VIETNAM

The coastal city of Hue, Vietnam, experiences periodic flooding from typhoons, which sometimes inundate areas of the city with one meter (3.3 feet) of water. Flooding can occur quickly and in the past has resulted in deaths and damage. As the city has developed, the increase in paved areas has exacerbated flooding, which has increased runoff during storm events. USAID is working with Hue planners and managers to make decisions with climate impacts in mind. For example, the Climate Impacts Decision Support Tool helped city planners decide to site a new development farther back from the coastline than they had originally planned, and to modify agriculture in the coastal zone to grow more salt-tolerant crops (Reeder and Ferm, 2014).

City planners examining map of Hue, Vietnam.

Photo credit: S. Reeder.

4.3 COMMUNITIES AND LIVELIHOODS

Climate change stressors are likely to pose a threat to coastal livelihoods that depend on natural resources, especially in sectors such as fisheries, aquaculture, and tourism. In large part, as described in Section 4.1, changes to coastal and marine ecosystems will increase impacts to communities and income-generating livelihoods. For example, climate impacts on coral reefs and the fisheries they support may have implications for livelihoods in the fishery and tourism industries. Sea level rise may reduce the health and the extent of coastal wetlands, adversely affecting shellfish harvesting, aquaculture, and other livelihood activities in these areas. Other effects on communities and livelihoods may be more directly related to the infrastructure that supports coastal activities. For example, extreme events, such as storms and floods, may damage or destroy aquaculture facilities or agricultural crops, leading to decreased income and sustainability of the livelihoods in these sectors.

4.3.1 WILD FISHERIES AND AQUACULTURE

Wild fisheries and aquaculture are the world's leading sources of animal protein, with wild fisheries playing a much larger role than aquaculture. Fisheries consist of areas where wild fish or marine species are harvested for commercial purposes. Aquaculture is managed farming of fish or marine species. Aquaculture can be based in natural water bodies such as estuaries, or in land-based ponds or tanks. Fish provide 19% of the protein intake in developing countries; that amount can exceed 25% in the poorest countries and 90% in some coastal regions (Béné et al., 2007). In 2010, fisheries and aquaculture as an industry provided livelihoods for an estimated 54.8 million people, worldwide (FAO, 2012). As of 2008, approximately 45 million people were employed in aquaculture; at least 12% of these were women (FAO, 2010; IOC/UNESCO et al., 2011). In 2010, the Food and Agriculture Organization (FAO) estimated that wild fisheries and aquaculture supplied 148 million metric tons (163 U.S. tons) and estimated the value of world aquaculture production at US$119 billion and wild fisheries at approximately US$100 billion (FAO, 2012). At least US$50 billion is lost each year from poor wild fisheries management; improving management could increase production by 50% (World Bank and FAO, 2008). The fisheries and aquaculture industries range greatly in size, from subsistence to small-scale commercial fisheries to large regional fleets.

Climate change stressors, such as changes in sea-surface temperature, sea level, or storm surge may affect both wild fisheries and aquaculture. For example, higher sea-surface temperatures, changes in the upwelling that provides nutrients to support fish stocks, or changes in salinity may shift the location of suitable habitat for fisheries. In many wild fisheries, scientists have linked the migration of species to changing sea-surface temperatures and other climate conditions (e.g., Pinsky et al., 2013). As wild fish stocks migrate with changing conditions, communities built around reliable and abundant wild fishery resources could be forced to adapt, either by traveling large distances to follow the fish, or by shifting to alternative livelihoods. Simultaneously, some areas might experience a broadening of the fishery industry to take advantage of new ranges among fishery species.

Many of the impacts of climate change on aquaculture will be similar to those on wild fisheries, but with some potential differences. Although wild fisheries might be located in inland river and lake ecosystems, they mostly occur in coastal or deep water. Aquaculture, however, is typically located along the coast, in freshwater, or inland – not in deep water. More extreme precipitation events may therefore more significantly affect aquaculture in the coastal zone because of higher sediment and pollutant loads in runoff and in coastal waters. Plus, although wild fish stocks can migrate to track changing climate conditions, the fixed infrastructure on which aquaculture relies may leave fewer options for adaptation. For example, increased water temperatures in the coastal zone may lead to increased prevalence of aquatic pathogens and diseases. However, properly managed aquaculture conducted on land in enclosed systems can be quite efficient and can potentially withstand many climate impacts.[7]

7. Despite some hope that aquaculture can replace declining wild fisheries, aquaculture relies heavily on water resources and ecological services and may not be able to compensate for climate impacts on wild fisheries.

FISHERIES IMPROVED FOR SUSTAINABLE HARVEST

USAID's Fisheries Improved for Sustainable Harvest (FISH) Project has broadly applied an ecosystem-based approach to fisheries management to increase fish populations, improve food security, conserve biodiversity, and enhance the resiliency of Philippine coastal communities. Over seven years, improved management of 77,477 hectares (191,450 acres) of marine waters resulted in an average overall increase of 13% in fisheries biomass from 2004 baseline information, surpassing the program target of a 10% increase. Fish populations of multiple fisheries and species were improved in each region, reversing a long-term decline in fisheries and increasing productivity. In the Danahon Bank region, FISH demonstrated that well-managed fisheries can increase productivity three-fold, increase total harvest by 76%, and increase fish market values by 73%. Such changes in management patterns in these municipalities increased both food on the table and income for many coastal families dependent on the Danahon Bank for food and livelihoods. By reducing the impacts of non-climate stressors, projects like this can reduce the vulnerability of fisheries to climate change stressors.

Source: USAID, 2010.

4.3.2 TOURISM AND RECREATION

Tourism and recreation sustain the economies of many coastal communities in the developing world. Both tourism and recreation rely on healthy coastal ecosystems – including coral reefs, beaches, and wetlands – to attract tourists. As a result, the same climate change impacts that affect other coastal and marine resources can also negatively affect tourism and recreation. For example, increased storm intensity and sea level rise may accelerate the erosion of beaches (Nicholls et al., 2007), which are an important tourist attraction and recreational amenity in many coastal communities. Temperature increases may combine with rainfall changes to reduce water quality in coastal areas, leading to increased beach closures. A loss of beach area could also affect wildlife, such as sea turtles and shorebirds; wildlife is a key tourist attraction in some communities. Coral bleaching and mortality from increases in sea-surface temperature and from ocean acidification may also have negative implications for tourism. Even the perception of climate change impacts may change the way tourists look at destinations, potentially reducing their desirability and thereby affecting the livelihoods of local residents who depend on tourism.

4.3.3 WATER RESOURCES

Every community depends on sustainable freshwater of sufficient quality and quantity to provide for its population, to sustain economic development, and to maintain ecosystems. Climate-driven changes to water resource availability could disrupt populations and ecosystems in coastal zones. In coastal zones and small islands, the most significant climate change impacts to water resources are likely to come from increased temperatures, changes in average and extreme precipitation, and sea level rise. Reduced precipitation, coupled with increasing temperatures and evaporation, could affect water collection systems and groundwater infiltration, further decreasing the availability of water resources on islands that may already be water-stressed. Sea level rise will likely affect storm-water drainage and expand areas of groundwater and estuary salinization, decreasing the freshwater supply (Bates et al., 2008). Inundation, shoreline change, and saltwater intrusion because of rising sea levels may pose particular threats to underground aquifers on small islands (Field et al., 2014).

In addition to the direct effects of water supply changes on society, key ecosystems that support biodiversity and economic activities – ecosystems such as freshwater wetlands, mangrove forests, and coral reefs – may

also change under altered precipitation, temperature, and sea levels. These climate changes may indirectly reduce water availability or water quality and will alter ecological services and natural resource availability. Water is already in short supply or of poor quality in many coastal areas, so additional climate stressors may result in systems reaching a tipping point. For a more extensive discussion on climate change impacts on water resources, refer to *Climate Change and Water: An Annex to the USAID Climate-Resilient Development Framework* (USAID, 2014a).

4.3.4 HUMAN HEALTH

Human health is closely tied to reliable and clean water resources. It also depends on factors that may be indirectly related to climate, such as the presence of disease vectors. Coastal flooding will probably cause some of the most acute climate impacts on human health and safety. Climate-related flooding could be a result of inundation from sea level rise and storm surge or from extreme precipitation events that overwhelm storm sewers or drainage structures. While the means to address these different types of floods may be very different, their impacts on human health are similar. Storms and floods can influence human health and well-being directly, and they can also have indirect impacts on health by, for example, degrading water quality and promoting disease, such as diarrhea and cholera. In addition to their effects on physical well-being, extreme events can also have effects on mental and emotional health because of the stress and anxiety that displacement and greater susceptibility to infection can create (Field et al., 2014). These impacts are likely to put additional stress on already stretched health systems in developing countries.

Climate change will also influence the spread of disease in coastal communities, primarily through the expansion of suitable conditions for disease-carrying insects. For instance, the mosquito vector (*Aedes aegypti*) that is responsible for the spread of dengue fever can expand geographically, reproduce more frequently, and remain active for more days each year with higher temperatures (Knowlton et al., 2009; Scott and Morrison, 2010). Diseases may also return to areas where health workers had eradicated them in the past. In addition, rising temperatures may influence the spread of emergent diseases, such as West Nile virus, Chikungunya virus, and Rift Valley fever virus (Tabachnick, 2010). Viruses are not the only diseases that may benefit from higher temperatures; disease-causing bacteria may also multiply. For example, studies have linked increases in sea-surface temperature to an increased incidence of cholera (Islam et al., 2009; Paz, 2009; Reyburn et al., 2011).

5. PRINCIPLES OF ADAPTATION FOR COASTAL ZONES

People have gained adaptation experience in recent years in the area of coastal zone management, as well as in other pertinent sectors and fields, such as disaster risk reduction. In this section, we highlight some good practices and lessons learned through experience. These principles of adaptation can help inform adaptation planning and implementation in the coastal context.

The key to taking action to address climate vulnerability is first to understand how climate impacts might affect the achievement of intended development outcomes in the coastal zone, as well as any specific management or planning objectives there. The purpose of considering adaptation actions is to ensure that climate impacts will not significantly impede projects that planners and managers are undertaking to help countries develop. We call this the "development-first approach": keeping development on track is paramount, and requires considering how climate may affect development (see USAID, 2014b).

Taking adaptation action to address climate impacts does not necessarily require a vastly different manner of thinking, approach to doing business, or changes to policy or operations. Adaptation actions are often incremental and have multiple benefits. Most adaptation actions address both climate variability and climate change. Many adaptation actions also address non-climate stressors. For example, adaptation actions such as restoring coastal wetlands or dune ecosystems may create a coastal zone that is more resilient to storm surge, population growth, *and* climate change. Nevertheless, some aspects of climate change can pose serious risks to coastal ecosystems, infrastructure, or communities and may require more significant changes, especially in situations when planners and managers are considering high-cost infrastructure investments or other long-lived decisions.

Below are some best practices for managing climate vulnerability. Planners and managers should take these general principles into consideration in planning and implementing specific adaptation actions in the coastal zone, such as those identified in Appendix A. For example, planners and managers should consider addressing non-climate stressors (Section 5.6) and preparing for multiple climate futures (Section 5.3) when planning adaptation actions for the tourism sector (Adaptation Action 8 in Appendix A). These principles

provide general ways of approaching climate change adaptation that have been successful in the coastal zone and in various sectors, regions, and levels of government.

5.1 MAINSTREAM ADAPTATION

Rather than create an entirely new or parallel set of programs and policies to cope with climate vulnerability, we suggest that planners and managers incorporate consideration of climate impacts into existing decision-making, a concept known as "mainstreaming." The best time to address climate impacts is through established decision-making processes for the coastal zone; mainstreaming leverages existing resources, requires minimal resources to implement, avoids the disruption that reorganization can create, and generates less opposition than creating new institutions. The importance of mainstreaming underlies the new USAID climate-resilient development framework (USAID, 2014b) and the development-first approach.

5.2 ENGAGE IN NO-REGRETS DECISION-MAKING

No-regrets decisions make sense under both current and historical climate conditions and pay off regardless of what the future looks like. For example, reducing coastal communities' reliance on sensitive resources for their livelihoods by promoting sustainable alternatives is likely to improve resilience under all climate conditions. Investing in such projects provides immediate benefits by improving livelihoods and protecting coastal resources, but may also provide additional benefits under climate change by reducing the sensitivity of coastal resources to climate stressors such as ocean acidification or increased sea-surface temperatures. Some people may object that the idea of no-regrets is not sufficiently ambitious to tackle the challenges of climate change; however, developing countries often face significant infrastructure and capacity deficits that make no-regrets decisions a necessary first step to a more climate-resilient future. Still, a strategy built only on no-regrets options may not be sustainable over the long-term, once changes in our climate begin to create substantial challenges. Therefore, no-regrets decision-making is best thought of as a first step before tackling long-term adaptation.

5.3 ADDRESS NON-CLIMATE STRESSORS

Non-climate stressors, such as population growth and urban development, pollution, environmental degradation, and extractive resource use may be more significant contributors to overall vulnerability than climate stressors. These non-climate stressors may be easier to address than climate stressors like sea level rise or increased sea-surface temperatures. Furthermore, reducing non-climate stressors that degrade critical ecosystems can increase their resilience to climate variability and change. Thus, adapting successfully to climate impacts may depend on addressing the most damaging non-climate stressors contributing to vulnerability. For example, managing pollution or excessive nutrient or sediment loading may increase the ability of coral reefs to withstand climate impacts. More essentially, planners and managers should undertake development in a way that does not *increase* vulnerability to risks from climate impacts.

5.4 PREPARE FOR MULTIPLE POSSIBLE CLIMATE FUTURES

Although this document describes the state-of-the-science regarding climate impacts on the coastal zone, much uncertainty exists in these projections. Rather than looking to the scientific community to provide a single answer for what the future holds, planners and managers should prepare for a range of future climate conditions. Often, although the direction of projected climate change is known, the magnitude is less certain. A future with large increases in sea-surface temperature and ocean acidity might require a different approach than a future with small increases in sea-surface temperature and ocean acidity. Nevertheless, some approaches might operate reasonably well under either scenario. Long-term resilience calls for an approach to

coastal planning and management that can respond to a range of future climate conditions. A key aspect of this is strengthening adaptive capacity to respond to climate impacts as their magnitude and direction of change become clearer. For example, increasing the availability and accessibility of climate information to coastal planners and managers enables them to more effectively prepare for and respond to climate variability and extremes in the short-term, as well as climate change over the long-term.

5.5 ACKNOWLEDGE THAT CLIMATE VARIABILITY AND CHANGE ARE DRIVERS IN COASTAL SYSTEMS

Planners and managers in coastal areas should explicitly consider the impacts of climate change, as well as climate variability, in all management, planning, and policy actions. This broad effort will ensure that policymakers collectively take climate impacts into account in their decisions about coastal and marine ecosystems, infrastructure, communities, and livelihoods. Such consideration often begins with a vulnerability assessment. Vulnerability assessments help planners and managers consider if and how current weather and climate or projected future changes may affect the objectives of a project or agency in managing resources. Such assessments can inform the identification and selection of adaptation actions.

5.6 PROMOTE ADAPTIVE MANAGEMENT

Planning for adaptation is a dynamic, iterative process that entails reviewing strategies, programs, and projects throughout the course of implementation to ensure that they meet their objectives. A flexible, adaptive approach – rather than a rigid, prescriptive one – allows for either taking incremental steps toward reducing vulnerability or postponing decisions until better information is available. An example of adaptive management is purchasing land for infrastructure relocation, but only relocating the infrastructure if necessary. Adaptive management also enables leaders to take advantage of unexpected opportunities. This is particularly important in the coastal context, where the high risk of potential impacts from extreme events such as storms can also provide valuable adaptation opportunities. For example, rebuilding infrastructure destroyed in a storm provides an opportunity to update building standards and better integrate adaptation considerations into new infrastructure investments.

5.7 EXAMINE AND LEARN FROM BEST PRACTICES

Many planners and managers in the coastal zone are already incorporating climate impacts into their decision-making. Coastal planners and managers should review actions taken by other levels of government, sectors, or regions for lessons and innovations that can be applied to their own circumstances. Although many current best practices are targeted toward planning for climate variability, they can be modified and adapted to address climate change as well.

5.8 REMOVE BARRIERS TO ADAPTATION

Some existing laws, funding mechanisms, and management approaches may function under the outdated assumption that the climate does not change over the long-term. As a result, some of these approaches can function as barriers that discourage or prevent adapting to a changing climate or that promote behavior that increases climate vulnerability. Also, the different bodies that govern management of resources in the coastal zone (e.g., water resources, urban development, agriculture and forestry, fisheries) often have uncoordinated policies that can discourage or prohibit adaptations that could reduce vulnerability to climate impacts. For example, a municipality may have a mandate to promote industrial development, while the environment ministry may have an incompatible mandate to protect mangrove forests. In addition, in many developing countries, weak legal frameworks, unenforced regulations, poor institutional and human resources, and

inadequate resource tenure and rights systems limit the available options for improving coastal resource management. Government agencies must acknowledge and improve outdated management approaches, which constrain the variety of options available to properly manage climate impacts.

5.9 RECOGNIZE THE SCALES AT WHICH PEOPLE MAKE DECISIONS

People have to make adaptation decisions at multiple geographic and decision-making scales, from individual fishermen to national ministries to international development agencies. Planners and managers must recognize the capacities, as well as the limitations, of any particular decision-making context so they can propose suitable adaptations at the appropriate level. Temporal scales are important, too. Some climate impacts will have near-term effects, while others will bring slow-onset challenges. An awareness of the temporal scale of anticipated climate impacts, as well as possible adaptation options, will help planners and managers select sensible adaptations that address near- and long-term impacts despite limited resources.

5.10 TAKE ADVANTAGE OF CLIMATE OPPORTUNITIES

Climate change may result in both negative and positive consequences for coastal communities and ecosystems. Part of adaptation is identifying opportunities and alternatives. In the case of coastal communities, this may entail taking advantage of alternative livelihood options in areas such as fishing, aquaculture, or tourism; in the case of ecosystems, this may mean closer coordination and collaboration on transboundary management. For example, recognizing that they face similar and shared climate impacts, such as increases in sea-surface temperature, countries of the Western Indian Ocean region have already begun to approach the management of coastal and marine ecosystems using regional instruments, such as the Nairobi Convention, as a way to collaborate across international borders.

NATIONAL ADAPTATION PLANS AND COASTAL ZONES

In June 2013, 30 representatives from 11 of the 15 member countries of the Economic Community of West African States (ECOWAS), academia, and key regional institutions convened in Accra, Ghana, for the West Africa Coastal Climate Change National Adaptation Planning Workshop, hosted by ECOWAS and USAID. The objectives of the workshop were to demonstrate an approach for integrating adaptation into development planning and decision-making, with a focus on coastal zones, and to agree on priorities for regional support of countries' national adaptation planning processes.

The 11 participating countries of ECOWAS.

Source: Stratus Consulting.

The workshop highlighted the similar climate and non-climate stressors that affect the coastal zones of West African countries, and the transboundary nature of many climate impacts. Participants discussed opportunities to learn from other countries in the region, and to coordinate and collaborate on responses to coastal zone stressors and impacts. Priority areas for regional action included mainstreaming climate change into policy, coastal erosion control measures, regional coordination to harmonize policy, and integrated natural resource management. To support these regional priorities and assist countries' national adaptation planning processes, regional institutions discussed the necessity of understanding gaps in meeting countries' needs, defining the roles and responsibilities of specific institutions, engaging relevant regional actors, and coordinating actions among institutions. They agreed that initial next steps should include mapping the activities of regional institutions to facilitate coordination and leveraging, as well as establishing a regional clearinghouse for research relevant to coastal issues.

6. OVERVIEW OF ADAPTATION ACTIONS

This section outlines the basic categories of adaptation actions for the coastal zone and provides a short introduction for each action; for more detail on specific categories, please refer to Appendix A. Although these actions appear individually, both below and in Appendix A, an integrated approach that combines a number of actions may often provide the most benefit. Generally, good information and the capacity to use it are prerequisites to successful adaptation. Appendix A discusses these issues in more detail.

USAID identifies three categories of priority activities for its adaptation programming:

- ***Improved science and analysis to inform decision-making concerning topics sensitive to climate.*** Adaptation activities may include investing in improved scientific capacity, such as access to and use of climate information and evidence-based analysis. This scientific capacity is important to help societies identify and monitor vulnerabilities and evaluate the costs and benefits of potential adaptation strategies. The more appropriate, comprehensive, and accessible the data and analysis, the better the decisions that people from the community to the national level can make to reduce climate vulnerability.

- ***Improved governance to address climate-related risks.*** Adaptation activities can promote improved public communication and education; participatory policymaking and planning; and strengthened advocacy at the community, civil-society, and private-sector levels to influence climate decision-making. Agencies can support processes during decision-making that ensure consultation with a broad range of partner country stakeholders, including women and traditionally marginalized populations. Such processes include working with government ministries and agencies concerned with climate to ensure that they engage in adequate and broad-ranging consultation and that they coordinate vertically across scales, and horizontally across institutions at both the planning and implementation stages.

- ***Piloting, implementing, and evaluating effective adaptation strategies to address climate-related risks.*** Adaptation activities can support site-specific, on-the-ground actions to reduce climate vulnerability in sectors including agriculture, health, urban planning and infrastructure, water management, and disaster risk reduction. These activities should target specific climate stressors of concern, and should focus on learning and demonstrating what works, what does not work, and why.

DETAILED DISCUSSIONS OF ADAPTATION ACTIONS

See Appendix A for detailed discussions of each adaptation action.

The first eight adaptation actions, below, largely fall into the third category of piloting, implementing, and evaluating adaptation strategies. However, information[8] and governance[9] issues are important in several of these actions. The ninth adaptation action focuses specifically on governance issues. We group the adaptation actions into categories: protecting and maintaining the functionality of marine and coastal ecosystems (Actions 1–2), managing the built environment (Actions 3–4), protecting coastal communities (Action 5), strengthening coastal and marine-based livelihoods (Actions 6–8), and strengthening coastal governance (Action 9). However, many of the particular adaptation actions we discuss also have important co-benefits that apply to other categories. See Exhibit 4 for illustrative examples of adaptation actions, which we number in accordance with how we categorize the actions in Appendix A.

6.1 PROTECT AND MAINTAIN FUNCTIONALITY OF MARINE AND COASTAL ECOSYSTEMS

Coastal ecosystems often provide critical services that have economic value to many developing countries, such as food security and flood protection. By helping improve the resilience of ecosystems, developing countries can sustain or even enhance ecosystem benefits in the face of climate variability and change. The two adaptation actions below reduce stressors on coastal ecosystems, thereby sustaining or improving their ability to provide critical ecosystem services.

ADAPTATION ACTION 1: RESTORE AND PROTECT COASTAL ECOSYSTEMS

Degraded ecosystems, whether as a result of climate or non-climate stressors, can be targeted for restoration to rebuild their functionality and improve their resilience to future climate impacts. Restoration of coastal ecosystems could involve removing or modifying human structures that disrupt natural coastal dynamics, such as bulkheads and seawalls; restoring or reintroducing ecosystems; building reefs or constructing artificial reefs; and replanting mangrove forests or seagrass meadows. Options for protecting coastal ecosystems include regulating development in sensitive coastal areas and establishing conservation areas.

ADAPTATION ACTION 2: REDUCE NON-CLIMATE STRESSORS THAT DEGRADE COASTAL ECOSYSTEMS

Many coastal ecosystems are already experiencing the effects of water pollution, land-use change, man-made controls of inland waterways, and extraction of resources. Options for reducing non-climate stressors include reducing industrial sources of contamination, reducing pollution from human and municipal wastes, improving land-management practices to reduce sedimentation and nutrient loading, and managing invasive species. To implement many of these actions, coastal municipalities will need to have adequate governance structures in place to communicate these problems to the public, develop regulations, and enforce them.

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8. Scientific information on weather and climate supports better decision-making. In many cases, especially in developing countries, practitioners may be working with limited scientific information (e.g., a poor climate observation network or a record with many data gaps). Improved science and analysis may be a necessary precursor to deciding among competing adaptation actions. In such cases, generating scientific information to support decision-making is appropriate. We emphasize, however, that many adaptation actions can reduce climate vulnerability in the near-term, even with preliminary or incomplete information or data; this is generally the case for no-regrets adaptations.

9. Governance can be a critical enabling condition that defines the sustainability, effectiveness, and practicality of any given adaptation action, [USAID, Forthcoming (b)]. Planners and managers may need to directly address governance issues to enable many adaptation actions. However, because governance challenges can be difficult and time-consuming to tackle, we encourage identifying opportunities to take action that improve resilience despite poor governance.

Adaptation Action 1: Restore and protect coastal ecosystems

Adaptation Action 2: Reduce non-climate stressors that degrade coastal ecosystems

Adaptation Action 3: Protect infrastructure and assets

Adaptation Action 4: Relocate infrastructure and assets

Adaptation Action 5: Disaster prevention, planning, and preparedness

Adaptation Action 6: Protect and manage fisheries

Adaptation Action 7: Protect and manage aquaculture

Adaptation Action 8: Adapt tourism planning and operations

Adaptation Action 9: Strengthen coastal governance

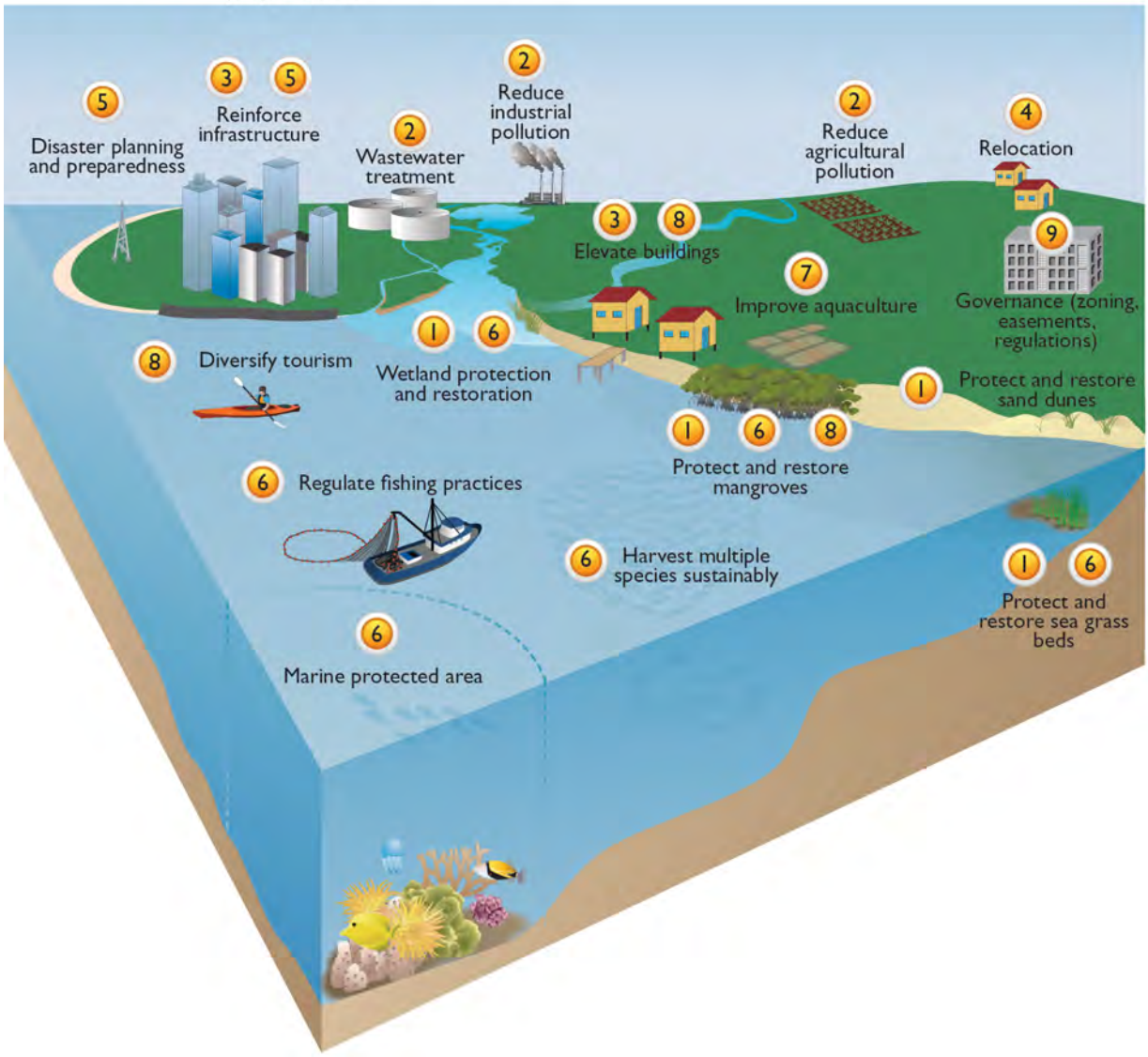

EXHIBIT 4. ILLUSTRATIVE EXAMPLE OF COASTAL ZONE ADAPTATION ACTIONS. The numbers in the exhibit correspond to the adaptation action numbers in Sections 6.1 through 6.5, below, and in Appendix A. For example, "2" above corresponds to "Adaptation Action 2" in both the text, below, and in Appendix A.

6.2 MANAGE THE BUILT ENVIRONMENT

Especially in developing countries, many opportunities exist for reducing the vulnerability of infrastructure to flood damage. The adaptation actions below encompass two major categories of action: protection and relocation. Deciding when to protect versus relocate infrastructure will depend on site-specific conditions, including the nature and location of the infrastructure, the elevation and shape of the coastal zone, and other factors. Strong governance systems are needed to inform these development decisions in the face of a changing climate.

ADAPTATION ACTION 3: PROTECT INFRASTRUCTURE AND ASSETS

Protection, in this context, helps assets within the built environment withstand storm surges, inundation, erosion, and other climate-related coastal impacts. The types of assets that could be protected include transportation infrastructure, potable water systems, sanitation systems, solid waste systems, energy systems, information and communications technology, flood control structures, cultural heritage assets, ports, and buildings (USAID, 2013). Protection could entail building new structures, such as levees; building adaptive structures, such as stilted buildings that allow water to flow under them; or modifying building codes to incorporate setbacks that reduce the vulnerability of new structures. Planners and managers should recognize that protecting the built environment can come at the expense of maintaining beaches and wetlands (see Adaptation Action 1); decision-making will need to balance the pros and cons of each action to determine the best compromise. Alongside protection, decision-makers should consider complementary actions, such as managed relocation of infrastructure away from coastal areas (see Adaptation Action 4) and non-structural approaches to reducing destructive inundation (see Adaptation Action 5). Note that the concept of green infrastructure, such as restoring mangrove forests to manage flooding or storm surge, is covered under Adaptation Action 1.

ADAPTATION ACTION 4: RELOCATE INFRASTRUCTURE AND ASSETS

In the long-term, managed retreat from the shoreline may be the most cost-effective solution for many coastal communities seeking to adapt to increased coastal hazards because of sea level rise and storms. Managed retreat encompasses a portfolio of strategies, programs, and projects, including planning and policy development, as well as physically relocating assets and compensating property owners. Development restrictions and land acquisition policies, such as those described in Adaptation Action 3, can help facilitate future relocation. Relocation can occur either as a disaster-mitigation strategy following a severe storm or as an anticipated adaptation to minimize exposure to coastal risks. In all cases, successful relocation strategies require working closely with communities and engaging stakeholders to ensure that relocation efforts are transparent and fair. Relocating assets can have ecological benefits, including maintaining natural shoreline dynamics and enabling shoreline ecosystems to migrate inland. However, in many cases, political barriers, humanitarian concerns, and legal disputes may delay or entirely prevent relocating facilities and infrastructure.

6.3 PROTECT COASTAL COMMUNITIES

Large populations in developing countries live along the coasts and are vulnerable to climate impacts. Some of the stressors, impacts, and responses are identical to those discussed in Adaptation Actions 3 and 4. However, additional adaptation actions are available to protect coastal communities, including process-driven opportunities such as disaster preparedness.

ADAPTATION ACTION 5: DISASTER PREVENTION, PLANNING, AND PREPAREDNESS

In recognition of the vulnerability of coastal communities to climate impacts, this adaptation action focuses on ways to build community capacity to prepare for extreme climate events and disasters. Although natural hazards are not preventable, the deaths, destruction of infrastructure, and loss of resources from these hazards can be mitigated. For example, when coastal communities have adequate warnings of heavy rains, community leaders can mandate the evacuation of more vulnerable populations, reducing their exposure. Specific actions include planning and coordination efforts, identification of hazards, and assessment of vulnerability. These efforts support the development of early notification systems through improved forecasting abilities and communications systems. Disaster prevention, planning, and preparedness help communities anticipate and cope with climate impacts. Furthermore, prevention efforts that restore native ecosystems protect inland areas and infrastructure from damages, making them more resilient to climate impacts (see Adaptation Action 1).

6.4 STRENGTHEN COASTAL AND MARINE-BASED LIVELIHOODS

Coastal resources provide coastal residents with livelihoods, ranging from fishing and aquaculture to beach and coral reef-based tourism. One way to address the climate vulnerability of livelihoods is to protect the resources that sustain the livelihoods; another is to plan and manage livelihood activities sustainably.

ADAPTATION ACTION 6: PROTECT AND MANAGE FISHERIES

The emphasis of this adaptation action is to prepare for and respond to climate impacts to coastal fisheries. Climate impacts will be more severe for coastal ecosystems that are already in poor health or that are characterized by low biodiversity. Adaptation actions that reduce non-climate change stressors on fisheries will enable them to better withstand climate impacts. These adaptation actions might include habitat protection and conservation through marine protected areas (MPAs); regulations to protect specific species, such as gear-type restrictions, quotas, and adaptive fisheries management; or broader fisheries management strategies, such as diversifying catch, reducing waste and loss, and promoting alternative livelihood opportunities.

ADAPTATION ACTION 7: PROTECT AND MANAGE AQUACULTURE

If properly managed, aquaculture can contribute to climate-resilient development by increasing food security, providing jobs, increasing trade, and making sustainable use of ecological services. However, if aquaculture is not managed properly, it can have potential negative impacts on ecosystem health and community resilience. The range of adaptation options, which attempt to address these potential negative consequences, include buffering aquaculture systems from climate stressors by improving water management, using effluents for crop fertilization, and cultivating fish and plants in the same system; relocating aquaculture infrastructure to lower-risk areas; increasing the efficiency of feed use; diversifying the species cultivated in aquaculture operations; protecting water from acidification; and improving the governance and regulation of the aquaculture industry.

ADAPTATION ACTION 8: ADAPT TOURISM PLANNING AND OPERATIONS

Tourism is a major driver of many coastal economies, but is highly vulnerable to many of the coastal climate impacts that we describe in this annex. Adapting tourism planning and operations to address climate impacts can help strengthen coastal and marine-based livelihoods by protecting the unique features and services that tourists seek. Additionally, carefully considered planning efforts can help coastal communities avoid

adaptation actions that might have apparent short-term benefits, but that may cause negative impacts in the long-term. Adapting tourism involves diversifying tourist activities, protecting or relocating tourist facilities and services, protecting ecosystems and ecosystem services, improving the provision of information about climate risks, and acquiring and providing insurance. The variable adaptive capacity of tourism operators and destination communities should be considered when determining which of these actions will be most feasible and beneficial to implement.

6.5 STRENGTHEN COASTAL GOVERNANCE

Coastal governance is the formal and informal political, social, economic, and administrative systems that determine how resources are allocated, used, developed, managed, and delivered in the coastal zone. The ways that planners and managers in the coastal zone govern their resources has a critical influence on the sustainability, effectiveness, and practicality of any given adaptation action. In addition, the social, political, and economic context, such as the political economy, surrounding some of these adaptation actions often require a degree of governance intervention for the actions to have a realistic chance of success.

ADAPTATION ACTION 9: STRENGTHEN COASTAL GOVERNANCE

Strong governance is important for all adaptation actions in the coastal zone, particularly because (a) poor governance frameworks are an obstacle to creating and implementing sustainable adaptation actions, (b) community and country characteristics shape the feasibility and effectiveness of potential climate-related interventions, and (c) adaptation actions present an opportunity to integrate initiatives that strengthen governance and support sustainable development. Adaptation options to strengthen governance include integrated planning and management strategies, improving decision-making efficacy, enhancing education and outreach activities to communicate about risks, increasing regulatory compliance assistance, and improving enforcement capacity. The potential effectiveness of options for strengthening coastal governance varies across countries because of location-specific environmental, political, social, and economic characteristics. For example, differences in national- and state-level governmental processes and cross-governmental cultural norms may influence the effectiveness of national-level adaptation actions.

7. SUGGESTED RESOURCES

This section presents a list of recommended resources for further reading on the topics discussed in this annex. Many of these resources appear as citations throughout the annex, but we include additional resources that may be of interest to development practitioners.

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APPENDIX A: ADAPTATION ACTIONS

As the main text of this document discusses, coastal zones lie at the interface between land and sea, and are vulnerable to a wider range of climate stressors than many other regions. For example, year-to-year variability in climate – such as droughts, intense precipitation events, storm surges, and sea-surface temperature anomalies all affect coastal zones. Additional effects will come from climate change, such as rising air and sea-surface temperatures, changing precipitation regimes, intensifying storms, rising sea levels, and increasing ocean acidification. Therefore, climate change adds a new dimension to coastal zone planning and management. It is important to note that along urban coastlines non-climate stressors such as population growth, urban development, pollution, environmental degradation, and extractive resource use also pose immediate and severe threats and can be exacerbated by climate variability and change.

The main text of this document gave an overview of various adaptation actions that planners and managers can employ to improve coastal resilience to climate impacts. This appendix describes these adaptation actions in further detail, covering (a) how the action contributes to climate resilience, (b) a variety of specific options within the category of action, and (c) important considerations for implementation. In many cases, these adaptation actions could also help to address the hazards posed by non-climate stressors.

INTEGRATED APPROACHES TO CLIMATE-RESILIENT DEVELOPMENT

Before delving into the individual adaptation actions, we wish to note that a number of broader principles should be considered regardless of the adaptation action selected.

Integrating actions across categories. Often, the most prudent and effective path for climate-resilient development will entail the integrated application of a suite of adaptation actions drawn from multiple categories. For example, coastal urban areas will face significant risks from climate variability and change – including risks to infrastructure, communities, and livelihoods. In this situation, an integrated mix of adaptation actions may be most effective, including options drawn from *Adaptation Action 1: Restore and Protect Coastal Ecosystems, Adaptation Action 3: Protect Infrastructure and Assets, Adaptation Action 4: Relocate Infrastructure and Assets,* and *Adaptation Action 5: Disaster Prevention, Planning, and Preparedness*. A wide variety of specific options often exists within each category; planners and managers can link these strategically to increase their effectiveness.

Assembling climate change information. Coastal planners and managers cannot make informed decisions on appropriate adaptation actions without access to information on the climate and non-climate stressors currently affecting their region, and the potential future changes in climate their regions may face. Climate information might include infrastructure maps illustrating areas that are vulnerable to sea level rise or flooding, historical climate records that can be used to evaluate the distribution and magnitude of past extreme events, or water-quality data summarizing baseline conditions in the coastal zone. These pieces of information must be assembled to help inform future development decisions in the context of a changing climate.

Distributing climate change information. The ability to use this information is closely linked to capacity. Coastal planners and managers must have the capacity to gather relevant information, assemble it, and make it available to those who will use it. This will require time, resources, and personnel to gather and assemble relevant information; coordination among different stakeholders to ensure that the information can be broadly disseminated; and secure and resilient facilities to house digital and paper sources of information.

Using integrated coastal zone management (ICZM). ICZM is one way to combine the aforementioned strategies; an ICZM approach promotes the compatibility and balance of coastal uses, cooperation between decision-making bodies and stakeholders, the use of preventive and precautionary approaches that limit coastal development in unsustainable areas, and an awareness of the economic and environmental costs and benefits of coastal management strategies (UNEP, 2010). Long-term planning, facilitated by an ICZM approach, is necessary to avoid investing in actions that inadvertently harm the coastal environment, exacerbate climate impacts, and put more people and coastal property at risk.

SPECIFIC ADAPTATION ACTIONS

The remainder of this appendix describes individual adaptation actions, many of which can form a part of an ICZM strategy. These actions are as follows:

- Protect and maintain the functionality of marine and coastal ecosystems
  - *Adaptation Action 1: Restore and protect coastal ecosystems*
  - *Adaptation Action 2: Reduce non-climate stressors that degrade coastal ecosystems*
- Manage the built environment
  - *Adaptation Action 3: Protect infrastructure and assets*
  - *Adaptation Action 4: Relocate infrastructure and assets*
- Protect coastal communities
  - *Adaptation Action 5: Disaster prevention, planning, and preparedness*
- Strengthen coastal and marine-based livelihoods
  - *Adaptation Action 6: Protect and manage fisheries*
  - *Adaptation Action 7: Protect and manage aquaculture*
  - *Adaptation Action 8: Adapt tourism planning and operations*
- Strengthen coastal governance
  - *Adaptation Action 9: Strengthen coastal governance*

Adaptation Action 9 is cross-cutting; governance considerations are referenced in many of the other adaptation actions.

Exhibit A.1 illustrates many of the adaptation actions described in this appendix. Although it does not include all of the specific options within each adaptation action category, this illustration provides a visual representation of the types of adaptations that may be used to improve the resilience of the coastal zone. Visual representations of these key examples appear at the beginning of each adaptation action, but do not necessarily include all of the options for each action. Note that some adaptation actions serve more than one category and that some categories may benefit from integrating a variety of actions illustrated in the exhibit.

Adaptation Action 1: Restore and protect coastal ecosystems

Adaptation Action 2: Reduce non-climate stressors that degrade coastal ecosystems

Adaptation Action 3: Protect infrastructure and assets

Adaptation Action 4: Relocate infrastructure and assets

Adaptation Action 5: Disaster prevention, planning, and preparedness

Adaptation Action 6: Protect and manage fisheries

Adaptation Action 7: Protect and manage aquaculture

Adaptation Action 8: Adapt tourism planning and operations

Adaptation Action 9: Strengthen coastal governance

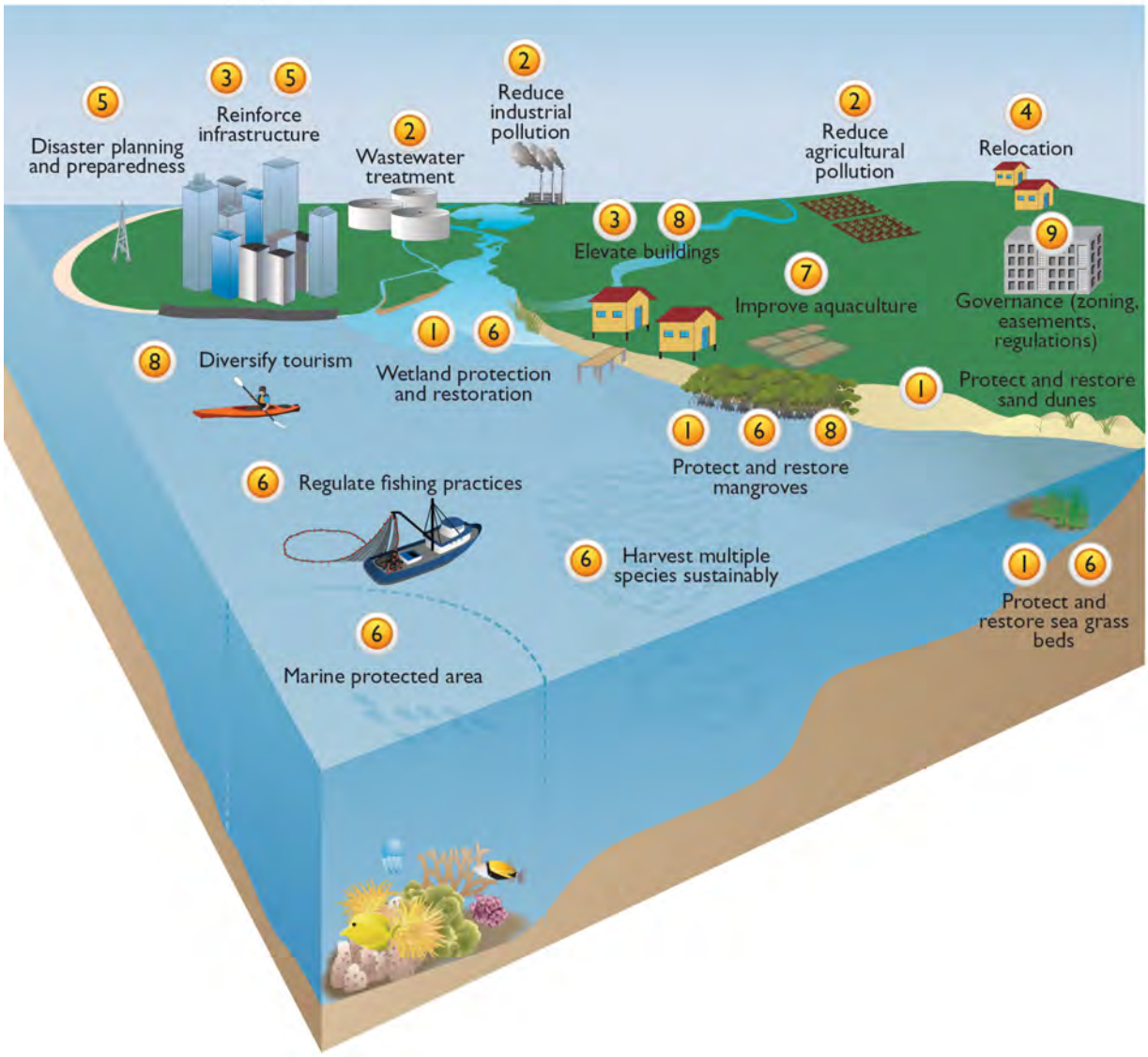


EXHIBIT A.1. ILLUSTRATIVE EXAMPLES OF COASTAL ZONE ADAPTATION ACTIONS. The numbers in the exhibit correspond to the adaptation action number in Appendix A, as well as the descriptions of the adaptation actions in Section 6 of the main document.

CLIMATE-RESILIENT DEVELOPMENT: INTEGRATING ELEMENTS FROM MULTIPLE ADAPTATION ACTION CATEGORIES

Practitioners will likely want to draw on adaptation options from many adaptation action categories. Consider, for example, the need to address climate-related stressors on fisheries. Options drawn from multiple categories may work together as part of an integrated management approach. Some examples of using cross-category actions for fisheries might include:

- ***Adaptation Action 1: Restore and protect coastal ecosystems*** aims to use natural buffers to protect coastal fisheries from climate impacts. For example, creating MPAs can preserve spawning areas for species that are affected by rising water temperatures.
- ***Adaptation Action 2: Reduce non-climate stressors that degrade coastal ecosystems.*** By lessening stressors on coastal ecosystems they can better respond to climate impacts. For example, coral reefs that support fisheries would be more resilient to climate change if excessive nutrient or sediment loading is reduced.
- ***Adaptation Action 4: Relocate infrastructure and assets*** is an option for communities or assets subject to significant or potential repeated climate impacts. Relocation has the co-benefit of supporting restoration of coastal ecosystems (Adaptation Action 1).
- ***Adaptation Action 5: Protect and manage fisheries.*** Climate impacts could affect the availability of certain species for harvesting. This adaptation option offers options for preserving fishery resources, by regulating practices that cause waste and diversifying the catch to reduce stress on overfished species.
- ***Adaptation Action 6: Protect and manage aquaculture.*** Aquaculture can provide food and livelihoods in coastal communities and provide alternatives to wild fisheries. This adaptation action offers options for buffering aquaculture and aquaculture inputs from climate impacts.
- ***Adaptation Action 8: Adapt tourism planning and operations.*** Tourism provides for many livelihoods in the coastal zone that could be alternatives to fishing.
- ***Adaptation Action 9: Strengthen coastal governance.*** Adaptation actions that strengthen coastal governance, such as increasing compliance assistance and enforcement capacity, complement and enhance other adaptation actions, such as those described above.

ADAPTATION ACTION 1: RESTORE AND PROTECT COASTAL ECOSYSTEMS

Climate variability and change present a number of risks to marine and coastal ecosystems, including reefs, barrier islands, beaches and sand dunes, river deltas, coastal forests, mangrove forests, marshes, wetlands, tidal flats, and subtidal ecosystems such as seagrass meadows. Sea level rise will cause coastal ecosystems to migrate inland over time, higher temperatures will shift habitats for many species and threaten coral reefs, and more frequent and intense storms may lead to ecosystem damages. These effects can impair ecosystem function and reduce the benefits that people receive from these ecosystems. Common benefits or services that coastal ecosystems provide are protection, food security, and recreation. Protecting ecosystems promotes climate-resilient development and helps ensure that ecosystem benefits and services continue into the future.

HOW CAN RESTORATION AND PROTECTION OF COASTAL ECOSYSTEMS CONTRIBUTE TO CLIMATE-RESILIENT DEVELOPMENT?

Although management strategies designed to preserve coastal ecosystems will provide clear benefits to the ecosystems themselves, these strategies can also play an important role in climate-resilient development. Coastal ecosystems collectively provide critical ecosystem functions that are important to human society, including storm protection, flood mitigation, erosion control, fisheries, water storage, groundwater recharge, pollution abatement, and retention and cycling of nutrients (USAID, 2009; Ellison, 2012).

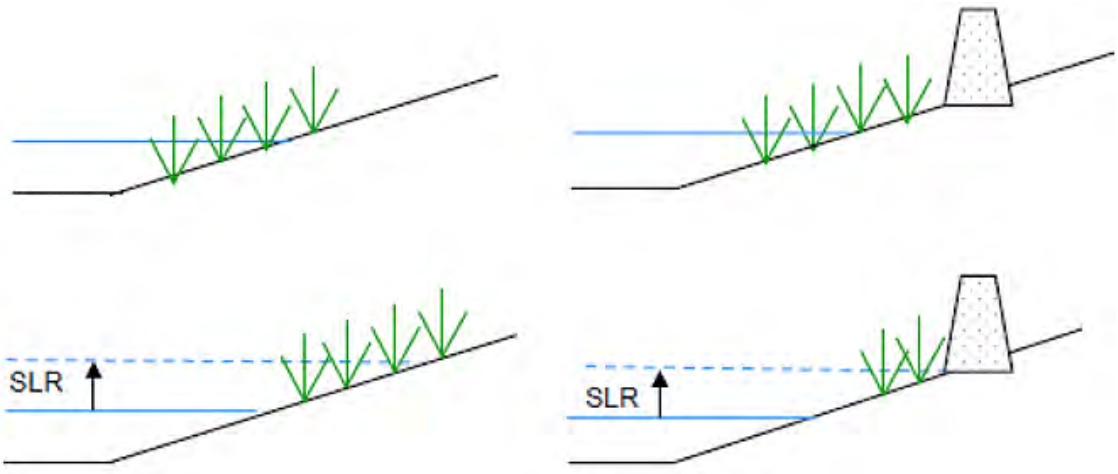
For example, reefs, mangrove forests, marshes, and barrier islands are among the key coastal ecosystems that protect people and infrastructure from damaging coastal storms, including hurricanes, cyclones, and typhoons. Likewise, these ecosystems can lessen the impacts of storm surges by dissipating wave and tidal energy and by providing buffer zones that protect human settlements (Linham and Nicholls, 2010). The protection provided by these coastal ecosystems can help communities adapt to climate vulnerability and change by protecting assets. *Adaptation Action 3*: *Protect Infrastructure and Assets* includes structural and regulatory options that may be used in conjunction with restoration of coastal ecosystems for improving community resilience. In addition, mangrove forests, marshes, coral reefs, and shellfish beds provide vital nurseries and habitat for fisheries, which contribute to livelihoods and food security for more than one billion people around the world (USAID, 2009). These ecosystems can also be the backbone of local tourism, providing livelihoods for many other coastal inhabitants. Coastal management actions that restore and protect these ecosystems will therefore contribute to climate-resilient development.

WHAT ARE THE OPTIONS FOR RESTORING COASTAL ECOSYSTEMS?

Degraded ecosystems, whether the damage stemmed from climate or non-climate stressors, can be targeted for restoration to rebuild their functionality and improve their resilience to future climate impacts. Restoration of coastal ecosystems could involve removing or modifying human structures that disrupt natural coastal dynamics, restoring or reintroducing ecosystems, building reefs or constructing artificial reefs, and replanting mangrove forests or seagrass meadows.

Option A: Remove or Modify Shoreline Hardening Structures

Sea walls, bulkheads, and other structures can protect coastal infrastructure. However, hard protective structures are relatively expensive and can have damaging side effects, including displacing erosion and sedimentation to other vulnerable areas and causing coastal squeeze (UNFCCC, 2006). Coastal squeeze refers to ecosystems that are trapped between a fixed landward boundary and rising sea levels. The establishment of hard coastal defenses could prevent coastal ecosystems from migrating inland in response to sea level rise (Linham and Nicholls, 2010). Exhibit A.1.1 illustrates the effect of the combination of sea level rise and hard defenses on the migration of ecosystems. When existing infrastructure has played a role in the degradation of established ecosystems, removing or modifying that infrastructure can be part of a plan to restore these degraded ecosystems and enhance their ecosystem services to human communities. Furthermore, plans for new infrastructure can be designed so as to limit their effect on existing ecosystems, facilitate the restoration of degraded ecosystems, and allow for the migration of those ecosystems over time.



Where hard defenses are not present, coastal habitats (shown in green) migrate upward and landward with sea level rise, as shown on the left. Where hard defenses are present, they block the migration of coastal habitats, therefore reducing the available area these plants can survive in, as shown on the right.

EXHIBIT A.1.1. COASTAL SQUEEZE, SHOWING EFFECTS OF SEA LEVEL RISE.

Source: Linham and Nicholls, 2010.

Dikes are commonly used as part of an effort to drain wetlands and protect coastal land from inundation. Some dikes include culverts that allow water to pass through the dike. These culverts often include doors, referred to as tide gates, that allow outgoing (i.e., ebb) tides to flow through the culvert but that prevent incoming (i.e., flood) tides from moving inland. Altering water flow in estuaries in this way can have undesirable physical, chemical, and biological effects on coastal ecosystems (Giannico and Souder, 2004; Erwin, 2009; Hallegatte, 2009). Although dikes and tide gates will always interfere with the natural functioning of estuarine ecosystems, some models of tide gates have fewer undesirable environmental effects (Giannico and Souder, 2005). The most fish-friendly tide gate designs include self-regulating or buoyant gates, muted tide regulators, top-hinged gates with a mitigator fish passage device, and gates with permanent holes to allow for the passage of fish and other organisms (Giannico and Souder, 2005). Self-regulating gates, which remain open except during extremely high flood tides, allow for the shortest possible disruption of tidal inundation,

better ecosystem connectivity, improved upstream water quality, and the least disruption to fish movement (Giannico and Souder, 2005; Greene et al., 2012).

Option B: Restore or Reintroduce Ecosystems

Changes in sea levels, ocean temperatures, and ocean chemistry have caused degradation or the complete loss of many coastal ecosystems from places where they previously existed. In some cases, reintroduction or recreation of these ecosystems can be a viable adaptation option.

For example, restoration of degraded reefs can be accomplished by rebuilding damaged reefs and constructing artificial reefs. Artificial reefs have been found to increase the density and biomass of species in the ecosystem. In addition to providing habitat for marine organisms, artificial reefs can be designed to discourage trawling, an activity that can negatively affect ecosystem health (Charbonnel and Bachet, 2011). Another technique for improving fish habitat involves the use of structures such as decommissioned oil and gas platforms as artificial reefs. The Freeport Sulphur Mine Artificial Reef in the northern Gulf of Mexico was found to foster high levels of biomass and fish density in the immediate area around the reef structure (Boswell et al., 2010).

When dunes degrade, a combination of beach nourishment and restoration of natural dunes can provide important ecosystems and reduce both coastal erosion and flooding. Beach nourishment involves transporting sediment from dredged sources and depositing it on beaches to temporarily reverse the loss of sediment. The cost of nourishment using a local dredge site is approximately US$3–15 per cubic meter (US$4–20 per cubic yard), with the main determinant of the cost being the transport distance of the material [Linham and Nicholls, 2010; costs in 2009 US$). Nourishment can also be used in conjunction with dune creation or restoration to enhance the overall resilience of beach and dune ecosystems. Although the costs of beach nourishment and dune creation can be high, restoration of existing dunes can be considerably less expensive if new sediment is not needed (Linham and Nicholls, 2010). However, in some locations beach nourishment has to be repeated; it does not always provide a permanent solution. Dune restoration involves building fences or planting vegetation on the seaward side of existing dunes to trap sand that wind or waves transport, thereby stabilizing bare sand surfaces. For beaches threatened by erosion, such restoration can enhance the natural functioning of dunes and slow the loss of sand. Furthermore, removing hard structures that can increase erosion, such as seawalls and breakwaters, can serve to restore beach ecosystems.

Restoring other coastal ecosystems, such as marshes, mangrove forests, and seagrass meadows, can also improve coastal ecosystem resilience. Degraded marshes can be restored by replanting and restoring appropriate flow and sediment regimes. Restoring mangrove forests can be accomplished by replanting mangroves and removing hard infrastructure adjacent to mangroves, with special consideration given to site selection. Sites already experiencing sea level rise or erosion may not be suitable (Ellison, 2012). Considerations for seagrass restoration include reversing ecosystem degradation, selecting an appropriate area for restoration, selecting an appropriate donor population, and optimizing hydrodynamics to minimize stress and disturbance (van Katwijk et al., 2009). All of these coastal ecosystems should be positioned at elevations and salinity levels that optimize the survival of the species within them; the implementation of land-use policies that allow these ecosystems to migrate inland through time is thus an important consideration for all of these cases.

When restoring or reintroducing these ecosystems, there can be long-term benefits to replication. Replication, or creating multiple similar ecosystems in different locations, can help reduce risks associated with climate change by ensuring that some of these coastal ecosystems survive if others do not; replicated ecosystems create a redundancy that provides insurance if key ecosystems are negatively affected (CCSP, 2008).

GREEN COAST: COMMUNITY-BASED COASTAL MANGROVE FOREST RESTORATION

Mangrove forests are critical ecosystems; they protect coastlines from climate impacts such as coastal storms and associated coastal flooding. Green Coast – administered by Wetlands International, together with the World Wildlife Fund (WWF), the International Union for Conservation of Nature, and Both ENDS – provides financial and technical support to local communities for livelihood activities and helps communities with coastal restoration projects, including planting mangroves. Through the program, more than 893 hectares (2,207 acres) of coastline have been restored in areas of Indonesia that the 2004 tsunami damaged (Wibisono and Sualia, 2008; Colls et al., 2009).

Mangrove restoration project.

Photo credit: U.S. Department of State.

WHAT ARE THE OPTIONS FOR PROTECTING COASTAL ECOSYSTEMS?

Many existing ecosystems are already vulnerable to climate and non-climate stressors. Protecting these ecosystems can prevent further damage and improve their functionality and resilience to climate impacts. Two strategies for protecting coastal ecosystems are regulating development in sensitive coastal areas and establishing conservation areas. Adaptation Action 2 discusses reducing other stresses on coastal areas, such as pollution and invasive species.

Maintaining and restoring beneficial coastal dynamics begins with avoiding policies that harm the coastal environment. These harmful policies include inappropriate coastal protection schemes, sand and coral mining, and coastal ecosystem conversion (Klein et al., 2001). Taking into account the protection and restoration of

beneficial coastal dynamics in coastal management and planning can be both environmentally and economically efficient (Klein et al., 2001). In addition to avoiding policies that degrade ecosystems, reversing existing policies and development that negatively affect coastal ecosystems can improve the climate resilience of those ecosystems and human communities (Klein et al., 2001). As Adaptation Action 9 discusses, strong governance regimes can help managers and planners implement effective coastal zone management and protection.

Option C: Regulate Development in Sensitive Areas

Coastal development can impair the functioning of ecosystems by destroying, removing, reducing, and fragmenting ecosystems, as well as increasing the flow of pollutants and nutrients into ecosystems (e.g., by increasing impervious surface area). In addition, many ecosystems will need to migrate to new locations in the future to maintain their optimal elevation, salinity, or temperature. Limiting or preventing coastal development near areas designated as key ecosystems will help protect the functioning of these ecosystems, and can also allow for their natural migration as climate conditions change.

One way to manage effects on sensitive coastal areas is to require parties to obtain a permit or license before engaging in activities or uses that may injure these resources. For example, permit and license requirements may be established through targeted legislation focused specifically on wetlands, or through broader environmental legislation that more generally restricts the scope of allowable effects. Regulatory programs may require those who seek permits to first avoid and minimize impacts to wetlands and then mitigate any wetlands that are lost or degraded through permitted activities by restoring or preserving a wetland in another location, resulting in "no net loss" of wetlands. These approaches generally focus on the regulation of uses in *existing* wetlands, and would therefore need to be combined with policies that allow for inland migration. Other management actions, such as modification of river discharge to increase sediment supply and vertical accretion in coastal wetlands, can also preserve wetlands in the face of rapid sea level rise in the future. Existing and intact dune ecosystems can also be protected through restrictions on coastal development or the designation of protected areas.

In addition to development restrictions, public and private parties can use a variety of incentives to preserve and restore existing wetlands. Common incentives for private landowners include tax credits or exemptions for preserving wetlands, cost-sharing for protecting and restoring wetlands, and technical and financial assistance. Incentives can be offered for a variety of beneficial actions, such as the adoption of local environmental development restrictions, incorporation of sustainable infrastructure, adoption of best management practices, and others (Grannis, 2011).

Policies built around licensing, permits, and tax credits, as described above, will in many cases be the most efficient incentive to support responsible development in coastal zones. However, many developing countries may not have the capacity to institute or manage such programs. In these cases, more direct controls may be required, such as prohibitions or restrictions on development in sensitive areas. The choice of appropriate actions will depend on the needs and capacity of each coastal area.

REGULATIONS TO ALLOW LANDWARD MIGRATION OF COASTAL ECOSYSTEMS

To prevent the loss of coastal wetlands to sea level rise, land-use regulations could enable inland wetland migration. Three general approaches include establishing zoning or setback regulations to accommodate a minimum amount of sea level rise; establishing proactive rolling set-asides that move with the sea level; and responding to sea level rise by moving structures as they are endangered (see also Adaptation Actions 3 and 4).

Vanuatu.

Photo credit: Peace Corps.

Zoning, overlay districts, and setbacks – One approach is to preemptively set aside areas for wetlands retreat by preventing development on adjacent land. This can be accomplished by acquiring the title, an easement, or the development rights to the upland area, or by local ordinance or state statute (Grannis, 2011; Titus, 2011). Regulatory tools such as zoning ordinances, overlay zones, and setbacks can allow governments to identify vulnerable areas and impose special restrictions in these areas. For example, a local setback ordinance can establish a minimum development distance from the shore.

Rolling easements – Another option is to enable natural migration of wetlands by applying a rolling boundary designed to preserve the coastline as it migrates inland. The foundation of the concept is to allow coastal development in areas vulnerable to sea level rise with the *advanced* determination that the land will be abandoned when the sea rises enough to submerge it. Rolling easements may be established through mandatory regulation, such as local zoning restrictions or permit conditions, or through voluntary property rights mechanisms, such as conservation easements, restrictive covenants, or migrating property lines (Titus, 2011). For example, rolling easements could be used to purchase the rights of property owners to construct structural measures to prevent the coastline from moving inland and to require that landowners remove any other structures (e.g., houses, other buildings) on the land as they become threatened by sea level rise (Grannis, 2011). Rolling easement regulations should establish thresholds that trigger removal requirements.

Managed retreat – If areas are not set aside for coastal wetland migration, managers can take a responsive stance to govern forced retreat. Managed retreat allows wetlands and coastal ecosystems to migrate inland as the shoreline retreats. The premise is that people and development will have to move as the shoreline does (NOAA, 2007). As with rolling easements, managers may wish to develop thresholds to trigger relocation efforts so that relocations are foreseeable and prioritized.

Option D: Create Conservation Areas or Buffers

Another way to protect coastal ecosystems such as wetlands or mangrove forests is to designate them as protected areas. For example, MPAs are used to preserve spawning areas for harvested species, nursery areas for harvested species, and offshore reefs (MPAs are discussed further in Adaptation Action 6). Also, where opportunities exist, coastal ecosystems may be acquired through purchase, donation, easements, or other means, by public, private, or nongovernmental entities. Once the conservation area is established, the managing entity can designate allowable uses or activities. Some wetlands or mangrove forests may need to be restored to provide the greatest benefit. Long-term management (e.g., modification of river discharge) may be necessary to protect the ecosystem from sea level rise or sedimentation. If managed properly, these areas can also provide shoreline protection from hazards.

Designation may occur through a variety of means. For example, conservation easements may be established through the creation of national parks, reserves, or sanctuaries; through local initiatives, such a public-private partnership to set aside an area for public use; or through nongovernmental means, such as via purchase by private conservation organizations. In many cases, the acquisition will be opportunistic, relying on the availability of landowners willing to sell or donate their land.

THE CENTER FOR THE CONSERVATION AND ECO-DEVELOPMENT OF SAMANÁ BAY AND ITS SURROUNDINGS

The Center for the Conservation and Eco-Development of Samaná Bay and its Surroundings (CEBSE) in the Dominican Republic is working to strengthen the resilience of coastal communities to the adverse impacts of climate change. Threats include increased flooding, storm surge, and sea level rise, as well as the erosion of coastline, beaches, and hillsides. Mangrove health is also a concern; residents have cut down mangroves for various reasons, including producing charcoal. CEBSE's relevant activities include:

Stakeholders in the Dominican Republic.

Photo credit: Nora Ferm, USAID.

- Restoring mangrove forests by developing a nursery to grow seedlings and then working with coastal landowners to plant them
- Protecting and restoring watersheds that provide water for coastal communities, such as by reforesting them to prevent erosion during heavy rains, demonstrating silviculture practices so people understand that they do not need to choose between their agricultural livelihoods and standing forests, and showing how the trees can help protect livelihoods against climate stresses
- Educating people about the causes and effects of climate change and adaptive measures by training high school students and media to communicate about climate change and facilitate trainings
- Optimizing artisanal fishing practices to reduce the vulnerability of fishing communities
- Working with municipalities in the Samaná province to implement land-use plans that include a focus on climate change adaptation

WHAT NEEDS TO BE CONSIDERED FOR IMPLEMENTATION?

Planners and managers need to analyze each potential adaptation option to select the best course of action. Typical considerations for any given adaptation option are in the "Adaptation options considerations" text box; a mix of adaptation options may be used to address specific climate risks to a community, region, or nation.

ADAPTATION OPTION CONSIDERATIONS

- Effectiveness
- Feasibility
- Cost
- Unintended consequences
- Additional benefits
- Implementation timing
- Flexibility
- Robustness

The feasibility of coastal restoration and protection will vary with existing governance structures for preserving lands and regulating land uses; the capacity of governments to issue, monitor, and enforce permits or other regulations; the quality of existing coastal ecosystems available for preservation; and the political will and public support for preserving these resources. Other issues that need to be considered for implementation include:

- ***Information and uncertainty.*** Many locations will have limited data and maps illustrating where sea level rise is expected to encroach on coastal lands, making it difficult to determine where land should be protected or set aside for wetland migration and where land could be developed. Predicting the response of natural systems to unknown or uncertain climate impacts and determining how effective wetland protection will be at improving community resilience in a given location is also difficult.
- ***Prioritizing coastal areas for restoration and protection.*** For coastal restoration and protection to be an effective adaptation strategy for coastal areas, stakeholders will need to assess their vulnerabilities to climate impacts, identify the location and extent of existing coastal ecosystems, and then prioritize areas for conservation and restoration,[10] In some cases, communities may also need to use outside expertise to support vulnerability assessment and adaptation planning. Priority should be given to protect or restore ecosystems, which can provide multiple critical functions, including coastal protection, water quality, and ecosystem functions.
- ***Cost.*** There are trade-offs between the amount of ecosystem protection provided and the complexity and cost of implementation. The cost of different ecosystem protection or restoration activities will vary depending on land costs and opportunities to set aside land, existing government capacity to regulate land uses and enforce permits, the complexity of the protection or restoration effort, and the amount of scientific data available to identify priorities.
- ***Monitoring and enforcement.*** To be effective, local governments must have the capacity to effectively monitor and enforce permits, limitations, or other land-use decisions. Funding for increased training may be necessary to build capacity within implementing agencies to take on these crucial functions.
- ***Long-term management.*** Protected coastal ecosystems will likely require long-term management, particularly in locations where development or other factors prevent coastal ecosystems from migrating inland. For example, management actions could include modification of river discharge to increase sediment supply and vertical accretion in coastal wetlands. Management of upstream waters will also play a role in long-term adaptation in the coastal zone. For example, limiting pollution from industry or

10. See the National Oceanic and Atmospheric Administration's (NOAA's) Digital Coast website (http://coast.noaa.gov/digitalcoast/) and Gitay et al., 2011.

agriculture can help protect fisheries and other coastal resources. In many locations, local community management will likely play an important role.

- ***Livelihoods and property rights.*** There are many ongoing activities in coastal areas (e.g., fishing/aquaculture, oil and gas development, shipping, recreation) and many people depend on coastal ecosystems for their livelihoods. Although preserving coastal ecosystems can help build resilience and provide support for some traditional resource use, it may also conflict with other uses. For example, setting aside land for wetland migration may be complicated by private ownership of priority lands, especially in areas where property rights are not well established. Regulations that limit whether and how property owners can develop their land can also lead to legal challenges. Political and stakeholder involvement in coastal protection and restoration – especially in the face of competing uses of these lands, costs to coastal land owners, and loss of tax revenue for communities – will be crucial.

Co-benefits

Because coastal ecosystems such as wetlands, estuaries, mangrove forests, and others play a role in providing critical ecosystem services, their protection can lead to other community benefits, in addition to contributing to coastal climate adaptation. These benefits can include:

- ***Carbon capture.*** Many coastal ecosystems, particularly peatlands, mangrove forests, and salt marshes, act as natural carbon sinks by storing significant amounts of carbon in their belowground and aboveground biomass. Although the amount of carbon stored in wetland sediment and soils varies across wetland type, over multi-decadal timescales all wetland types function as net carbon sinks. Drainage and destruction of wetlands causes the carbon stores to be released. Considering coastal ecosystems' role as carbon sinks, coastal communities could also earn carbon credits for restoration activities to help meet greenhouse gas reduction targets. Minimizing wetlands loss can play an important role in climate mitigation (World Bank et al., 2010).

- ***Economic and cultural benefits.*** Coastal ecosystems provide economic and cultural benefits, including those derived from tourism and recreation, commercial fishing, erosion control, water storage, groundwater recharge, pollution abatement, flood mitigation, and storm protection. Beaches, coral reefs, wetlands, and other coastal ecosystems around the world support extensive tourist industries and local economies. Wetlands in particular are also critical to the existence of economically valuable commercial fisheries, as two-thirds or more of the fish and shellfish consumed globally are dependent on coastal wetlands at some stage in their lifecycle.

- ***Improved safety and security.*** Coastal ecosystems, including beaches, dunes, and wetlands, enhance the safety and security of coastal areas by shoring up coastlines against flooding, storm surges, and other effects of natural disasters. In addition to the shoreline stabilization role played by wetland plant roots, aboveground vegetation provides a physical barrier that slows down waves, storm surges, and tidal swells. *Adaptation Action 3: Protect Infrastructure and Assets* includes structural and regulatory options that may be used in conjunction with restoration of coastal ecosystems for improving community resilience.

Exhibit A.1.2 provides a summary of some of the major implementation considerations for options to restore and conserve coastal ecosystems. For each option, the table identifies key feasibility challenges in implementation; the relative cost of implementation compared to other options included in the table; the level of decision-making typically involved (e.g., national, regional, local); and other considerations including benefits, effectiveness, flexibility, unintended costs, or timeframe.

EXHIBIT A.1.2. IMPLEMENTATION CONSIDERATIONS FOR COASTAL ECOSYSTEM PROTECTION, RESTORATION, AND MIGRATION OPTIONS.

Option	Feasibility	Cost	Level of decision	Other considerations
Restoration of coastal ecosystems				
Option A: Remove or modify shoreline hardening structures	• Difficult to implement in areas with highly developed coastlines; social and economic implications may make this option infeasible in some places • More feasible in areas with less-developed coastlines	• Low costs for physically removing the structures • Potentially high costs to evaluate replacement options or loss of property	• Decision can range from a community to national level	• Medium- to long-term timeframe of implementation
Option B: Restore or reintroduce ecosystems	• May require land purchase and access • Requires labor and materials for planting, depending on the level of rehabilitation required (including grading, replanting, and water-control structures)	• Moderate to high costs, depending on the size of the area	• Decision can range from a community to a national level	• Short-term implementation timeframe • Full effects of restoration in the medium- to long-term timeframe
Protection of coastal ecosystems				
Option C: Regulate development in sensitive areas	• Difficult to implement in areas with poor regulations or enforcement capacity	• Low costs for implementing zoning or other regulations to restrict development, but could have a large economic cost if the result is a reduction in trade or tourism • Municipal or regional budget limitations may prevent enforcement of regulations	• Decision typically made at the regional government or national level, although municipal-level zoning regulations can address coastal ecosystems concerns, as well	• Determining which sites to protect, and engaging community members, could be a lengthy process
Option D: Create conservation areas or buffers	• Feasibility will depend on availability of land; may require land purchase	• Moderate costs for creating and enhancing corridors; if land purchase is required, dependent on cost of purchasing land	• Decision can range from a community to a national level	• Medium- to long-term timeframe for implementation

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ADAPTATION ACTION 2: REDUCE NON-CLIMATE STRESSORS THAT DEGRADE COASTAL ECOSYSTEMS

Coastal ecosystems are under pressure from a number of non-climate stressors, such as population growth and urban development, livelihood activities, pollution and nutrient loading, extractive resource use, sediment delivery, and weak resource governance. Reducing these stressors can increase coastal ecosystems' resilience to climate variability and change, including their ability to accommodate projected changes in temperature, precipitation, and storm severity. Reducing non-climate stressors can enhance or maintain coastal ecosystems' ability to provide critical ecosystem services, contribute to livelihoods for people, and offer refuge to many plant and animal species.

HOW CAN REDUCING NON-CLIMATE STRESSORS ON COASTAL ECOSYSTEMS CONTRIBUTE TO CLIMATE-RESILIENT DEVELOPMENT?

Many coastal ecosystems are already experiencing the effects of water pollution, land-use change, human controls of inland waterways, and extraction of resources. As a result, coastal ecosystems are particularly susceptible to climate impacts. Reducing non-climate stressors, such as industrial waste, untreated sewage, and invasive species, as well as sedimentation and nutrient loading in the coastal zone, can help systems maintain resilience in the face of increasing climate-related pressures. Because there are ancillary benefits to each of these actions beyond improving the climate resilience of coastal ecosystems, reducing these existing ecosystem stressors is a "no-regrets" adaptation approach (Colls et al., 2009).

WHAT ARE THE OPTIONS FOR REDUCING NON-CLIMATE STRESSORS ON COASTAL ECOSYSTEMS?

Coastal ecosystems are directly connected to the watersheds that drain adjacent land masses. This means that many human actions far from the coastal environment can have a significant effect on coastal ecosystem health. For example, land-based pollutants (e.g., agrochemicals, biological wastes, industrial pollutants) migrate to the coastal zone through surface run-off and aquifer discharge. Nutrients carried in run-off can contribute to algal blooms and hypoxia in the coastal zone (Smith, 2003). Projected climate impacts include changing precipitation patterns that could lead to increased pollutant concentrations and sudden pulses of increased runoff with higher pollutant loads. Managing contaminants from upstream sources will help to preserve coastal ecosystem health, thereby improving the resilience of these ecosystems to climate-related stresses.

Options for reducing non-climate stressors include reducing industrial sources of contamination, reducing pollution from human and municipal waste, improving land-management practices to reduce sedimentation and nutrient loading, and managing invasive species. To implement many of these actions, coastal municipalities will need to have adequate governance structures in place to communicate these problems to the public, develop regulations, and enforce them. Depending on the level of governance already in place, these steps may present one of the most significant challenges for developing coastal nations.

Option A: Reduce and Prevent Sources of Contamination

Coastal ecosystems are currently affected by industrial, agricultural, and human waste products, particularly in the developing world. Human health is also affected. Efforts to reduce these wastes are therefore good no-regrets options, as there will be clear environmental and public health benefits to these actions regardless of specific climate impacts. Both coastal and upstream industries are potential sources to address. Near the coast, industries that are potential sources of contaminants may include petroleum drilling or refining, chemical manufacturing, shipping, waste management, and industrial waste from coastal cities. Upstream sources might include agriculture, livestock, and industrial wastes from upstream cities.

Contaminant sources can be reduced in a number of ways. For example, industrial processes can be modified to decrease the amount of toxic materials used or to replace toxic substances with less hazardous products. In some cases, spills or accidents are significant sources of contamination, so revising emergency plans and fortifying structures against extreme weather can also be a useful adaptation approach. In agriculture, careful attention to the appropriate use of herbicides and pesticides can help reduce production costs and pollution. Good agricultural practices have been developed for most agricultural activities and these methods can be transferred to users at all scales with adequate support.

Option B: Reduce and Prevent Pollution from Municipal and Human Waste

Industrial, municipal, and sanitary waste management practices can be improved to reduce stress on ecosystems. For example, improving landfills can help prevent contamination of wetlands or groundwater resources along the coast, and improving sanitation services can prevent pollution of waterways.

Disposal of solid waste continues to be an issue in many developing countries. Solid waste amounts tend to increase as living standards rise because of an increase in the use of disposable products (NOAA, 2013). Education efforts and recycling can offer one possible management solution and offer financial benefits through providing employment and generating revenue. Socioeconomic impacts and benefits should be a factor in developing plans to improve solid waste management.

In many developing countries, raw sewage is dumped directly into waterways. From there, these wastes often migrate downstream into the coastal zone, where significant impacts occur. These impacts include the addition of nutrients, chemical wastes from metabolized drugs, endocrine-disrupting chemicals, and other inputs that can impair all coastal ecosystem types. Improving the sanitation systems that manage human waste can also improve coastal resilience by reducing nutrient loads that cause algal blooms, eutrophication, and associated problems in coastal waters. Many cities have outdated, decentralized, or otherwise ineffective wastewater treatment systems, which often result in raw sewage being transported directly into coastal waters. Modernizing, centralizing, or otherwise upgrading these systems can improve coastal water quality and safety, and can also improve ecosystem quality in these areas.

U.S. NATIONAL ESTUARIES PROGRAM

Oyster harvesting.

Photo credit: Jay Leverone, Sarasota Bay Estuary Program.

Estuaries are a bridge between saline and freshwater ecosystems. Estuarine ecosystems are home to numerous animal species and are an important economic resource for many coastal communities. Estuaries are subject to climate stressors, such as sea level rise and changes in salinity, as well as non-climate stressors. For example, estuaries are typically vulnerable to changes in hydrologic flows from development, invasive species, ecosystem loss or degradation, high levels of nutrients from agricultural fertilizers, pathogens from human or animal solid waste, and other pollutants or toxins found in run-off. The U.S. Environmental Protection Agency's National Estuaries Program attempts to address non-climate stressors in U.S. estuaries. The program works with communities to create comprehensive conservation and management plans to address water quality, ecosystem, and living resources challenges in estuarine watersheds.

Sources: U.S. EPA, Undated (a), Undated (b).

Option C: Reduce and Prevent Sediment and Nutrient Loads from Non-point Sources

The amount of sediment and nutrients reaching the coastal zone can affect the health of coastal ecosystems in a variety of ways. For example, reefs may be smothered or coastal water quality degraded by sediment and nutrients from upstream sources. Often, the majority of sediment and nutrients delivered to the coastal system come from nonpoint sources in upland regions far from the coastal zone. Protecting intact land-based ecosystems to reduce run-off and maintain downstream water quality can therefore be an important option for protecting coastal ecosystems.

Conversely, coastal wetlands can be subject to subsidence if sediment is not supplied quickly enough to offset losses from coastal erosion (Ellison, 2012). Sediment supply from rivers to the coastal zone therefore needs to be carefully managed to improve ecosystem functions. Options for restoring adequate sediment delivery to the coastal zone include river management practices that divert sediment back into coastal ecosystems.

Managing upland sediment production

A number of activities result in erosion from uplands, which leads to the run-off of sediment and associated contaminants. Areas that are currently subject to erosion and soil loss are generally those that are also most vulnerable to increased damage from climate impacts. Methods for soil conservation and prevention of run-off are well-developed, particularly for agriculture, but implementation remains a challenging issue in many developing countries. Strategies may include creating buffer zones around agricultural lands to trap sediment, or no-till practices that reduce sediment sources. A particularly problematic and often unrecognized threat is run-off associated with urban development and non-permeable surfaces. Regulations, monitoring, and support services are required to make progress toward reducing soil loss and related issues.

In some locations, the forestry industry is a major source of erosion. Forestry activities destabilize slopes and change the sediment dynamics of coastal zones. Forestry can endanger coastal communities and livelihoods by creating changes in water flows, ecosystems, and groundwater recharge. In certain situations, forestry can contribute to landslides. Forestry should only take place when sound practices are used; this includes preserving old-growth forests and other critical ecosystems, as well as reforesting areas that were deforested. Proper reforestation uses native, non-invasive species with an emphasis on those species that can stabilize soil quickly with minimal water needs. Reforestation is known to reduce soil loss, retain water in terrestrial areas, and stabilize slopes. Both rural and urban forestry on all scales should be prioritized as an approach to soil conservation and watershed management that also yields significant economic benefits, including increased food security.

In-stream sediment management

Many major river systems around the world now have dams, levees, or other structures to improve navigation, provide flood control, or generate hydropower. However, these structures also interfere with natural sediment transport processes in rivers by trapping sediment behind dams, or reducing the ability of floodplains to sequester sediment. As a result, managed river systems tend to deliver different quantities of sediment at different times of the year than free-flowing rivers. Strategies that reconnect managed rivers to their floodplains and adjacent wetlands, in particular, can help improve the delivery of sediment to the coastal zone. These strategies can include dam removals to allow sediment to continue flowing downstream rather than becoming trapped in reservoirs, or river diversions to reconnect flowing rivers and associated sediments to floodplains and coastal marshes.

Option D: Control Invasive Species

In many coastal ecosystems, invasive species have displaced many of the native species that serve important functions in coastal ecosystems. Strategies for controlling invasive species can include preventing their introduction, eradicating species that are already posing a threat to native species' populations, or containing invasive species so they are unable to migrate beyond currently affected areas. These adaptation actions will help maintain ecosystem conditions for native species and allow ecosystems to remain healthy and functional as they confront climate stressors, such as increased sea-surface temperatures and sea level rise.

WHAT NEEDS TO BE CONSIDERED FOR IMPLEMENTATION?

Planners and managers need to analyze each potential adaptation option to select the best course of action. Typical considerations for any given adaptation option are in the "Adaptation options considerations" text box; a mix of adaptation options may be used to address specific climate risks to a community, region, or nation.

ADAPTATION OPTION CONSIDERATIONS

- Effectiveness
- Feasibility
- Cost
- Unintended consequences
- Additional benefits
- Implementation timing
- Flexibility
- Robustness

The feasibility of reducing non-climate stressors in the coastal zone varies depending on the stressors in a given location and the available enforcement mechanisms. Other issues that planners and managers should consider for implementation include:

- *Cost.* There are trade-offs between the reduction of non-climate stressors and the complexity and cost of implementation. The cost of different activities will vary depending on the amount of infrastructure or enforcement that is needed to manage the problem.

- ***Effectiveness.*** Some non-climate stressors are more detrimental to the coastal zone than others and some are more difficult to address. Each community must weigh options for addressing non-climate stressors to determine which option will result in the greatest benefit with what is feasible.
- ***Monitoring and enforcement.*** To be effective, local governments must have the capacity to effectively monitor and enforce industry or waste-management programs. Funding for increased training may be necessary to build capacity within implementing agencies to take on these crucial functions.
- ***Long-term management.*** Reducing non-climate stressors is an ongoing task that will likely require long-term management. For example, management actions that regulate industries or that implement erosion-control programs will continue far into the future.

Exhibit A.2.1 provides a summary of some of the major implementation considerations. For each option, the table identifies key feasibility challenges in implementation; the cost of implementing the measure, relative to other options included in the table; the level of decision-making typically involved (e.g., national, regional, local); and other considerations.

EXHIBIT A.2.1. IMPLEMENTATION CONSIDERATIONS FOR OPTIONS TO REDUCE NON-CLIMATE STRESSORS.

Option	Feasibility	Cost	Level of decision	Other considerations
Option A: Reduce and prevent sources of contamination	• Feasibility depends on the nature of existing infrastructure	• Cost can range significantly depending on option used	• Decisions typically made at the local level, with guidance from national-level statutes	• Medium- to long-term timeframe of implementation; requires ongoing management
Option B: Reduce and prevent pollution from municipal and human waste	• Feasibility depends on existing infrastructure	• Cost can range significantly depending on the nature and condition of existing sewer and waste-management systems	• Decisions typically made at the local level, with guidance from national-level statutes	• Medium- to long-term timeframe for implementation
Option C: Reduce and prevent sediment and nutrient loads from non-point sources	• Controlling sediment could require a high level of effort because upstream decision-makers will need to agree with sediment-control measures • Restoration of wetlands is likely to aid in sediment control; this could reduce reliance on cooperation from upstream decision-makers	• Cost can range significantly, depending on option used; smaller efforts, such as planting vegetation to trap sediments, may be more cost-effective than removing dams, for example	• Decision can range from the local to the national level	• Medium- to long-term timeframe of implementation; requires ongoing management
Option D: Control invasive species	• More feasible in smaller areas • Once a species has invaded, it is usually difficult to eradicate	• Low costs for increasing management oversight if species is already managed, but costs can be high for new species and removal projects • Ongoing monitoring and species-control costs should also be considered	• Decision typically made at the regional or national level	• Researching and monitoring to determine species to manage could take considerable time • Medium- to long-term timeframe of implementation; invasive species are difficult to remove and control and will require ongoing management

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ADAPTATION ACTION 3: PROTECT INFRASTRUCTURE AND ASSETS

Protection measures secure existing assets against climate impacts from sea level rise, storm surge, flooding, and erosion. These measures may include building new structures, such as levees; building adaptive structures, such as stilted buildings; or modifying building codes to incorporate setbacks that reduce the vulnerability of new structures. To design and implement protection measures, planners and managers must consider cost, timing, data availability and uncertainty, local zoning regulations, and technical considerations. Planners and managers should recognize that protecting the built environment can come at the expense of maintaining beaches and wetlands (see Adaptation Action 1). Planners and managers must consider a number of social factors such as local participation, environmental justice, institutional capacity building, legal issues, and political will. Alongside protection, decision-makers should consider complementary actions, such as managed relocation of infrastructure away from coastal areas (see Adaptation Action 4) and non-structural approaches to reducing destructive inundation (see Adaptation Action 5). Note that the concept of natural or green infrastructure, such as restoring mangrove forests to manage flooding or storm surge, is covered under Adaptation Action 1.

HOW DOES PROTECTING INFRASTRUCTURE AND ASSETS CONTRIBUTE TO CLIMATE-RESILIENT DEVELOPMENT?

Protection measures can help address the risks posed by flooding, storm surge, and the impacts of sea level rise (see Exhibit A.3.1). Protection of existing assets can reduce a community's vulnerability to coastal impacts without requiring relocation to other areas. Planners and managers can decide to protect a subset of assets that provide critical services or are otherwise highly vulnerable. Alternatively, they can support or encourage more widespread adoption of protection measures across public and private properties.

EXHIBIT A.3.1. POTENTIAL IMPACTS FROM CLIMATE CHANGE ON EXISTING ASSETS WITHIN THE BUILT ENVIRONMENT.

Climate change impact	Impact on existing assets within the built environment
Sea level rise	• Greater inundation risk and damage from storm surge • Changes in flood-risk areas, changes in erosion rates along the coastline, and the movement of sensitive coastal ecosystems inland
More intense storms	• Could cause more frequent and severe damage to assets
Changes in freshwater runoff	• Increases in runoff could damage natural ecosystems that manage and control water, leading to increased flooding of human-made structures

Protection measures increase the resilience of assets to current or projected coastal stressors. The protection of assets should be considered alongside:

- Other structural measures; see USAID's Water Annex (USAID, Forthcoming), especially Adaptation Action 6
- Non-structural measures, such as the creation of water retention areas and the preservation or enhancement of natural buffering systems including beach dunes and mangrove forests; see Adaptation

Action 1 in this document, as well as Adaptation Actions 5 and 7 in the USAID Water Annex (USAID, Forthcoming)

- Establishing advance-warning systems for disaster response; see Adaptation Action 5

WHAT ARE THE OPTIONS TO PROTECT INFRASTRUCTURE AND ASSETS?

Protection, in this context, involves actions that enable assets within the built environment to withstand storm surges, inundation, erosion, and other climate-related coastal impacts. The types of assets that should be considered for protection include transportation infrastructure, potable water systems, sanitation systems, solid waste systems, energy systems, information and communications technology, flood-control structures, cultural heritage assets, ports, and buildings (USAID, 2013). Protection measures can temporarily reduce impacts on existing coastal assets. They can complement or provide an alternative to long-term retreat from coastal areas prone to impacts; protection measures can also help in areas where larger-scale storm surge and flood-control methods are not feasible (ADPC, 2005). Because of the cost and difficulty of relocating existing assets and built infrastructure, protection measures may be the only practical option, especially in the short term.

The protection options described below include structural improvements to physically reinforce or elevate assets, and policies and regulations that prevent siting assets in coastal areas likely to face impacts. Protection and restoration of coastal ecosystems help to maintain natural coastal buffers (see Adaptation Action 1) and should be considered instead of or in combination with the options described below.

Option A: Make Structural Improvements to Protect Existing Assets

Existing assets can be protected against damage from storm surges, inundation, and erosion, or modified to accommodate climate change effects.

- ***Protection*** includes measures to protect structures and keep water out, including sealing buildings with waterproof sheeting, deploying sandbags, or using other water-proofing materials; shoring buildings against the force of storm surge and flood waters by strengthening foundations; and making other design changes to protect buildings against scour, erosion, settlement, or inundation (ADPC, 2005; DARA, 2010). This can also include elevating coastal infrastructure such as roads and bridges, burying water pipelines and other utilities, or any other physical protection measures.
- ***Accommodation*** includes measures that allow water to flow through structures and reduce the force that storm surge and flood waters exert on a structure. Buildings can be modified to remove walls, leaving only the structural framing exposed to storm surge and flood water; piers, piles, posts, or stilts can raise buildings. Pier foundations are supported by concrete footings that can be reinforced to support horizontal forces from storm surge and flood water. Piles are wood or concrete supports that are mechanically driven into the ground; they are less affected by scour and erosion from fast-flowing water than the surface-mounted foundations that support many other buildings. However, piles must be supported by bedrock or held in place by the surrounding earth. Posts, columns, or stilts are steel, bamboo, or timber supports that are set in pre-dug holes, sometimes cast in concrete for improved support; they must be braced to support horizontal forces using "knees," cross-bracing, rods, or guy-wires. Buildings and roads can be elevated on earthen mounds or embankments that are shored against erosion by vegetation, rocks, or concrete rubble. Communities may also design floating houses or structures that rise with water levels to protect these assets from tidal flooding in coastal areas (ADPC, 2005).

DESIGNING A CLIMATE-RESILIENT ROAD IN KOSRAE, MICRONESIA

On the island of Kosrae, a section of a road follows the coastline approximately 7 to 10 meters above mean sea level. Before completing construction of the roadway, the government analyzed how climate may affect the area. Climate models projected that hourly rainfall would exceed assumptions used in earlier designs and that the road could wash out. A cost-benefit analysis of building the road to the new standard determined that construction costs would be higher than without the upgrades, but repair and maintenance costs would be significantly lower, making the climate-resilient road a recommended investment.

Additionally, the analysis found that the planned coastal road would go through the last stand of a highly endangered tropical montane tree species and therefore would have significant environmental implications. Subsequently, the forest area was legally listed as a reserve and the road route was changed. The new road will feature improved drainage works to accommodate an hourly rainfall of 254 millimeters (10 inches), a 42% increase in capacity over the original design. The incremental cost of the climate-proofing upgrades was approximately US$511,000 (in 2004 US$; ADB, 2005). The road opened on May 29, 2014 (SPREP, 2014).

Island of Kosrae.

Photo credit: U.S. Global Change Research Program.

FLOOD-PROOFING THROUGH REBUILDING AFTER DISASTER IN BANGLADESH

Cyclone Sidr struck Bangladesh in 2007, destroying millions of homes and settlements. The country is now incorporating protection against future floods as it rebuilds. The United Nations Development Programme (UNDP) launched the Core Family Shelter Program to rebuild homes that will now be more resilient to future floods and cyclones. Bamboo posts are treated with a preservative to increase their longevity, and concrete blocks protect the bottom of the posts. Traditional-style homes are stabilized by adding a layer of mud-cement mixture on top of their earthen bases. Homes also are built with brick walls, anchored roofs, and windows reinforced with bracing that can withstand tidal forces (UNDP, 2012).

Resilient rural housing in South West Bangladesh.

Photo credit: Risal Ahmed, in association with RESET Development.

Option B: Establish Policies and Regulations to Prevent Poor Siting and Building

A number of legal and policy approaches can be taken to prevent poor siting and building decisions in a community. These include policies that support adaptive planning (see Option A). The tools are presented in the context of protecting existing assets, but are also closely related to tools that support managed relocation from high-risk coastal areas (see Adaptation Action 4).

- ***Practices that support natural systems*** should be a first option to protect assets. For example, as discussed in Adaptation Action 1, in planning the development of conservation areas, urban or industrial development can be restricted or prohibited so as not to interfere with the intent of the conservation area. Such conservation preserves ecosystems that protect human infrastructure. However, careful integration of some activities, such as eco-tourism, and the ability to enforce conservation restrictions, should be considered in parallel.

- ***Proactive land-use planning*** can help (a) prevent developing new sites in risk-prone areas or minimize risk in the built environment by limiting further development or redevelopment, (b) establish criteria and identify sites for priority protection actions based on economic and natural resource assets, (c) determine what type of action is appropriate (e.g., protection, retrofit, removal, or abandonment of assets), and (4) identify different options based on short-term, medium-term, and long-term climate impact scenarios and risks.

- ***Zoning ordinances*** typically flow from land-use plans and regulate what type of land use can occur in a given area. For example, setbacks, or areas of no construction, prevent lands that are vulnerable to climate impacts from being developed or further developed. Setbacks can be chosen based on erosion rates and storm exposure during severe storms or on best estimates of safe distances. Setbacks can be established through law or regulation or by purchasing development rights or land from property owners.

- ***Building codes*** can be designed or amended to account for projected sea level rise, flooding, and increased storm intensity; governments can establish requirements for new structures placed in floodplains. For example, if current structural requirements protect against a severe flood that might occur once in 100 years, new structural requirements could protect against severe flooding that is only anticipated to happen once in a 500-year period. Measures also can include limitations or requirements for rebuilding or renovating structures in hazard-prone areas.

- ***Insurance*** provides another mechanism that creates incentives or disincentives for investment in coastal structures. In particular, when national insurance programs subsidize private homeowners' insurance in hazard-prone areas, governments can amend programs to better account for the cost and risk of flooding because of climate impacts. Such amendments can include raising premiums, increasing deductibles, limiting coverage, or discontinuing coverage.

SETBACKS, SEA LEVEL RISE, AND SEA TURTLES

Playa Junquillal in Costa Rica is a small coastal community and one of the few remaining nesting beaches for the critically endangered eastern Pacific leatherback turtle (*Dermochelys coriacea*). The village sits atop an old sand bar and is surrounded by a mangrove forest that runs along the coastline and by the river estuary behind the village. The Conservación – Baulas del Pacífico (CBP) project, translated into English as the Pacific Leatherback Conservation project, has been working in the area for 10 years. CBP takes an integrated approach to marine turtle conservation, jointly addresses climate change, turtle conservation, and coastal community wellbeing. The CBP Program includes monitoring and protecting sea turtle nesting sites, community education, and training programs; the program is also actively involved in the development of the local community.

Leatherback turtle.

Photo credit: U.S. Fish and Wildlife Service.

Erosion of the beach at Junquillal in recent years has concerned community members; the additional threat of sea level rise prompted the WWF and CBP to carry out a study of the potential effects. A sea level rise inundation model for the community's coastline identified areas most prone to future flooding. As well as identifying vulnerable turtle nesting areas, the model is being used to design setback regulations for the village. Because of its location, sea level rise threatens the community on both sides. CBP is working with the Junquillal Development Association (ADIJ) to develop a land-use planning regime that considers appropriate setback distances in those areas vulnerable to flooding. Representatives from ADIJ and CBP also participate in regional planning workshops, have contributed data and technical information, and performed more than nine years of research at the beach that can be incorporated into the coastal development plans. By implementing these setback regulations and climate-sensitive planning, Junquillal may ensure the long-term availability of nesting ecosystems for marine turtles while also protecting investments in the community's growth.

WHAT NEEDS TO BE CONSIDERED FOR IMPLEMENTATION?

Planners and managers need to analyze each potential adaptation option to select the best course of action. Typical considerations for any given adaptation option appear in the "Adaptation options considerations" text box; a mix of adaptation options may be used to address specific climate risks to a community, region, or nation.

ADAPTATION OPTION CONSIDERATIONS

- Effectiveness
- Feasibility
- Cost
- Unintended consequences
- Additional benefits
- Implementation timing
- Flexibility
- Robustness

Protection should be considered simultaneously with other strategies to determine which suite of options makes the most sense for improving the resilience of a particular location. For example, protection strategies may be most relevant in locations where critical services need to be maintained and cannot be relocated. Other implementation considerations include:

- ***Cost and timeframe.*** Cost depends on a number of factors, including: the level of protection required (e.g., based on the design flood for the area), the siting and type of asset or

infrastructure to be protected, and the materials required and their local availability. Designing for protection is typically easiest and least expensive if improvements are made before a structure is built. For existing structures, decisions about when and how to protect them can depend on the structure's vulnerability and expected lifetime, as well as the likelihood and timescale of more severe effects from future changes in climate.

- ***Flexibility.*** Information on the rate and intensity of observed and projected coastal impacts can cover a wide range. For example, the projected average precipitation in an area may include opposite extremes, from increases to decreases in precipitation. To inform design specifications and decisions about which protection or other measures to undertake, it may be important to incorporate flexibility into planning. Uncertainty surrounding information on expected storm surge height, sea level rise, tropical cyclones, wind, and shoreline erosion rates may make decisions challenging and affect political will to take action. Flexible strategies that provide protection under a range of climate impact scenarios can facilitate action.

- ***Technical expertise.*** Protection measures can require significant technical expertise to implement. For example, flood-resilient design should consider the siting, foundation, shape, and structure of buildings. Where possible, structures should be built on firm, elevated ground outside of water retention or drainage areas. Foundations should be set at a sufficient depth to avoid scour and subsidence. For supports used to elevate buildings, designers must consider the material, the height of the supports, and the bracing (ADPC, 2005, citing SLUMPDMP, 2003). In some cases, outside technical expertise from engineers, architects, or contractors may be needed.

- ***Participation and engagement.*** A variety of social factors influence the success of protecting the built environment. Engaging the public in decision-making related to the built environment can help develop buy-in for challenging decisions, help planners and managers identify and understand local and traditional knowledge that could inform protection decisions, and help ensure that decisions are in the best interest of the community and environment. Public engagement can also garner support for efforts to protect the built environment through new standards, codes, or regulations.

- ***Legal and political considerations.*** Regulatory approaches that limit how property owners develop their properties can lead to claims that the government has violated owners' rights. Furthermore, adaptation actions may be stymied by political issues. These challenges stem from, for example, (a) the potential cost imposed on coastal property owners, (b) the potential loss of tax revenue from coastal owners should property values decline or become unavailable for development, and (c) real or perceived issues of equity with regard to impacts, access, and livelihoods.

- ***Enforcement and organizational capacity.*** Enforcement is particularly important for policies and regulations that prevent poor siting and building. Enforcement should be considered in the design of policies or regulations to make them more feasible to administer and, if possible, align the incentives of stakeholders with protection objectives. Organizations charged with implementing protection options should have a clear mandate for enforcement and sufficient resources to carry out the mandate.

Exhibit A.3.2 summarizes some major implementation considerations for protection options. For each option, the table identifies key feasibility challenges in implementation; the cost of implementing the measure, relative to other options included in the table; the level of decision-making typically involved (e.g., national, regional, local); the timeframe for implementation; and other considerations.

EXHIBIT A.3.2. IMPLEMENTATION CONSIDERATIONS CONCERNING OPTIONS TO PROTECT INFRASTRUCTURE AND ASSETS.

Option	Feasibility	Cost	Level of decision	Timeframe	Other considerations
Option A: Make structural improvements to existing assets to protect against climate change effects					
Protection	• Depends on extent of protection required, type of building or infrastructure, and cost	• Depends on type and local availability of materials • Cost is a key consideration in determining feasibility	• Local and regional • Can be implemented by the local community, with support from government or other external groups, such as nongovernmental organizations (NGOs)	• Short-term, particularly for emergency or seasonal measures • Long-term for permanent changes in design and construction	• Only protects to a specified level; may not protect assets from events beyond scope • Not feasible in high-impact areas with large wave action or high water velocities
Accommodation	• Depends on extent of accommodation required, type of building or infrastructure, availability of embankments or elevated areas to position assets, flood conditions, and cost	• Depends on type and local availability of materials • Often high immediate capital cost (e.g., for elevation of roads), but with longer-term cost-savings (DARA, 2010) • Using existing embankments can reduce cost (ADPC, 2005)	• Local and regional • Can be implemented by the local community, with support from government or other external groups such as NGOs	• Moderate, depending on the scale of the accommodation action	• Large structures may require demolition and reconstruction
Option B: Establish policies and regulations to prevent poor siting and building					
Proactive land-use plans	• Depends, in part, on the binding nature of the plan and requirements for updating the plan; voluntary plans should meet minimal resistance	• Cost of the plan development should be low but implementation costs could be high	• While plans are typically developed at the local level, they can be spearheaded at the regional or national level through guidelines, technical support, and funding	• Moderate; subject to amendments and updates	• Plans are often voluntary • Lack of political will, if plans restrict development • Localities often lack funds to fully implement plans

EXHIBIT A.3.2. IMPLEMENTATION CONSIDERATIONS CONCERNING OPTIONS TO PROTECT INFRASTRUCTURE AND ASSETS.

Option	Feasibility	Cost	Level of decision	Timeframe	Other considerations
Zoning ordinances	• Use of setbacks common in some locations; in other locations, resistance from property owners and local government may be problematic	• Cost could be high for local governments because high-value coastal areas provide a tax base for the local government • Cost could be high for property owners who lose coastal property or development rights	• Typically local, but may be determined or informed by regional, national, or international law	• Long-term and permanent setbacks will likely need to be adjusted as sea level rises in the long-term	• Changing setbacks typically only addresses future structures and not existing ones • Setbacks can be politically controversial
Building codes	• Many existing building codes address hazards; updating codes may be most feasible following an extreme storm event, for example	• Cost of developing codes is low but implementation, including inspection and enforcement, could be a major expense; also could be costly for builders	• Local or regional decision but can be informed by national and international guidance and codes	• Long-term and permanent	• Difficult or expensive for existing buildings to meet new codes • Considerable information may be needed to determine flood-prone areas, especially projecting into the future (e.g., 500-year flood risk) • Enforcement may be challenging and expensive
Insurance	• May face resistance from coastal communities • Not relevant in all countries	• Shifts cost from tax payers to coastal property owners	• National	• Typically runs with owner, not property, and is renewed annually; some recommend long-term policies with terms that stay with the property	• Many will drop insurance after property purchase, rendering changed policies ineffective

REFERENCES AND RESOURCES

Report summarizes six case studies selected to help countries adapt to current and future climate risks and shows why and how reducing climate change risk is part of sustainable development. Six case studies include infrastructure development projects (Kosrae and Rarotonga), community development planning and regulations (Rarotonga and Pohnpei), and national strategic development plans (Federated States of Micronesia and Cook Islands):

ADB. 2005. Climate Proofing a Roadbuilding Infrastructure Project in Kosrae, Federated State of Micronesia. In *Climate Proofing: A Risk-based Approach to Adaptation.* Asian Development Bank.
Available: http://www.adb.org/sites/default/files/pub/2005/climate-proofing.pdf.

Practical "how-to" guide describing concepts of flood-proofing dwellings, homesteads, and other assets in the built environment. Provides an overview of flood-proofing practices including relocation, elevation, and flood-proofing. Resource explains options for community-level flood-proofing approaches, outlines a process for undertaking flood-proofing activities, and summarizes limitations, future challenges, and additional resources:

ADPC. 2005. Integrated Flood Risk Management in Asia: A Primer. Asian Disaster Preparedness Center.

SLUMPDMP. 2003. Guidelines for Settlements Planning and Construction in Floodprone Areas. Sri Lanka Urban Multi-hazard Disaster Mitigation Project. Sri Lanka, Centre for Housing Planning and Building.

Good practice database entry provides further details on the Kosrae circumferential road, including the cost of the project to the State of Kosrae, and the specific precipitation levels that the climate-proofed road will be designed to:

Asia Pacific Adaptation Network. 2012. Adapting Coastal Road Designs to Take into Consideration the Impacts of Climate Change. Available: http://www.apan-gan.net/adaptation-practices/adapting-coastal-road-designs-take-consideration-impacts-climate-change.

Journal article explores short-, medium-, and long-term management actions for protection of Ghana's coastal areas:

Boateng, I. 2012. An Assessment of the Physical Impacts of Sea-level Rise and Coastal Adaptation: A Case Study of the Eastern Coast of Ghana. *Climatic Change* 114(2):273.

Report explores local government options for coastal adaptation to climate change:

Britton, R. 2010. Coastal Adaptation to Climate Change: Report on Local Government Planning Practice and Limitations to Adaptation.
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Glossary briefly lists key definitions related to land-use practices and tools for climate change adaptation:

Praha, E. and S. Mooney. Undated. Preparing for the Future: Climate Change and Monterey Bay Shoreline. Application of Land Use Practices and Tools to Prepare for and Adapt to Climate Change. Center for Ocean Solutions.
Available: http://www.centerforoceansolutions.org/sites/default/files/Application%20of%20Land%20Use%20Practices%20and%20Tools%20to%20Prepare.pdf.

Report summarizes the vulnerability of countries around the world to health impacts, weather disasters, ecosystem loss, and economic stress. Provides a thorough summary of climate change adaptation options, and evaluates their performance in terms of cost-effectiveness, co-benefits, feasibility, scalability, and the robustness of evidence available on each option:

DARA. 2010. Climate Vulnerability Monitor 2010. Available: http://daraint.org/climate-vulnerability-monitor/climate-vulnerability-monitor-2010/.

Report produced by the IPCC that provides an assessment of extreme weather and climate events:

Handmer, J., Y. Honda, Z.W. Kundzewicz, N. Arnell, G. Benito, J. Hatfield, I.F. Mohamed, P. Peduzzi, S. Wu, B. Sherstyukov, K. Takahashi, and Z. Yan. 2012. Changes in impacts of climate extremes: Human systems and ecosystems. In *Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation,* C.B. Field, C.B., V. Barros, T.F. Stocker, D. Qin, D.J. Dokken, K.L. Ebi, M.D. Mastrandrea, K.J. Mach, G.-K. Plattner, S.K. Allen, M. Tignor, and P.M. Midgley (eds.). A Special Report of Working Groups I and II of the Intergovernmental Panel on Climate Change (IPCC). Cambridge University Press, Cambridge, UK, and New York, NY, USA, pp. 231–290.

Paper discusses social justice challenges related to flood and disaster management:

Lebel, L., T. Foran, P. Garden, and J.B. Manuta. 2009. Adaptation to climate change and social justice: Challenges for flood and disaster management in Thailand. In *Climate Change Adaptation in the Water Sector*, F. Ludwig, P. Kabat, H. van Schaik, and M. van der Valk (eds.).

Article provides a description of legal and regulatory options for the built environment:

Nichols S. and C. Bruch. 2008. New Frameworks for Managing Dynamic Coasts: Legal and Policy Tools for Adapting U.S. Coastal Zone Management to Climate Change. *Sea Grant Law and Policy Journal* 1:19–41. Available: http://nsglc.olemiss.edu/SGLPJ/Vol1No1/vol1no1.pdf.

Report, while designed for U.S. coastal managers, provides general information that is applicable beyond the United States about the planning process, vulnerability assessments, adaptation strategies, and plan implementation and maintenance:

NOAA. 2010. Adapting to Climate Change: A Planning Guide for State Coastal Managers. NOAA Office of Ocean and Coastal Resource Management.
Available: http://coastalmanagement.noaa.gov/climate/docs/adaptationguide.pdf.

Report describes the concept of rolling easements and provides a comprehensive summary of the tools available for achieving rolling easements, including exploring the pros and cons of rolling easements:

Titus, J. 2011. Rolling Easements. Climate Ready Estuaries. U.S. Environmental Protection Agency. June. Available: http://www2.epa.gov/sites/production/files/documents/rollingeasementsprimer.pdf.

Publication details the impacts of Cyclone Sidr on communities in Bangladesh, and a response effort coordinated by the United Kingdom's Department for International Development and the UNDP to design and build structures designed to weather cyclone and storm impacts:

UNDP. 2012. Rebuilding Lives: Family Shelters for Cyclone Sidr Survivors. United Nations Development Programme.

Series of fact sheets produced by USAID addresses multiple infrastructure issues related to climate change:

USAID. 2013. *Addressing Climate Change Impacts on Infrastructure: Preparing for Change*. United States Agency for International Development. April.

Annex presents a sector-specific application of the USAID Climate Resilient Development Framework:

USAID. Forthcoming. *Climate Change and Water: An Annex to the USAID Climate-Resilient Development Framework*. United States Agency for International Development.

Report on a climate-proof road project in Kosrae, Micronesia:

SPREP. 2014. Climate-proof Road Opens in Kosrae, FSM. Secretariat of the Pacific Regional Environment Program. Available: http://www.sprep.org/climate-change/climate-proof-road-opens-in-kosrae-fsm.

ADAPTATION ACTION 4: RELOCATE INFRASTRUCTURE AND ASSETS

In the long-term, managed retreat from the shoreline may be the most cost-effective solution for many coastal communities seeking to adapt to increased coastal hazards because of sea level rise and storms. Managed retreat encompasses a portfolio of strategies, programs, and projects – planning and policy development, as well as physical relocation of assets and subsequent compensation of property owners. Relocation of assets can have ecological benefits, including maintaining natural shoreline dynamics and enabling shoreline ecosystems to migrate inland. However, in many cases, political barriers, humanitarian concerns, and legal disputes may delay or entirely prevent relocation of facilities and infrastructure. Relocation can occur either as a disaster-mitigation strategy following a severe storm or as an anticipated adaptation to minimize exposure to coastal risks. In all cases, successful relocation strategies require working closely with communities and engaging stakeholders to ensure that relocation efforts are transparent and fair.

RELOCATING AFTER HURRICANE MITCH IN HONDURAS

After Hurricane Mitch struck Honduras in 1998, more than 1,200 families were forced to relocate from temporary shelter camps in Tegucigalpa to an inland site in the Amarateca Valley. Lack of coordination and planning hindered the relocation effort and the local government and public utilities were not prepared to provide infrastructure services for the new settlement. When the families arrived in the valley, they found no water, sewage, electricity, or solid waste collection. As a result, the new settlement adopted temporary and improvised infrastructure solutions, such as pit latrines and water supplied by tanker trucks. These temporary solutions led to problems early on in the new settlement, including public health hazards and social unrest. However, over time, new businesses and infrastructure moved into the Amarateca Valley. Ten years after the disaster, the valley is a population center with textile factories, grain processors, and automobile parts manufacturing, among other businesses (World Bank, 2010a).

Improved roadway drainage.

Photo credit: USAID.

HOW DOES RELOCATION CONTRIBUTE TO CLIMATE-RESILIENT DEVELOPMENT?

Relocating assets that are currently exposed to coastal hazards, or that may become exposed in the future, reduces a community's vulnerability to climate impacts. Moving farther from the coast or to higher elevations provides increased protection from sea level rise and storm surge. Because tropical storms lose intensity as they travel inland, infrastructure built inland is less exposed to severe storms. Managed retreat away from sensitive coastal areas creates a buffer zone that allows natural coastal defenses to protect the inland built environment. Barrier islands, mangrove forests, and wetlands can increase the resilience of the coast by allowing the natural environment to provide low-cost protection from coastal storms and erosion. In cases where a disaster completely destroys a community or renders it uninhabitable, relocation may be the only option for displaced people.

Climate impacts may influence the need for relocation. Exhibit A.4.1 summarizes some of the ways that climate may affect coastal assets.

EXHIBIT A.4.1. POTENTIAL IMPACTS OF CLIMATE CHANGE ON COASTAL ASSETS.

Climate change impact	Impact on coastal assets
More severe storms	• Increased risk of flooding and damage to coastal infrastructure, as well as injuries and mortality from more frequent or intense tropical storms
Sea level rise	• Destruction and damage to coastal property because of flooding, erosion, and exposure of new areas to storm surges, waves, currents, and tides

WHAT ARE THE OPTIONS FOR RELOCATION?

Relocation away from hazardous areas is typically employed as part of a broader portfolio of planning approaches referred to as managed retreat. Relocation can occur either as a planned adaptation option to minimize exposure to coastal hazards or as an emergency response following a severe storm. Studies suggest that planning in advance for shoreline retreat reduces cost and minimizes human suffering (U.S. CCSP, 2009a, 2009b).

THE KIRIBATI ADAPTATION PROJECT

The Republic of Kiribati, an island nation of 32 atolls in the Pacific Ocean, is susceptible to the effects of sea level rise from climate change. The nation is integrating adaptation into its national development planning through the Kiribati Adaptation Project. Recognizing that some adaptation actions may necessitate land acquisition or resettlement, the government formulated a Land Acquisition and Resettlement Framework to guide the process. The Kiribati framework focuses on incentivizing voluntary resettlement because involuntary resettlement can cause long-term hardship and impoverishment. The government also recommends executing resettlement as a sustainable development program that involves stakeholders in the planning process and provides sufficient investment to ensure economic sustainability. It follows the World Bank's Involuntary Resettlement Policy, which specifies that displaced people should know about their options and rights, have choices among feasible resettlement alternatives, and have prompt and effective compensation for losses because of resettlement (GOK, 2011).

The Republic of Kiribati is integrating adaptation into national plans for development and has begun preparing for resettlement away from the coast.

Photo credit: NASA.

Option A: Planned Relocation

Planned relocation is part of a managed retreat from the shoreline to prepare for expected increases in coastal hazards. Planned relocation encompasses planning and policy development to restrict or limit private ownership of land or facilities in high-risk areas, and physical relocation of assets and subsequent compensation of property owners (NOAA, 2007b). Managed retreat establishes thresholds to trigger relocation actions. A community may choose to make plans to relocate assets at a designated date, after a storm event damages or destroys an asset, or when sea level rise reaches a pre-determined level. Critical supporting infrastructure such as road networks, drinking water, waste water, and electrical power systems are candidates for landward relocation. Communities may also choose to relocate valuable facilities and cultural resources to preserve their heritage.

To be cost-effective, managed retreat generally requires planning decades in advance because of the long lifetimes of investment in buildings and infrastructure (U.S. CCSP, 2009a). Advanced planning also allows communities to monitor shoreline changes and take incremental action to increase resilience. However, examples of planned asset relocations to date are rare and fraught with logistical difficulties.

The entity managing the relocation, most likely a government or development agency, must have the requisite authority to initiate relocation. This authority may include holding the property rights for the land in question or jurisdiction over the assets. Planning and executing the physical relocation of an asset from its current location to its new one will necessitate negotiations with existing land owners. Even in cases in which property rights are not well established, agencies will likely need to negotiate with communities that will be directly or indirectly affected (e.g., by the loss of transportation services). Relocation success depends on the involvement and buy-in of the community, incentives for relocation, and funding mechanisms to purchase land and compensate property owners.

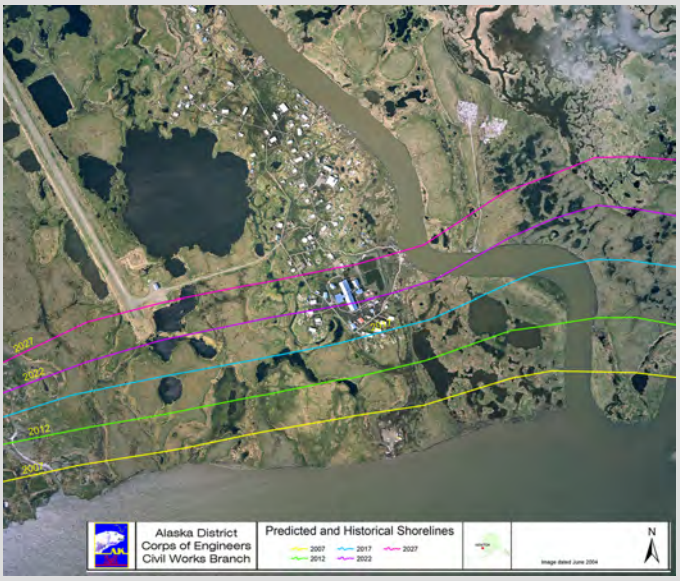
Development restrictions and land acquisition policies, such as those described briefly below and in Adaptation Action 3, can help facilitate future relocation.

- ***Restrictions on development*** regulate the type of land use that can occur in a given area and can enable the relocation of assets at a later date. For example:
  - *Size or density limitations* allow development in coastal areas, but limit the size or footprint of the allowable development, making it easier to move in the future.
  - *Rolling easements* are a collection of legal mechanisms, such as regulations and property restrictions, to allow the shore or human access along the shore to migrate inland over time (Titus, 2011). A rolling easement can ensure that communities are able to relocate infrastructure inland as needed. For example, some governments may not have the right to relocate washed-out infrastructure (such as a coastal road) across private property. A rolling easement could provide the community with the authority to do so, along with legally enforceable expectations about the future need to relocate it (Titus, 2011).
  - *Zoning and erosion overlay districts* limit development within areas prone to erosion. Based on the estimated level of risk, the erosion overlay zones could allow different types of development and shoreline protection in different areas (NOAA, 2007a).

- ***Land acquisition policies*** provide mechanisms for government or development agencies to acquire land in high-risk areas securing the authority to initiate relocation.
  - *Buyout programs* enable public agencies to purchase vulnerable property from land owners, making it financially feasible for property owners to relocate facilities further inland.
  - *Removal requirements* involve an agreement with a landowner that he or she will remove or relocate structures when the shoreline migrates landward.

RELOCATION OF VILLAGE OF NEWTOK, ALASKA

The Village of Newtok, Alaska, began planning for relocation in 1994 in response to severe coastal erosion problems that were aggravated by climate variability and change. The Newtok Traditional Council selected Mertarvik as the site for their new village, which was part of a National Wildlife Refuge managed by the U.S. Fish and Wildlife Service (USFWS). As of early 2012, the community layout for the new settlement was complete and the first construction was underway. Very little existing infrastructure in Newtok will be relocated to Mertarvik, with the exception of some selected homes, the school, and the town's clinic. The village will construct new roads, water and sewer systems, an airport, a power plant, and community buildings. The total relocation will cost an estimated US$80–130 million (HDR Alaska, 2008; Feifel and Gregg, 2010; State of Alaska, Undated). Unfortunately, progress in Newtok has stalled because of the grounding of a barge in 2012 and local political turmoil in 2013 (Goldenberg, 2013).



Shoreline map for Newtok, Alaska.

Image credit: U.S. Army Corps of Engineers, Alaska District.

Option B: Post-disaster Relocation

Post-disaster relocation usually occurs following a major weather-related catastrophe, such as a hurricane or coastal storm. In most cases, post-disaster relocation of infrastructure occurs during resettlement, as development agencies and governments work to relocate communities away from vulnerable areas. For example, the town of Hilo, Hawaii, suffered tsunamis that inundated a large portion of the community in both 1946 and 1960. Following the 1946 tsunami, the town rebuilt on the same footprint. However, after the 1960 tsunami, the town decided to convert the old town site into an open space for a park and soccer fields. Using federal money, the Hawaii Redevelopment Agency acquired properties further inland and helped to relocate individuals and businesses to alternative sites (Hwang, 2011).

Post-disaster planning typically focuses on returning people to their homes, restoring land rights, and reconstructing. However, relocating a community is sometimes the best option after a disaster, particularly in places where land will become increasingly vulnerable as climate impacts increase in severity or intensity, for example on small islands. Finding sites suitable for relocation is challenging and, if not done carefully, can

lead to the loss of community, livelihoods, and culture. All aspects of community development must be considered and addressed, including the provision of basic services like health care, housing, transportation, energy, water, and sanitation.

WHAT NEEDS TO BE CONSIDERED FOR IMPLEMENTATION?

Planners and managers need to analyze each potential adaptation option to select the best course of action. Typical considerations for any given adaptation option are in the "Adaptation options considerations" text box; a mix of adaptation options may be used to address specific climate risks to a community, region, or nation.

ADAPTATION OPTION CONSIDERATIONS

- Effectiveness
- Feasibility
- Cost
- Unintended consequences
- Additional benefits
- Implementation timing
- Flexibility
- Robustness

Planned relocation will require strategies to navigate the complexities and challenges associated with acquisition of land and property rights, as well as technical expertise and adequate funding to support the relocation or reconstruction of assets. Post-disaster relocation has additional implementation considerations. Factors involved in the decision to relocate may include cost-effectiveness, the condition of structures, property owner interests, and availability of land (NOAA, 2007b). Other factors include:

- ***Acquisition of land and property rights.*** Government or development agencies will likely need to obtain legal authority to acquire land before relocating assets to a new site, or they may need to purchase property in the relocation. Accessing land for relocation requires long lead times and may require significant financing if it is necessary to compensate private land owners. In some countries, the lack of existing land-use planning and enforcement may make planning for relocation difficult, especially where land rights are not well established, such as most peri-urban areas near large coastal megacities.
- ***Relocation and reconstruction of assets.*** Identifying suitable land for relocation is challenging. Risk mapping using remote sensing techniques, surveys, and historical records can help identify areas vulnerable to coastal erosion and storms. Spatial analysis may also help to identify parcels of land that may be available for relocation. Moving or rebuilding assets requires significant capital costs and planning. Services and facilities must remain accessible throughout the relocation effort.
- ***Post-disaster relocation.*** Disaster response agencies can evaluate vulnerability to coastal hazards before a disaster occurs. If the planning process identifies relocation as a viable and cost-efficient future option for an area that is particularly prone to coastal hazards, disaster agencies can begin coordinating with appropriate government agencies to define frameworks for relocation, financing options, an assistance strategy, and criteria for selecting a relocation site.
- ***Importance of community involvement and stakeholder engagement.*** Relocation is highly controversial. To date, most successful managed retreat efforts have begun at the local level, with all major stakeholders involved in the process at the outset. Engaging stakeholders in the decision-making process so that they understand climate risks and the options to protect coastal livelihoods can help minimize community opposition. In addition, local organizations and governments are often in the best position to identify vulnerabilities before a disaster event and to monitor risk factors. For example, in Saint Lucia, an island nation in the Lesser Antilles, local disaster committees assist with the identification of structures that are vulnerable to natural disasters (World Bank, 2002).

- ***Resource rights.*** Relocation may affect access to coastal resources. In some cases, changing access to these resources may complicate relocation. For example, relocation may limit access to traditional food sources.

- ***Livelihoods.*** Every effort should be made to maintain livelihoods in a relocation. However, this can be challenging (e.g., tourism may not be as profitable from a new location). Negative effects and viable options for alternative livelihoods must be explored as part of the relocation process.

Co-benefits

Communities will likely implement anticipatory relocation as part of a suite of coastal retreat strategies that allow for natural shoreline migration and the landward migration of important ecosystems. Limiting human development in vulnerable coastal ecosystems and facilitating the restoration or protection of natural processes will result in healthier and more resilient ecosystems that are better able to provide ecosystem services. In addition, relocation inland can provide opportunities for transforming coastal areas into green, public areas.

Relocation often requires reconstructing assets in the new location, providing an opportunity to rebuild structures with enhanced design and engineering features to make them more resilient to any hazards in the new location. Because planned relocation can require long lead times and community engagement, these efforts can be opportunities to raise awareness about coastal risks and encourage communities to proactively address those risks through other complimentary approaches.

Exhibit A.4.2 provides a summary of some of the major implementation considerations. For each relocation action, the table identifies key feasibility challenges in implementation; the cost of implementing the measure, relative to other options included in the table; the level of decision-making typically involved (e.g., national, regional, local); and the timeframe for implementation.

EXHIBIT A.4.2. IMPLEMENTATION CONSIDERATIONS CONCERNING RELOCATION OPTIONS.

Option	Feasibility	Cost	Level of decision	Other considerations
Option A: Planned relocation	• May be feasible in certain communities, but faces notable challenges	• Little is known about relocation costs; initial estimates for relocating Alaskan coastal communities are from US$20 to US$200 million each for villages of 250 to 600 residents (Kates et al., 2012) • Relocation is potentially more cost-effective over the long-term than shoreline accommodation and protection strategies • Costs of relocation include the cost of acquiring land and the capital cost of rebuilding the facility or infrastructure • Considerable "up-front" costs, but avoided costs in the future • In high-value coastal areas, the cost of relocation is likely to be high; in these areas, shoreline protection might make more sense, at least in the short-term	• Local governments may have control over developing strategies for anticipatory shoreline retreat and relocation	• Planning for relocation must begin early to enable adequate time for negotiations between land owners, community members, etc.
Option B: Post-disaster relocation	• Disaster assistance and development agencies generally only consider relocation in areas of extremely high vulnerability, since the challenges associated with relocation can be significant	• The impact of a disaster imposes huge societal costs, both economic and social; post-disaster relocation can help avoid some of these costs, vis-à-vis future disasters, though adequate planning and preparation	• National governments and international development and aid organizations may be involved in decision-making	• Successful post-disaster relocation may require advance planning to be successful

REFERENCES AND RESOURCES

Article analyzes the attitudes of Australian residents to possible managed retreat options:

Alexander, K., A. Ryan, and T. Measham. 2011. Managed Retreat of Coastal Communities: Understanding Responses to Projected Sea Level Rise. CSIRO. Available: http://www.csiro.au/Organisation-Structure/Divisions/Ecosystem-Sciences/SEED-Paper-43.aspx.

Case study introduces the history of the Newtok, Alaska relocation and provides additional resources:

Feifel, K. and R.M. Gregg. 2010. Relocating the Village of Newtok, Alaska, due to Coastal Erosion (Case Study on a Project of the Newtok Planning Group). Product of EcoAdapt's State of Adaptation Program. Available: http://www.cakex.org/case-studies/relocating-village-newtok-alaska-due-coastal-erosion.

Chapter of the Handbook for Reconstructing after Natural Disasters describes general principles for relocation of communities and provides case studies:

GFDRR. 2012. Chapter 5: To Relocate or Not to Relocate. *Handbook for Reconstructing after Natural Disasters.* Global Facility for Disaster Reduction and Recovery.
Available: https://www.gfdrr.org/sites/gfdrr/files/publication/SaferHomesStrongerCommunitites.pdf.

Framework for land acquisition and resettlement that the Government of Kiribati is drafting as part of the Kiribati Adaptation Programme:

GOK. 2011. Kiribati Adaptation Programme Pilot Investment Phase: Land Acquisition and Resettlement Policy Framework. Revised 2011. Government of the Republic of Kiribati.

Media report on the progress of relocation efforts in Newtok Village, Alaska:

Goldenberg, S. 2013. Relocation of Alaska's Sinking Newtok Village Halted. *The Guardian*. August 5.
Available: http://www.theguardian.com/environment/2013/aug/05/alaska-newtok-climate-change.

Community layout plan for the new Mertarvik community, where the residents of Newtok are planning to relocate:

HDR Alaska. 2008. Mertarvik Community Layout Plan. HDR Alaska, Inc.
Available: https://www.commerce.state.ak.us/dnn/Portals/4/pub/Newtok_CLP_Update_Final.pdf.

Article describes lessons learned from disaster recovery planning in four case studies: Hilo, Hawaii; Valdez, Alaska; the Sichuan Earthquake; and Louisiana after Hurricanes Katrina and Rita:

Hwang, D. 2011. Disaster Recovery Planning: Lessons Learned from Past Events. *Solutions to Coastal Disasters* 924–935. Available: http://ascelibrary.org/doi/pdf/10.1061/41185%28417%2978.

Article describes situations where the vulnerabilities and risks are so large that they require transformational rather than incremental adaptations; relocation is an example of transformational adaptation:

Kates, R.W., W.R. Travis, and T.J. Wilbanks. 2012. Transformational adaptation when incremental adaptations to climate change are insufficient. *PNAS* 109(19):7156–7161.
Available: http://sciencepolicy.colorado.edu/admin/publication_files/2012.06.pdf.

NOAA's Ocean & Coastal Resource Management site describes zoning and erosion overlay districts with example case studies from within the United States:

NOAA. 2007a. Ocean & Coastal Resources Management: Establish Zoning and Erosion Overlay Districts. National Oceanic and Atmospheric Administration.
Available: http://coastalmanagement.noaa.gov/initiatives/shoreline_ppr_overlay.html.

NOAA's Ocean & Coastal Resource Management site describes managed retreat strategies with example case studies from within the United States:

NOAA. 2007b. Ocean & Coastal Resources Management: Managed Retreat Strategies. National Oceanic and Atmospheric Administration.
Available: http://coastalmanagement.noaa.gov/initiatives/shoreline_ppr_retreat.html.

Guidance aims to help U.S. state coastal managers develop and implement adaptation plans to mitigate the risk of coastal hazards, including climate change:

NOAA. 2010. Adapting to Climate Change: A Planning Guide for State Coastal Managers. National Oceanic and Atmospheric Administration Office of Ocean and Coastal Resource Management.
Available: http://coastalmanagement.noaa.gov/climate/adaptation.html.

NOAA's Ocean & Coastal Resource Management site describes erosion control easements with example case studies from within the United States:

NOAA. 2012. Erosion Control Easements. National Oceanic and Atmospheric Administration.
Available: http://coastalmanagement.noaa.gov/initiatives/shoreline_ppr_easements.html.

History describes the relocation of the Cape Hatteras Lighthouse in Cape Hatteras, North Carolina:

NPS. 2012. Cape Hatteras: Moving the Cape Hatteras Lighthouse. National Park Service.
Available: http://www.nps.gov/caha/historyculture/movingthelighthouse.htm.

Report provides an overview of the impact of sea level rise and analyze the potential need for relocation and resettlement of coastal communities:

Oliver-Smith, A. 2009. Sea Level Rise and the Vulnerability of Coastal Peoples: Responding to the Local Challenges of Global Climate Change in the 21st Century. Available: http://www.ehs.unu.edu/file/get/4097.

Titus, J. 2011. Rolling Easements. Climate Ready Estuaries. U.S. Environmental Protection Agency. June.
Available: http://www2.epa.gov/sites/production/files/documents/rollingeasementsprimer.pdf.

Newtok Planning Group website describes the history of relocation plans for the Newtok community:

State of Alaska. Undated. Planning & Land Management. Newtok Planning Group. Innovative Readiness Training (IRT) Program Mertarvik. Division of Community and Regional Affairs. Department of Commerce, Community, and Economic Development.
Available: http://commerce.state.ak.us/dnn/dcra/PlanningLandManagement/NewtokPlanningGroup/IRTMertarvik.aspx.aspx.

Chapter describes and evaluates different options available for shore protection and retreat in the Mid-Atlantic region of the United States:

U.S. CCSP. 2009a. *Coastal Sensitivity to Sea-level Rise: A Focus on the Mid-Atlantic Region*. Chapter 6: Shore protection and retreat. U.S. Climate Change Science Program.
Available: http://downloads.globalchange.gov/sap/sap4-1/sap4-1-final-report-all.pdf.

Chapter describes the implications of shoreline protection and retreat strategies that coastal communities in the region are considering:

U.S. CCSP. 2009b. *Coastal Sensitivity to Sea-level Rise: A Focus on the Mid-Atlantic Region.* Chapter 10: Implications for Decisions. U.S. Climate Change Science Program.
Available: http://downloads.globalchange.gov/sap/sap4-1/sap4-1-final-report-all.pdf.

Report describes the challenge of natural hazard risk management in the Caribbean and make recommendations for mitigating risk:

World Bank. 2002. Natural Hazard Risk Management in the Caribbean: Revisiting the Challenge. Caribbean Group for Cooperation in Economic Development.
Available: http://siteresources.worldbank.org/INTDISMGMT/Resources/cgced_final.pdf.

Handbook developed to assist policymakers and project managers engaged in large-scale post-disaster reconstruction programs make decisions about how to reconstruct housing and communities after natural disasters:

World Bank. 2010a. Safer Homes, Stronger Communities: A Handbook for Reconstructing after Natural Disasters. Available: http://www-wds.worldbank.org/external/default/WDSContentServer/WDSP/IB/2010/01/27/000334955_20100127044847/Rendered/PDF/528390PUB0safe101Official0Use0Only1.pdf.

Report identifies key socioeconomic and biophysical zones of vulnerability to climate change, assesses the policy and institutional frameworks for adaptation, and evaluates existing adaptation options:

World Bank. 2010b. The Social Dimensions of Adaptation to Climate Change in Vietnam.
Available: http://www-wds.worldbank.org/external/default/WDSContentServer/WDSP/IB/2011/01/11/000356161_20110111012856/Rendered/PDF/589030NWP0EACC10Box353823B01public1.pdf.

ADAPTATION ACTION 5: DISASTER PREVENTION, PLANNING, AND PREPAREDNESS

Climate-related droughts, floods, and tropical storms already affect coastal communities. Climate change is likely to exacerbate these events, as well as the effects of disasters that are not related to climate, such as tsunamis. In recognition of the vulnerability of coastal communities to climate impacts, this adaptation action focuses on ways to build community capacity to prepare for extreme climate events and disasters. Specific actions include planning and coordination efforts, identification of hazards, and assessment of vulnerability. These efforts support the development of early notification systems through improved forecasting abilities and communications systems.

HOW DOES DISASTER PREVENTION, PLANNING, AND PREPAREDNESS CONTRIBUTE TO CLIMATE-RESILIENT DEVELOPMENT?

The concept behind risk reduction is simple: by reducing risk, communities protect their populations, as well as their economic, environmental, and cultural resources. By mitigating the effects of natural hazards, the community reduces effects on its members, reduces recovery time, and becomes more climate-resilient.

Coastal communities in urban areas are particularly vulnerable to climate-related risks because of the combination of high population concentrations and valued assets, as well as exposure to severe storms, disasters, and sea level rise. The insurance company Lloyd's of London estimates that if adaptation actions are not taken, global losses from coastal flooding for high-risk properties could double by 2030 relative to 2008 losses, with detrimental consequences for these communities (Lloyd's, 2008). Non-climate stressors such as population growth, increased settlement on coastal lands, environmental degradation, and unstable socioeconomic conditions further increase coastal communities' vulnerability to the effects of climate change.

The adaptation options included here support climate-resilient development in two key ways. First, disaster prevention, planning, and preparedness help communities anticipate and cope with climate impacts. Second, prevention efforts that restore native ecosystems protect inland areas and infrastructure from damages, making them more resilient to climate impacts (see Adaptation Action 1). As an added benefit, restoring natural areas costs less than restoring built infrastructure and simultaneously supports ecosystems and their services.

WHAT ARE THE OPTIONS FOR DISASTER PREVENTION, PLANNING, AND PREPAREDNESS?

Vulnerable communities must be able to prepare for and meet recovery needs for responding to extreme events and disasters. To do this effectively, communities must build capacity beforehand, for example by ensuring that various agencies have access to the same information and developing formal structures to streamline communications during extreme events. Most disaster-affected coastal populations have developed risk-reduction strategies to use limited resources to their best advantage. Adaptation options should build on these strategies, as well as take into account the core elements of risk reduction, tailor interventions to reflect the decision-making dynamics of affected populations, and strive to foster self-sufficiency and productivity over the long-term.

Community protection encompasses interventions that emphasize three core elements and well-practiced areas of disaster risk reduction: prevention, planning, and preparedness. Together, these three risk-reduction areas reduce exposure and sensitivity, and increase adaptive capacity.

Although natural hazards are not preventable, the deaths, destruction of infrastructure, and loss of resources from these hazards can be mitigated. For example, when coastal communities have adequate warnings of heavy rains, community leaders can mandate evacuation to move vulnerable populations, reducing their exposure. To do this, communities must have structures in place to ensure that information is being collected and disseminated in an efficient manner. In the short- to medium-term, planning activities can ameliorate the effects of hazards. For example, establishing housing enhancement programs to reinforce structures enables communities to protect lives and property during floods, thereby decreasing vulnerability. To do this, adequate governance structures must be in place to develop and enforce such programs. In the longer-term, preparedness actions can facilitate a quick response to hazard events. For example, a well-rehearsed early warning system that projects flooding and storm patterns can help farmers prepare for expected food shortages, improving adaptive capacity. All of these methods of mitigating the effects of climate impacts require capacity building, in advance of an extreme event, to be successful.[11]

Option A: Disaster Prevention

In the simplest of terms, disaster prevention refers to risk reduction and community protection measures that protect people or economic assets by detecting, containing, and forestalling processes that could lead to disaster vulnerability. For developing nations, disaster prevention is often viewed as one of the most critical components of risk reduction and community protection, but it is also difficult to promote. In practice, communities must understand disaster prevention as part of a process that will help to secure protection against a disaster. This includes building capacity and investment in activities such as:

- Environmental and land forestry legislation and good land-use practices, which improve the ability of natural ecosystems to act as buffers against extreme weather events or other climate impacts
- Enforcement of construction codes, which improves the ability of man-made structures to withstand extreme weather events or other climate impacts
- Large-scale infrastructure, such as dams or seawalls, which protect vital resources against extreme events or other climate impacts[12]
- Sustainable development projects that address food security, rural development, fisheries, and forestry, which improve overall community resilience to climate impacts

Good prevention planning is based on two major undertakings: hazard identification and vulnerability assessment. Coastal communities must identify the actual threats confronting their lives and property and then evaluate or assess the risk of the hazards and determine the community's capacity to address the consequences of the disaster. For example, if flooding is a recurring disaster event, the community would

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11. See the IPCC *Special Report on Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation* (IPCC, 2011) for more information on disaster risk reduction strategies relevant to climate change.

12. Dams have the potential to reduce some aspects of climate vulnerability through measures such as water storage. However, dam construction can impinge on land rights, significantly alter natural ecosystems, and affect resident species.

identify the areas most at risk and then determine the actions required to reduce the risk, such as better land use; improved irrigation and water management; or upgraded infrastructure, such as dams or flood-proof building design.[13]

Option B: Disaster Planning and Coordination

Effective planning and coordination are key components to all risk-reduction options. For example, USAID coordinates disaster risk reduction planning with countries, other donor governments, international organizations, and United Nations relief agencies, as well as private, voluntary, and NGOs. However, the primary responsibility for disaster risk reduction planning rests with central, regional, and local governments; these bodies must ensure that they have the capacity to coordinate all disaster preparedness and response efforts.

To develop proper planning and coordination capabilities, planners and managers should conduct three key activities:

1. Identify and develop an authoritative multi-disciplinary team that meets international and national standards to coordinate a proper response to all hazards, supports affected local government efforts, and coordinates with international disaster relief entities
2. Introduce and apply tools and systems in rapid assessments and coordination, based on local and international expertise
3. Strengthen linkages between communities and the national government in anticipation of disaster events

Emergency management teams or entities can vary widely in their responsibilities, relationships with other organizations, implementation methods, and resources. Regardless, they must be able to assess the threats to the community; prioritize objectives, tactics, and resources; coordinate with other organizations; inform the public; and quickly become operational. For coastal communities threatened with recurring hazards, local agencies must also coordinate with national agencies, tourism administrations, businesses, and disaster management offices in neighboring communities.

CYCLONE PREPARATION IN INDIA

In 1999, Cyclone Ob5 struck the two Indian states of Odisha and Andhra Pradesh; the cyclone, which is also known as the Odisha Cyclone, killed 10,000 people. After this event, the two states began to increase their strategic planning efforts. The state of Odisha created a new State Disaster Management Authority to plan and prevent another tragedy. Both states became part of the World Bank's National Cyclone Risk Mitigation Project, which has helped them to build cyclone shelters, develop evacuation routes, and conduct evacuation drills. In anticipation of Cyclone Phailin in October 2013, the two states evacuated nearly one million residents. To carry out the evacuation with just a few days' notice, the states put in years of planning and coordination. The evacuation saved countless people's lives (World Bank, 2013a, 2013b).

13. For more information on conducting a vulnerability assessment, see USAID's *Climate Change Vulnerability Assessment: An Annex to the USAID Climate-Resilient Development Framework* (USAID, Forthcoming), which is another annex to *Climate Resilient Development: A Framework for Understanding and Addressing Climate Change* (USAID, 2014).

Option C: Disaster Preparedness

The purpose of preparedness is to anticipate the effects of extreme climate events to mitigate hazards for a community. Preparedness is an investment to maintain and improve an effective response capacity. This includes activities such as formulating and testing disaster plans, training disaster responders, preparing the public, and conducting media outreach campaigns on disaster preparedness. The challenge at the community level is to garner support and identify resources to invest in preparedness activities. Generally, communities give preparedness a low priority, so that centralized organizations for disaster preparedness are typically lacking. Instead, planners and managers must gather support from households, local organizations, and private-sector entities, as well as fire, police, and medical professionals.

Common options to prepare communities for extreme climate events include:

- Developing or improving early warning systems that observe, forecast, detect, and warn of climate-related hazards.
- Developing and delivering early warning notifications that are timely and that community members readily understand. This preparation will require community outreach to educate residents on preparedness and appropriate responses to specific warning messages or events.
- Streamlining prevention by integrating meteorological, hydrological, and climate data across all government levels and agencies.
- Identifying or upgrading facilities that can be used as proper accommodation and shelter for highly vulnerable population segments during evacuations or relocations (e.g., during heat waves).
- Supporting tools and technologies, such as geographic information systems that provide information for risk assessment, planning, and decision-making.
- Disseminating relevant knowledge and information on hazards and vulnerabilities, including which hazards and vulnerabilities are changing because of climate change. Communities can substantially reduce the effect of hazards if citizens are well-informed.

WHAT NEEDS TO BE CONSIDERED FOR IMPLEMENTATION?

Planners and managers need to analyze each potential adaptation option to select the best course of action. Typical considerations for any given adaptation option are in the "Adaptation options considerations" text box; a mix of adaptation options may be used to address specific climate risks to a community, region, or nation.

ADAPTATION OPTION CONSIDERATIONS

- Effectiveness
- Feasibility
- Cost
- Unintended consequences
- Additional benefits
- Implementation timing
- Flexibility
- Robustness

First, planners and managers must consider cost and other resource limitations when preparing risk-reduction actions. In resource-constrained communities, risk-reduction actions cannot crowd out other investments that are required to maintain key community services.

The effectiveness and feasibility of disaster preparedness and risk-reduction actions will depend largely on the degree to which the community is involved in the process. Community participants can help risk-reduction experts understand the community's values and help design effective and appropriate assistance. In addition, by working with local groups and their members, implementers can strengthen civil society, enhance community accountability, and improve ongoing community reactions to crises. In a broad sense, risk-reduction implementation through

community participation increases the likelihood that people will take ownership of interventions and maintain activities over the long-term. Both formal and informal groups merit consideration, including government-based organizations, community health committees, traditional healers, pastoral associations, and women's committees.

Community involvement also helps ensure that disaster prevention and preparedness strategies are flexible. Crises become disasters when individuals and communities do not have the flexibility to adapt to challenges or the capacity to prepare for and respond to them. Robust community involvement ensures that individuals and communities can strengthen their own abilities to prevent and mitigate emergencies. For example, when emergencies repeatedly threaten communities, community members often organize to respond, creating mechanisms or informal cooperatives to help manage risk. Capacity building can strengthen the community's ability to handle risk or restore its ability to cope after an extreme event.

Co-benefits

A well-designed disaster preparedness plan will require community involvement and organization. If properly implemented, one clear benefit to this process will be more flexible, resilient, and cohesive communities.

Exhibit A.5.1 provides a summary of some of the major implementation considerations. For each option, the table identifies key feasibility challenges in implementation; the cost of implementing the measure, relative to other options included in the table; the level of decision-making typically involved (e.g., national, regional, or local); and the timeframe for implementation.

EXHIBIT A.5.1. IMPLEMENTATION CONSIDERATIONS FOR DISASTER PREVENTION, PLANNING, AND PREPAREDNESS.

Option	Feasibility	Cost	Level of decision	Other considerations
Option A: Disaster prevention	• Variable, depending on action; legislation of land-use practices or enforcement of codes may be easier to implement than large-scale infrastructure projects	• Variable depending on project; large-scale infrastructure projects will be most costly	• Large infrastructure projects may require national-level support or integration with trans-boundary decision-making • Local governments may have control over land-use regulations or enforcement of regulations	• Large infrastructure projects could take years • Creation of land-use regulations or enforcement of regulations could take place on a shorter time scale
Option B: Disaster planning and coordination	• Depends on multiple agencies at different levels of government, plus neighboring communities, to coordinate resources and capabilities	• Low to moderate planning costs • Administrative costs	• Multiple levels of government and communities; however, planning and coordination can still take place even if not all actors participate	• Efforts can begin with short notice, but may take years to fully develop
Option C: Disaster preparedness	• Depends on the robustness of preparedness activities	• Moderate administrative and planning costs • Higher costs for the development of monitoring and notification tools • Moderate to high costs for acquiring adequate emergency equipment and supplies	• Multiple levels of government and community	• Efforts can begin with short notice, but may take years to fully develop

REFERENCES AND RESOURCES

Document provides the authoritative assessment of extreme events by the IPCC:

IPCC. 2011. *Special Report on Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation (SREX)*. Intergovernmental Panel on Climate Change. November.

Document addresses climate change and insurability of coastal regions:

Lloyd's. 2008. Coastal Communities and Climate Change: Maintaining Future Insurability. September. Available: http://www.lloyds.com/~/media/lloyds/reports/360/360%20climate%20reports/360_coastalcommunitiesandclimatechange.pdf.

Report suggests actions to prepare for extreme events:

Red Cross/Red Crescent Climate Centre. 2007. Red Cross/Red Crescent Climate Guide. November. Available: http://www.climatecentre.org/downloads/File/reports/RCRC_climateguide.pdf.

Annex to the climate-resilient development framework examines vulnerability assessment:

USAID. Forthcoming. *Climate Change Vulnerability Assessment: An Annex to the USAID Climate-Resilient Development Framework*. United States Agency for International Development.

USAID main framework document describes the climate-resilient development approach:

USAID. 2014. *Climate-Resilient Development: A Framework for Understanding and Addressing Climate Change*. United States Agency for International Development. March.

Document outlines a process for assessing coastal vulnerabilities and options to increase resilience:

U.S. Indian Ocean Tsunami Warning System Program. 2007. How Resilient is Your Coastal Community? A Guide for Evaluating Coastal Community Resilience to Tsunamis and Other Coastal Hazards. U.S. Indian Ocean Tsunami Warning System Program supported by the United States Agency for International Development and partners, Bangkok, Thailand.

News stories discuss the impacts of Cyclone Phailin in India:

World Bank. 2013a. Cyclone Devastation Averted: India Weathers Phailin. Available: http://www.worldbank.org/en/news/feature/2013/10/17/india-cyclone-phailin-destruction-preparation.

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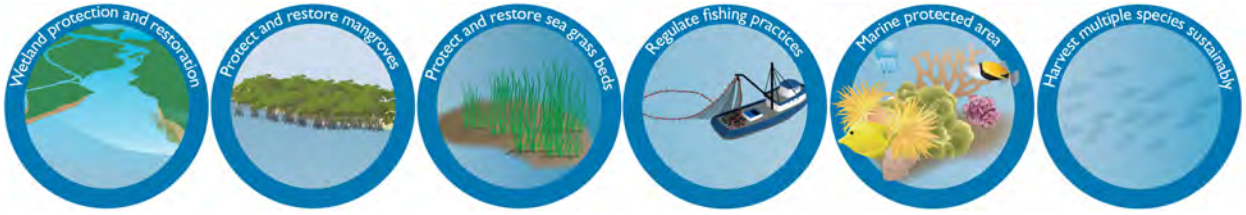
ADAPTATION ACTION 6: PROTECT AND MANAGE FISHERIES



The availability and sustainability of aquatic natural resources, including fish, shellfish, marine habitat, and fish-dependent wildlife, are directly tied to the health and productivity of coastal and marine ecosystems. The livelihoods that commercial fishing and subsistence fishing provide are also dependent on healthy fisheries and coastal and marine ecosystems. However, the combined effects of climate impacts and other stressors, including coastal pollution and overfishing, threaten the health of marine resources and the livelihoods that depend on them. Adaptation Action 6 addresses how planners and managers can best focus their conservation and management strategies to address the greatest risks that climate impacts pose.

The emphasis of this adaptation action is to prepare for and respond to climate impacts to coastal fisheries. Many of the options included in this adaptation action also support general fisheries' best management practices. For detailed information on sustainable fisheries management and aquaculture, please refer to USAID's *Sustainable Fisheries and Responsible Aquaculture: A Guide for USAID Staff and Partners* (USAID, 2013). Additionally, information on aquaculture is available in Adaptation Action 7, below.

HOW DOES FISHERIES MANAGEMENT CONTRIBUTE TO CLIMATE-RESILIENT DEVELOPMENT?

Climate impacts on coastal fisheries may result in the loss of habitat, species diversity, and reduced ocean productivity (Hoegh-Guldberg and Bruno, 2010; Doney et al., 2012; see Exhibit A.6.1). Changes in sea-surface temperatures, ocean acidification, sea level rise, severe storms, and changes in freshwater runoff can all affect the health, physiology, lifespan, and reproductive behavior and success of fish, corals, and invertebrates (Pratchett et al., 2009). Climate impacts will be more severe for coastal ecosystems that are already in poor health or that are characterized by low biodiversity. Adaptation actions that reduce non-climate change stressors will therefore result in healthier ecosystems that can better withstand climate impacts. These adaptation actions might include habitat protection and conservation through the development of MPAs, regulations to protect specific species, or broader fisheries management strategies.

Exhibit A.6.1 summarizes some of the potential impacts of climate change on fisheries.

Although overall ocean productivity is expected to decrease because of climate impacts, some regionally specific benefits to fisheries may occur. For example, shifts in ocean temperature and circulation patterns may expand productive oceanic food webs in particular locations. Adaptive fisheries management actions should take advantage of these opportunities to improve food security and livelihoods.

EXHIBIT A.6.1. POTENTIAL IMPACTS ON FISHERIES FROM CLIMATE CHANGE.

Climate change impact	Impact on fisheries
Changes in sea-surface temperatures	• Shifts in aquatic community composition, particularly toward the North and South poles • Shifts in fish migration timing and locations • Changes in the rates of metabolism, reproduction, development, photosynthesis, respiration, and productivity
Ocean acidification	• Inhibited shell and skeleton formation in calcifiers, such as invertebrates and corals • Impacts on fish development and behavior • Shifts in aquatic community composition • Reductions in tropical coral reef habitat • Reductions in phytoplankton productivity, which is the base of the marine food web
Changes in ocean currents	• Shifts in aquatic community composition • Changes to the dispersal of larvae • Changes to the coastal upwelling of nutrient-rich waters where fisheries are located
Sea level rise	• Inundation of coastal wetlands
More severe storms	• Damage to natural ecosystems • Changes to stratification of nutrients and distribution of species • Changes to fishing season length and timing
Changes in freshwater runoff	• Coastal eutrophication from increased agricultural runoff • Water quality degradation and chemical contamination • Shifts in coastal ecosystems from estuaries to salt marshes or vice versa • Potential effects on seasonal activities, such as migration and spawning

WHAT ARE THE OPTIONS FOR FISHERIES MANAGEMENT?

The ways that planners and managers manage coastal resources now will directly affect how aquatic ecosystems will respond to ongoing climate change. The fisheries management strategies discussed below include a broad set of measures that can strengthen fisheries-based livelihoods by increasing ecosystem resilience, reducing pressure on specific fish species, improving governance of coastal resources, improving monitoring capabilities, and enhancing critical fish habitat. These strategies apply not only to those regions experiencing adverse impacts of climate variability and change, but also those that have new opportunities associated with a shift in the habitat of fishery species, for example. These strategies can make the difference between sustainable fisheries and a decline or total collapse of fisheries resources.

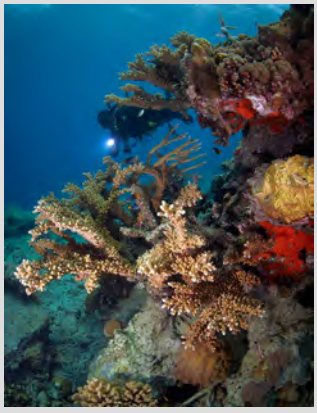
In addition to the options outlined below, a number of strategies designed to improve overall ecosystem health can benefit fisheries resources. These strategies are not included in this adaptation action, but are discussed in other adaptation actions in this appendix. For example, actions to protect or restore coastal ecosystems will improve the overall health of fisheries resources. Similarly, reducing external stresses to coastal ecosystems by decreasing pollution or managing invasive species will also have clear benefits to fisheries. Adaptation Actions 1 and 2, respectively, discuss these strategies in the broader context of overall coastal resilience.

Option A: Protect Habitat

MPAs are marine areas that receive some level of protection to preserve critical ecosystems and ecosystem services. Areas chosen for protection are often critical habitat or spawning and nursery areas for harvested species. However, degraded habitats can also be protected to aid in ecosystem recovery. Protected area use can range from being entirely closed to fishing to supporting limited-use activities, such as seasonal fishing and eco-tourism. Ecological health benefits are not only realized within the protected area but also in surrounding unprotected waters through the outward migration of adult fish and larval fish dispersal (Kling and Sanchirico, 2009). Protecting the most productive or diverse habitats, called "biodiversity hotspots," is a common approach taken for MPA design. Climate impacts may shift the location or nature of productive habitats. Therefore, MPAs must use a flexible approach that can adapt with changing conditions. This may include linking coastal and marine MPAs to maintain migration corridors for species of concern. Examples of coastal biodiversity hotspots include wetlands, estuaries, salt marshes, mangrove forests, and coral reefs. Monitoring data are critical for defining the location of these areas, and greatly assist in designing MPA networks.

NO-TAKE CORAL REEF MPAs IN MICRONESIA

No-take MPAs represent one tool for fisheries management to preserve fish species in key habitats and to enhance fish larval output to surrounding fishing grounds. Evidence recently emerged from a no-take MPA in Yap State, Federated States of Micronesia, that suggests that no-take MPAs enhance fisheries and their resilience to stressors such as predation (Houk et al., 2012).



Coral reef.

Photo credit: USAID.

MPA TRAININGS IN THE WESTERN INDIAN OCEAN REGION

In November 2013, 35 MPA managers from 8 countries in the Western Indian Ocean region participated in a training on understanding and communicating climate change in Grahamstown, South Africa, organized by USAID, NOAA, and the Western Indian Ocean Marine Science Association. The training provided participants with a foundational understanding of the causes of climate change, global climate trends, potential changes in climate, and the associated impacts.

Kayakers in a MPA.

Photo credit: NOAA/USFWS.

Participants gained experience with a process for identifying relevant climate stressors (e.g., increasing strength of cyclones) and non-climate stressors (e.g., illegal fishing, destructive fishing practices) and their potential effects on MPAs, which participants will apply in their respective MPAs. The training also included a field trip to a local MPA – several islands in the Algoa Bay, which are part of Greater Addo Elephant National Park. There, participants learned about the results of an experimental closure of fishing areas within 10 nautical miles of the main African penguin colonies near Cape Town. The skills and knowledge that participants gained will enhance their ability to manage their MPAs and contribute to sustainable fisheries. A follow-up training in May 2014 focused on vulnerability assessments and identifying and evaluating adaptation actions, including regulating fishing practices and managing fisheries-based livelihoods.

Option B: Regulate Fishing Practices

Governments can use a variety of active management strategies to improve the sustainability of fisheries resources. These management strategies reduce collateral damage to ecological resources from specific fishing methods or ensure that catches do not exceed the sustainable yield of the resource. Gear-type restrictions and quotas are two of the most common methods to ensure that fisheries are managed sustainably. Regardless of the specific regulations enacted, fisheries management should be adaptive so that adjustments can be made as conditions change.

ECOSYSTEM-BASED FISHERIES MANAGEMENT

Ecosystem-based fishery management (EBFM) strategies include closing specific geographical areas to fishing, enforcing gear-type restrictions, and developing individual fishing quota systems (Kling and Sanchirico, 2009). These policies provide benefits to the fisheries, as well as to the surrounding ecosystems. EBFM strategies have the ultimate goal of measuring success through metrics of the ecosystem, and not necessarily just through metrics of the fisheries. Thus, the root of EBFM is the preservation of ecological interactions that accompany biological diversity (Bascompte and Stouffer, 2009; Bascompte, 2010), which in turn maintain healthy aquatic environments. Elements of both Options A and B are often combined in EBFM strategies and initiatives.

Gear-type restrictions

Gear-type restrictions can be adopted to protect against ecosystem damage and the incidental take of undesirable sizes or species of marine life, also known as by-catch. Non-fish species such as marine mammals, sea turtles, and seabirds can also be captured by certain types of gear. An example is bottom trawling, which has a high potential to permanently alter slow-growing, deep-water coral and fish communities (Rogers, 2004). By-catch that is returned to the sea is often dead or dying; these animals cannot survive and become part of the fishery. Because of this, by-catch can have negative effects on the sustainability of a species, removing younger-year classes from the population before they can reproduce (Crowder and Murawski, 1998). Gear types that reduce the likelihood of catching, injuring, or killing by-catch should be used to the greatest extent possible. Two fishing techniques that can reduce by-catch impacts are tailoring the net mesh sizes for specific size classes or species of fish and using shorter set times so that by-catch can be returned to the sea uninjured.

Quota systems

Introducing open fisheries to quota systems has the potential to increase the sustainability of a fishery. Limiting the number of fish that can be harvested ensures that enough adult fish will survive and reproduce to maintain harvestable populations over the long-term. Quota systems can also be tailored to specific fisheries. Some examples include harvesting only fish that have already spawned, avoiding harvesting during spawning times, or prohibiting the harvesting of gravid fish. Quota systems also provide incentives for environmental stewardship, since the quota value depends on the ecological health of the system and the fish it supports (Kling and Sanchirico, 2009). Successful quota systems should therefore be characterized by increasing quotas through time.

Adaptive fisheries management

Inflexibility in fisheries management policies can be a major impediment to adaptation. Fisheries and their associated ecosystems are dynamic and change through time. Climate change impacts that are expected to affect marine fisheries include changing sea-surface temperatures that may shift the thermally appropriate habitat for specific species, as well as ocean acidification, which can affect the bottom of the marine food web by impairing the ability of crustaceans to build their shells (Brander, 2010; Doney et al., 2012). Thus, flexible and adaptive fisheries management approaches are needed to ensure the long-term sustainability of fishery resources (Pomeroy, 2003). For example, diversifying fishery species may be necessary to adjust for changing habitats. Monitoring is critical to successfully implementing adaptive fisheries management. In addition to monitoring, this adaptation option requires an effective system to interpret the information gained during the monitoring and to react in a timely and appropriate manner.

Monitoring should focus on species of concern, including species that are already overharvested, limited by ecosystem productivity, or sensitive to climate or non-climate stressors. Adaptive fisheries management could include increasing catch quotas to account for the increased abundance of currently limited species or reducing catch quotas when conditions dictate. For example, changes in ocean currents can result in more upwelling and zooplankton biomass, increasing the abundance of prey and helping sustain a larger fish harvest.

Application of this adaptation option may not require intensive government involvement or resources. Some researchers point out parallels between adaptive fisheries management and more traditional fishing practices (Berkes et al., 2000). Some common characteristics included learning from past fishing success and using diverse fishing practices to account for environmental variability and natural fluctuations in fish availability. Supporting such practices in open or subsistence fisheries may be a low-cost option to practice adaptive fisheries management at a local level.

Option C: Manage Fisheries-based Livelihoods

Fisheries management needs to consider not just the biophysical aspects of fisheries, but also the social and institutional aspects of communities (Halbert, 1993). Good fisheries management therefore needs to integrate the well-being of communities with the well-being of fisheries. With this in mind, two key options can be implemented to improve overall fisheries management while maintaining livelihoods: alternative resource use and alternative livelihoods.

Alternative resource use can encompass many different strategies. For example, diversifying catch can reduce stress on overfished or sensitive food sources. The strategy of increasing catch of smaller fish and diversifying catch has been suggested for sections of the Pacific (Bell et al., 2009b). Reducing waste and loss is also key; 10–12 million metric tons of fish are lost annually because of spoilage (FAO, 2014). Reducing waste can help to increase overall efficiency, but in many cases may require improvements to refrigerated storage and transportation routes or vehicles. Outreach and education on potential future benefits and development of alternative livelihood options can reduce stress on fishery resources. For example, Torell and Tobey (2012) highlight opportunities, such as beekeeping in mangrove forests and other coastal areas; community-based ecotourism; shell jewelry crafts tied to coastal conservation; sustainable aquaculture, including seaweed, sponge, and sea cucumber farming; oyster and cockle collection in coastal wetlands tied to conservation actions; and adding value to existing managed small-scale fisheries. Any potential new activity should be thoroughly piloted and vetted to ensure a viable market exists for the new product or service and that it does not have unintended negative consequences to marine resources or people.

MARINE PROTECTION MEASURES AND ALTERNATIVE LIVELIHOODS IN ANDAVADOAKA, MADAGASCAR

Beginning in 2003 with an influx of commercial fishing, the remote village of Andavadoaka, Madagascar, transitioned from a barter and subsistence economy to a fishery-driven, cash-based economy. This shift put additional pressure on native reef octopus stocks, leading to overexploitation and negative impacts on local livelihoods. Working with the nation's marine science institute and an NGO, the village took control of their marine resource management and implemented new wetland protection measures in addition to seasonal fishing bans and no-take zones. Project leaders worked with community members to develop alternative, sustainable livelihoods including eco-tourism and aquaculture to offset interim fishing losses. Through these measures, the village was able to significantly increase both octopus catch numbers and sizes, in addition to providing a healthier ecosystem, effectively improving the livelihoods of villagers. Currently, Andavadoaka is working with various NGOs to replicate its success in 23 neighboring fishing villages (United Nations, 2008).

WHAT NEEDS TO BE CONSIDERED FOR IMPLEMENTATION?

Planners and managers need to analyze each potential adaptation option to select the best course of action. Typical considerations for any given adaptation option are in the "Adaptation options considerations" text box; a mix of adaptation options may be used to address specific climate risks to a community, region, or nation.

ADAPTATION OPTION CONSIDERATIONS

- Effectiveness
- Feasibility
- Cost
- Unintended consequences
- Additional benefits
- Implementation timing
- Flexibility
- Robustness

Adaptation actions that preserve or protect habitat and support healthy aquatic communities should be of primary importance to natural resource managers when trying to preserve or improve livelihoods that they support (USAID, 2009). Such actions will need to be strategic, intentional, and proactive, coming before the full effects of climate change are evident. Planners and managers must identify critical, productive habitats and take actions to protect them. The first phase in this process is to assess the vulnerability of regional natural resources to climate change impacts. Once identified, strategies to protect or preserve resources at risk should be implemented or integrated into current programs. Monitoring the success of applied actions is also important so that policymakers can adjust implementation strategies.

Not all coastal communities will experience the same climate impacts; as such, each type of fisheries-related adaptation action has its own implementation considerations relative to how it fits into the associated cultural, geographical, and political context.

Exhibit A.6.2 provides a summary of some of the major implementation considerations for Adaptation Action 6. For each option, the table identifies key feasibility challenges in implementation; the cost of implementing the measure, relative to other options included in the table; the level of decision-making typically involved (e.g., national, regional, or local); and the timeframe for implementation.

EXHIBIT A.6.2. IMPLEMENTATION CONSIDERATIONS FOR FISHERIES MANAGEMENT ADAPTATION OPTIONS.

Option	Feasibility	Cost	Level of decision	Other considerations
Option A: Protect habitats				
MPAs	• Requires educating people on the short- and long-term benefits • Applicable to open or non-managed fisheries	• Moderate costs associated with enforcing regulations, especially for large areas that are vulnerable to poaching • Initial loss of fishing revenue if closed to commercial fishing	• Broader target areas and diverse perceived benefits may require higher-level political unit (state or higher)	• Greater benefits often occur over time
Option B: Regulate fishing practices				
Gear-type restrictions	• Benefits ecosystem and other non-targeted fisheries	• Varied enforcement costs • Moderate costs to monitor effectiveness (i.e., by-catch reduction) • High potential costs to fishermen to acquire new fishing gear	• Can be implemented by all ranges of fishery management systems	• Sustainability benefits not immediately realized
Quota systems	• Potential to improve fisheries production and increase environmental stewardship	• May increase fishing efficiency, thus reducing costs to fishermen	• Typically implemented over large geographic areas for consistency • May require cooperation between states or separate management units to be effective	• Recruitment benefits increase over time
Adaptive fisheries management	• Requires high level of information and technical knowledge • Requires plasticity and adaptability of fisheries infrastructure to change. despite limited time • Values applicable to open/non-managed fisheries	• Moderate costs associated with monitoring and real-time data interpretation • Not often successfully applied in commercial fisheries • Small-scale application can significantly reduce associated assessment and monitoring costs	• Large-scale application requires coordination of broader political units, as well as stakeholder and management interests • State and federal involvement not a prerequisite for certain localized adaptation methods	• Benefits from expensive proactive action may not be realized for years

EXHIBIT A.6.2. IMPLEMENTATION CONSIDERATIONS FOR FISHERIES MANAGEMENT ADAPTATION OPTIONS.

Option	Feasibility	Cost	Level of decision	Other considerations
Option C: Manage fisheries-based livelihoods				
Alternative practices	• Requires availability of alternative species • Alternative species must be desirable • Fishers might require new training, skills, or equipment for alternative species	• Costs could include new equipment, processing techniques, or facilities	• The decision could be made at various levels, but would need to be backed by enforcement or monitoring	• Initial steps could be taken immediately to research market viability for alternatives • It could take years to move the fishing industry to alternative species
Alternative livelihoods	• Market must exist for the potential new livelihoods • Workers will need to be trained	• Training and facilities may need to be developed	• The decision could be made at various levels, but would need to have local implementers	• It could take years to build new livelihoods; their success is not guaranteed

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Boyce, D.G., M.R. Lewis, and B. Worm. 2010. Global phytoplankton decline over the past century. *Nature* 466:591–596.

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Brander, K. 2010. Impacts of climate change on fisheries. *Journal of Marine Systems* 79:389–402.

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ADAPTATION ACTION 7: PROTECT AND MANAGE AQUACULTURE

Aquaculture is a diverse and multidisciplinary activity, generally defined as the culture of aquatic organisms in water, where at least part of their lifecycle is under human control. Climate-related threats to aquaculture include changes to water quality or quantity, changes in sea-surface temperature, ocean acidification, and extreme storm events. Adaptation Action 7 describes ways to prepare for and respond to climate-related impacts on aquaculture.

Many of the options included in this adaptation action support best management practices for aquaculture, in general. For detailed information on aquaculture management see USAID's *Sustainable Fisheries and Responsible Aquaculture: A Guide for USAID Staff and Partners* (USAID, 2013). Additionally, information on fisheries management is available in Adaptation Action 6.

HOW DOES AQUACULTURE MANAGEMENT CONTRIBUTE TO CLIMATE-RESILIENT DEVELOPMENT?

As the world's wild-capture fisheries decline because of both climate and non-climate stressors, aquaculture is expected to increase. If properly managed, aquaculture can contribute to climate-resilient development by increasing food security, providing jobs, increasing trade, and making sustainable use of ecological services. Additionally, some forms of aquaculture make positive contributions to natural resources management. For example, bivalve culture (e.g., clams, oysters) helps improve water quality and provides habitats for other organisms. Finally, aquaculture can help maintain populations of endangered species that might not otherwise survive in the wild.

Climate impacts to aquaculture could result from changes in ocean conditions (e.g., water temperatures, ocean chemistry, storm magnitude), or from changes to inland freshwater systems. Some forms of aquaculture are also inter-related with wild capture fisheries. For example, shellfish culture often relies upon the collection of wild juveniles ("spat collection") as a source of farmed stock. Hence, climate impacts on wild fisheries and fisheries habitats will also affect aquaculture. Exhibit A.7.1 summarizes some of the climate impacts to aquaculture.

EXHIBIT A.7.1. POTENTIAL CLIMATE CHANGE IMPACTS ON AQUACULTURE.

Climate change stressor	Impact on aquaculture
Changes in sea-surface temperatures	• Changes to species physiology, behavior, and overall survival • Changes to primary productivity in herbivores and organisms that rely on filter feeding (i.e. bivalves such as oysters) • Limited or discontinued open-ocean and coastal aquaculture, depending on species tolerance • Changes to water quality parameters such as unionized ammonia, which is toxic to organisms • Increased hazardous algae blooms, which are toxic to aquatic organisms and humans • Reduced availability of fish meal and fish oil, which are primary ingredients in aquaculture feeds

EXHIBIT A.7.1. POTENTIAL CLIMATE CHANGE IMPACTS ON AQUACULTURE.

Climate change stressor	Impact on aquaculture
Changes in air temperature	• Damage to crops, such as soy, which is a primary ingredient in aquaculture feeds • Potential loss of harvest because of decomposition • Changes to species physiology, behavior, and overall survival • Increase in evaporative losses from surface impoundments
Changes in ocean chemistry (acidification)	• Harm to organisms that depend on calcium carbonate for building shells or skeletons • Impacts on fish physiology and behavior • Reduced productivity of phytoplankton used by some aquaculture organisms
Changes in ocean currents	• Impacts on collection of wild organisms for aquaculture farm stock • Changes to coastal upwelling of nutrient-rich waters, a source of food for many organisms
Sea level rise	• Damage to ponds or infrastructure and reduced potential pond sites • May exacerbate saltwater intrusion and permanently alter the salinity of ponds or deltas • Estuarine species habitat may migrate
Extreme weather events	• Damage to ponds and infrastructure • Changes in storm intensity may increase worker risks • Changes to production or migration schedules • Increased flooding may inundate land
Changes in freshwater runoff and precipitation	• Increased flooding and precipitation may affect infrastructure, but may also provide new opportunities for freshwater aquaculture • Changes in salinity regimes for near-shore and coastal aquaculture • Increased agricultural runoff may increase coastal eutrophication • Changes in offshore water quality • Changes to production or migration schedules

WHAT ARE THE OPTIONS FOR AQUACULTURE MANAGEMENT?

The adaptation options for aquaculture include a wide range of responses, including protecting aquaculture from climate impacts such as severe storms; protecting aquaculture inputs by securing feed supplies; diversifying aquaculture species; and others.

Proper operation and management of aquaculture is vital. If not managed properly, aquaculture can have potential negative effects on ecosystem health and community resilience. For example, improper siting of aquaculture can be responsible for the loss of critical coastal ecosystems, such as mangrove forests and estuaries, and can degrade water quality and quantity. The options included in this adaptation action attempt to address these potential negative consequences of aquaculture.

Option A: Buffer Aquaculture Systems from Climate Stressors

Aquaculture farmers struggle with the need to balance the ability to take advantage of the ecological services that coastal systems provide, while protecting their stocks from external threats, including environmental variability. With climate change, farmers will need to shield their farms from climate stressors including increased storm intensity, changes in ocean chemistry, or increasing water temperatures. Strategies to combat

these stressors may include adjusting for changing water supplies or constructing physical structures such as buildings or greenhouses to regulate temperature.

Most aquaculture has developed in response to the availability of free and abundant water resources. As these resources vary with increasing climate impacts, people will need to focus on how resources are used and how operations are timed in accordance with changes in water supplies and water quality. In coastal freshwater aquaculture systems, adjusting to changing water supplies can include actions such as reducing or eliminating water exchange, developing re-circulation systems, using effluent for crops, using aquaponic systems, increasing water storage and capture capabilities, and improving infrastructure.

- *Reduce or eliminate water exchange.* Aquaculturists have often relied on having unlimited quantities of water to both re-supply their farms and to improve water quality through constant or periodic water exchange with surrounding waters. In many cases, this may no longer be possible because of decreased ambient water quality, and farmers will need to reduce or eliminate water exchange, which requires a higher level of technical knowledge. Some industries, such as marine shrimp farming and the U.S. catfish industry, have already moved in this direction for a variety of reasons. For example, feeds and fertilizers work by producing "blooms" of phytoplankton and zooplankton in ponds, which act as supplemental feeds for many aquatic organisms. Most farmers now know that exchanging water laden with this primary productivity is equivalent to throwing away a valuable resource, and will avoid doing so unless they perceive that water exchange is required for some other reason. Reducing water exchange also reduces energy costs because less pumping is required.

- *Use recirculation systems.* Recirculation systems allow for water exchange and improvement of water quality by circulating the water through an external water treatment system that removes contaminants. In the case of tank systems, water is usually treated through a combination of physical, biological, and mechanical filtration. Some chemical additives or treatments may also be necessary. Careful attention to maintenance of the water treatment system and frequent water quality monitoring is also needed. In the case of pond systems, some farms release water into artificial wetlands or settling ponds, thus relying on natural biological, physical, and chemical processes to improve water quality. The advantage to these systems is that larger volumes of water can be handled and less equipment is necessary. The artificial wetlands or settling ponds can have ancillary uses or benefits such as producing other crops, serving as a water storage area, or providing habitat for water fowl and other animals. Both of these systems require pumping, which incurs costs and a larger carbon footprint.

- *Integrate aquaculture and agriculture by using effluents for crops.* Even if water exchange is not completely eliminated, water use can also be made more efficient in other ways. For example, effluents can be used to water agricultural crops. If this is done through improved irrigation systems, such as drip irrigation, effluent watering can improve agricultural production as well. In some cases, crop waste can be used for aquaculture feeds, or fed directly to herbivorous or omnivorous fish.

- *Increase the use of aquaponic systems.* Methods such as aquaponics, in which fish and plants are cultured in the same system, are becoming increasingly popular. Aquaponics requires more capital investment, infrastructure, and complex management than conventional aquaculture, but allows for more revenue streams and diversification. Aquaponics also conserves water. If training in aquaponics is available, more farmers may begin some form of aquaculture by combining it with their traditional agriculture practices. Because aquaponics uses tanks, it allows for aquaculture in places where it may not be possible to build holding facilities in the natural environment. Aquaponics is largely restricted to freshwater species because few plants grow in saline water.

- *Improve water storage and capture.* As water abundance and supply become more variable or scarce, additional water storage or supplemental sources may be needed. These could be in the form of reservoirs, cisterns, ponds, or wells. Increased use of either of these would be an adaptive measure for both aquaculture, but also for human, agricultural, and livestock use. Ponds also offer habitat to many species of plants and animals, and can also help replenish groundwater supplies.
- *Improved infrastructure.* Farmers must ensure that they use good planning and construction practices for all of their infrastructure, including pond dikes, buildings, and pumping stations. In particular, strong pond walls that resist flooding and erosion will be needed, and buildings may need to be elevated. Fuel and chemical storage areas also need to be protected from flooding to prevent hazardous spills.

Although measures that isolate or buffer operations from the environment lessen the chance exposure to environmental threats and internalize possible negative effects of the practice, most of these measures also incur additional costs because of the increased need for infrastructure or energy. Also, to some extent, the benefits that aquaculture derives from reliance on ecological services will be reduced. For example, once water exchange is reduced or eliminated, water treatment systems become necessary.

Option B: Relocate Aquaculture Infrastructure

Because of the dependence of aquaculture on natural water sources, farms have traditionally been built near or in water bodies. Many older farms and industries were developed in an ad hoc fashion with little consideration for potential weather-related damage. Farm placement may be in high-risk areas for flooding or storm damage. Some farms may need to be relocated as their current sites become more exposed and vulnerable to climate impacts.

Many common types of freshwater farms rely on "watershed ponds" that are built within the contours of the watershed area, such as freshwater tributaries to the ocean, so that their water source comes directly from the upper watershed. The location of these ponds leaves them vulnerable to flooding, and this vulnerability will increase because of climate impacts. Relocating ponds to areas that are more removed from flooding threats via canals or channels can improve their resilience. Ponds can also be built with adequate drains and overflow areas to allow for the release of water in case of heavy rainfall.

Simultaneously, sea level rise may inundate freshwater bodies along the coast, creating estuarine environments with saline or brackish water. Suitable habitats may shift for freshwater and marine species. In these areas, farmers will need to relocate if they wish to continue producing the same organisms.

In some cases, ecosystems can provide naturally productive habitats for aquaculture and that also protect against climate impacts. For example, in Vietnam some shrimp aquaculture now takes place within mangrove forests, which provide a natural buffer to climate stressors. This type of natural infrastructure solution links to Adaptation Action 1.

Option C: Increase Efficiency of Farming Inputs

Most forms of modern fish culture rely on artificial feeds, which usually include some percentage of fish meal and fish oil. Aquaculture uses approximately 68% of the global supplies of fish meal and 88% of fish oil (Tacon and Metian, 2008). These feed ingredients are predicted to become both scarcer and more costly as world food supplies are stretched. Overreliance on fish meal and oil could therefore financially harm aquaculture as wild fisheries decline. To improve the financial resilience of aquaculture to this threat, aquaculture farmers must use all feed ingredients as efficiently as possible and use feed sources that are less desirable as human foods.

Traditional selective breeding strategies that can improve the feed conversion ability of aquaculture species are recommended, as most aquaculture species are still essentially wild animals. Although the use of genetically modified organisms is currently rare in aquaculture, this may be another option to improve production efficiency. For example, Atlantic salmon have been genetically modified by insertion of Pacific salmon genes to grow twice as fast, reducing the total amount of feed needed to produce the same amount of fish.

Improving the efficiency of feed use can also be a cost-effective adaptation option. The timing, frequency, method, and rate of feed application determines how well feed is consumed by the aquaculture species and how effectively they can use it. For example, in marine shrimp, multiple smaller feedings at night with sinking feed improved feed conversion ratios. Farmers may need technical assistance to support feeding best management practices. Farmers may also need to test feed types and application methods on their own farms to determine what works best in their context (i.e., monitoring growth rate and survival of the fish over time).

The choice of target species is also important. Highly carnivorous fish require more inputs in the form of fish meal, fish oil, and other feed ingredients such as grains, although selective breeding could potentially reduce their feed needs. Therefore, aquaculture efforts should focus on lower trophic species such as clams, oysters, or mussels where possible. Culture species such as algae or invertebrates (e.g., shellfish) that do not require feeding can make aquaculture more sustainable in the face of climate impacts. Higher trophic species might use feed which competes directly with food sources for people. Emphasizing diversified aquaculture with herbivorous species may help reduce the use of all feed inputs.

Option D: Diversify Aquaculture Species

Adjust aquaculture species to changing environmental regimes

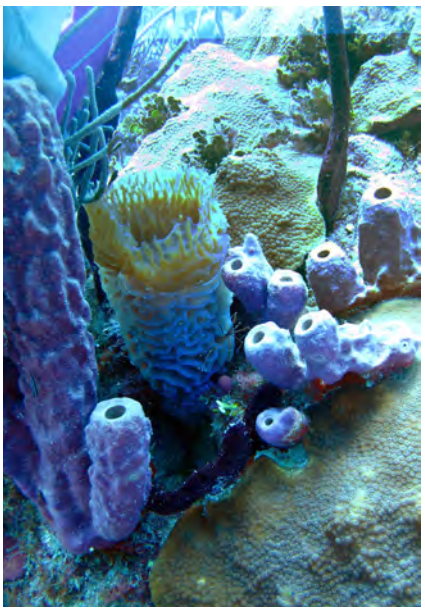
Most species, whether introduced or native, can survive only in defined ranges of environmental variables. Aquaculture has been responsible for transferring species around the world to take advantage of favorable environmental conditions in diverse regions. For example, trout species native to Europe are now cultured in Asia and Latin America. Tilapia from Africa are now cultured in nearly all tropical and semi-tropical parts of the world. As climates change, introduced or native species that have narrow environmental tolerances may no longer be viable for farming. Instead, species with wide ranges of temperature or water-quality tolerance should be prioritized. Careful analysis of the environmental tolerances of species and their potential for invasiveness should be taken into consideration when planning aquaculture into the future. Most regions in which aquaculture is practiced have many native species which have potential for aquaculture, but have not yet been developed as aquaculture species.

Domestication and selective breeding

Most aquaculture species are essentially wild animals and have not been bred to be as suited for culture conditions as have most agriculture and animal husbandry species. Selective breeding to emphasize traits that make aquaculture species more resilient to climate impacts will help improve traits such as survival, feed conversion ratios, and temperature tolerance. Some species that are being developed for aquaculture include air-breathing fishes, which have a variety of physiological and behavioral adaptations to survive low water levels, desiccation, and in some cases poor water quality. Use of genetic engineering also offers a means to develop species which survive and perform better, although care must be taken to prevent potential impacts.

Option E: Accommodate for Ocean Acidification

Ocean acidification is already affecting bivalve hatcheries and coral reef health in many locations around the world. Aquaculture of organisms that require calcium to build their skeletons or shells will need to consider the potential effects of ocean acidification into the future. Although more research remains to be done, it appears that the larval and juvenile stages of invertebrates, such as mollusks and echinoderms (e.g., sea urchins, sea cucumbers), are the most affected; larval fish can also be impacted. Hatcheries for these organisms will need to consider siting and, potentially, water treatment to buffer the effects of ocean acidification. Although coral culture is still a relatively uncommon activity, it is becoming more important as a substitute for coral collected in the wild, which usually involves damage to reefs. Coral farms may need to be relocated to cooler areas or different depths; more resilient species may need to be used.



Catalina Island coral reef.

Photo credit: Nora Ferm, USAID.

Option F: Improve Governance, Planning, and Coordination

As climate impacts become more pronounced, aquaculture farmers and their technical assistants will need better access to short- and long-term forecasts, and increased capacity to plan accordingly. Planning for aquaculture development must take into account changing landscapes and social context. For example, siting criteria for aquaculture (e.g., recommendations to avoid location ponds in flood zones) are generally well developed but are often ignored. Improved voluntary and regulatory measures to comply with siting criteria and "climate proof" criteria will be increasingly important in the future. Aquaculture should be integrated into watershed and coastal zone management initiatives. Ecosystems-based approaches, such as preserving key resources or ecosystems, are equally appropriate for aquaculture and for fisheries, particularly when the two sectors are intertwined (FAO, 2011). These integrated solutions that involve planning, coordination, voluntary action, regulation, and possibly enforcement are linked to governance issues, as discussed in Adaptation Action 9.

WHAT NEEDS TO BE CONSIDERED FOR IMPLEMENTATION?

Planners and managers need to analyze each potential adaptation option to select the best course of action. Typical considerations for any given adaptation option are in the "Adaptation options considerations" text box; a mix of adaptation options may be used to address specific climate risks to a community, region, or nation.

ADAPTATION OPTION CONSIDERATIONS

- Effectiveness
- Feasibility
- Cost
- Unintended consequences
- Additional benefits
- Implementation timing
- Flexibility
- Robustness

In some ways, aquaculture is a sector poised for adaptation. Over the last 20 years, the aquaculture sector has dedicated significant amounts of time, resources, and research to improving practices to become more environmentally friendly. Many best management practices in the aquaculture sector lend themselves well to climate adaptation. For example, the reduced reliance on fish meal and fish oil for aquaculture feeds and improved feeding practices have reduced the costs of rearing some species. This also leaves aquaculture in a better position to withstand future impacts on wild fisheries, which may reduce the availability of and increase the cost of fish meal. Additionally, through efforts to develop and implement environmental best management practices, intellectual and social capacity has grown in the sector

(e.g., USAID, 2013). Many adaptation options can be viewed as part of the continuum in the effort to make aquaculture more efficient and sustainable.

Other difficult challenges to adaptation exist. Some adaptation options, particularly those related to infrastructure and siting of farms, will require new efforts and are expected to present considerable costs and challenges. Aquaculture is heavily reliant on ecological services, such as water and aquatic primary productivity. Most culture organisms are wild, as opposed to the domesticated plants and animals that agriculture uses, and are not ideally adapted to culture conditions. Additionally, the aquaculture of some species is still entwined with wild fisheries, which will need to adapt to climate impacts as well. Complicating the scenario is the low number of comparable industries. Aquaculture is highly diverse, encompassing the production of hundreds of plant and animal species mostly produced on the small- and medium-scale by individuals, families, and small businesses. This industry is still growing and learning.

Exhibit A.7.2 provides a summary of some of the major implementation considerations for the aquaculture sector. For each option, the table identifies key feasibility challenges in implementation; the cost of implementing the measure, relative to other options included in the table; the level of decision-making typically involved (e.g., national, regional, local); and the timeframe for implementation.

EXHIBIT A.7.2. IMPLEMENTATION CONSIDERATIONS FOR AQUACULTURE ADAPTATION OPTIONS.

Option	Feasibility	Cost	Level of decision	Other considerations
Option A: Buffer aquaculture systems from climate stressors	• Technically feasible to varying degrees, but reduces the financial advantages of relying on ecological services • A variety of methods are currently available, e.g., water recirculation systems • Most new systems still require considerable research • A higher level of technical expertise is required; may not be immediately feasible to small-scale farmers lacking technical training	• Most methods represent modest increases in costs for improved technology, infrastructure, and technical capability • Ability to rely on "free" ecological services is considerably reduced	• In most cases, does not necessitate state or federal decision-making but may require technical or financial support, particularly for small farmers	• Benefits realized over time
Option B: Relocate aquaculture infrastructure	• Relocation is costly and may not be feasible for some systems (e.g., those depending on certain types of water)	• All methods involve relatively high costs	• Most likely requires government support and decision-making	• Reducing risk for disasters may be immediately realized; other benefits realized over longer periods of time
Option C: Increase efficiency of farming inputs (feed)	• Feasible in most cases • Often depends on improving technical capacity of managers and personnel	• Some initial costs for training and modifying systems, but generally low in cost • Initial costs often offset by improved production and lower production costs	• Can often be implemented by farm management • Government can support with training and extension services	• Benefits often seen immediately or over one production cycle
Option D: Diversify aquaculture species	• Generally feasible since suitable species exist for most conditions • Some industries may be challenged (e.g., trout farmers rely on cold waters) • Research is needed to address some issues, such as development of native species or selective breeding to adapt existing culture species	• Costs are moderate to high • Hatcheries, systems re-tooling, and training will be required	• Can be implemented at the farm level • Government can support research; extension and training required to change production	• Some benefits (i.e., lower mortality rate) should be realized soon after implementation

EXHIBIT A.7.2. IMPLEMENTATION CONSIDERATIONS FOR AQUACULTURE ADAPTATION OPTIONS.

Option	Feasibility	Cost	Level of decision	Other considerations
Option E: Accommodate for ocean acidification	• Few adaptation measures are available other than water treatment or relocation • Currently documented impacts are still localized, but may spread, thus requiring widespread effort and costs	• High	• Government support required; research needed to develop methods or possibly relocate hatcheries	• This topic is still new and benefits are hard to assess; realization of full ecological and economic benefits may take years
Option F: Improve governance, planning, and coordination	• Very feasible and is already underway in many locations	• Moderate to high costs depending on the level of government and proposed scope	• Government support required • Works best in close coordination with the private sector	• Some benefits may be immediate, but most expected over the longer term

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Report suggests a strategy for identifying fisheries and aquaculture management practices with regard to climate change:

FAO. 2011. *Strategies for Fisheries, Aquaculture and Climate Change: Framework and Aims 2011–16*. Food and Agriculture Organization, Rome, Italy.

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Available: http://www.fishconserve.org/arcel/admin/uploads/FPL101.pdf.

Journal article provides evidence of the spread of disease through the aquatic animal trade:

Rodgers, C.J., C.V. Mohan, and E.J. Peeler. 2011. The spread of pathogens through trade in aquatic animals and their products. *Rev Sci Tech Off Int Epiz* 30(1):241–256.

Journal article provides the results of a survey on aquaculture fishmeal inputs:

Tacon, A.G.J. and M. Metian. 2008. Global overview on the use of fish meal and fish oil in industrially compounded aquafeeds: Trends and future prospects. *Aquaculture* 285:146–158.

Guide suggests options for improving fishery and aquaculture practices:

USAID. 2013. *Sustainable Fisheries and Responsible Aquaculture: A Guide for USAID Staff and Partners*. United States Agency for International Development. June.
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ADAPTATION ACTION 8: ADAPT TOURISM PLANNING AND OPERATIONS

Tourism is a major driver of many coastal economies, but is highly vulnerable to many of the coastal hazards that climate impacts will exacerbate. Adapting tourism planning and operations to address climate impacts can help strengthen coastal and marine-based livelihoods by protecting the unique features and services that tourists seek. Additionally, carefully considered planning efforts can help coastal communities avoid adaptation actions that might have apparent short-term benefits, but that may have negative effects in the long-term. Adapting tourism involves diversifying tourist activities, protecting or relocating tourist facilities and services, protecting ecosystems and ecosystem services, improving the provision of information about climate risks, and acquiring and providing insurance. The variable adaptive capacity of tourism operators and destination communities should be considered when determining which of these actions will be most feasible and beneficial to implement.

HOW DO ADAPTATION OPTIONS FOR TOURISM CONTRIBUTE TO CLIMATE-RESILIENT DEVELOPMENT?

Exhibit A.8.1 summarizes some of the potential climate impacts on coastal tourism. Exhibit A.8.2 shows the ways that the tourism industry is exposed to a variety of climate change impacts, such as more-severe storms, sea level rise, increases in temperature, and decreases in precipitation. Coastal "hotspots," such as coral reefs, small islands, river deltas, and coastal urban zones that are typical tourist destinations, are particularly vulnerable to climate impacts because of the sensitivity of these regions and ecosystems or because of current exposure to non-climate stressors. Extreme weather events can exacerbate non-climate stressors such as poor water quality or pollution. If beaches are not safe for swimming or potable water is limited, for example, climate impacts will ultimately result in decreased tourist visits and negative consequences for tourism operators. The economic impacts of lost tourism could be severe in these hotspots, since a substantial portion of these countries' employment and gross domestic product are connected to tourism. Adaptation can bolster the business of tourism in destination countries and could result in economic benefits for the broader region or country as a whole.

An important synergy exists between the steps to adapt to climate impacts and the steps to protect ecosystem services. Adaptation, which often involves the preservation of sensitive ecosystems, contributes to the maintenance of ecosystem services, such as flood protection and enhanced water quality. In turn, preserving ecosystems and ecosystem services makes these regions more attractive, thereby facilitating the preservation or development of tourism and eco-tourism activities.

Not all segments of the tourism industry have the same capacity to adapt to climate impacts, as shown in Exhibit A.8.3. Tourists have a relatively high adaptive capacity and can choose to travel to a number of different coastal destinations. However, employees and communities have the lowest adaptive capacity should they experience a significant climate impact. Their livelihood is often tied directly to the destination itself; they may lack the resources to relocate, and their skills and products may not be readily transferrable to other professions or destinations. These individuals and communities have the most to lose from climate impacts, and the fewest options to secure their livelihoods if tourism is no longer a viable occupation. Adaptation can help protect tourism in coastal communities and lessen economic losses in the face of climate impacts.

EXHIBIT A.8.1. POTENTIAL IMPACTS ON COASTAL TOURISM FROM CLIMATE CHANGE.

Climate change stressor	Impact on coastal tourism
Higher temperatures	• Changes in length and quality of tourism seasons • Increased incidence of vector-borne diseases (reducing a destination's appeal and safety) • Decline in aquatic ecosystem health and related tourist activities in some locations (e.g., warmer waters contribute to coral bleaching) • Shifts toward higher latitude destinations • Elimination of some attractions (e.g., certain animal populations)
Changes in precipitation	• Diminished water supply or water quality • Flooding of tourism facilities • Increased incidence of vector-borne diseases (reducing a destination's appeal and safety)
Changes in ocean chemistry (acidification)	• Loss of tropical coral reef ecosystem • Decline in seafood for tourist consumption
Sea level rise	• Damage or destruction of coastal infrastructure • Loss of coastal land, including beaches
More severe extreme events	• Increased infrastructure damage • Higher operating expenses (e.g., insurance, backup water and power, evacuations) • More frequent or prolonged business interruptions • Increased reputation as a vulnerable or risky tourism area

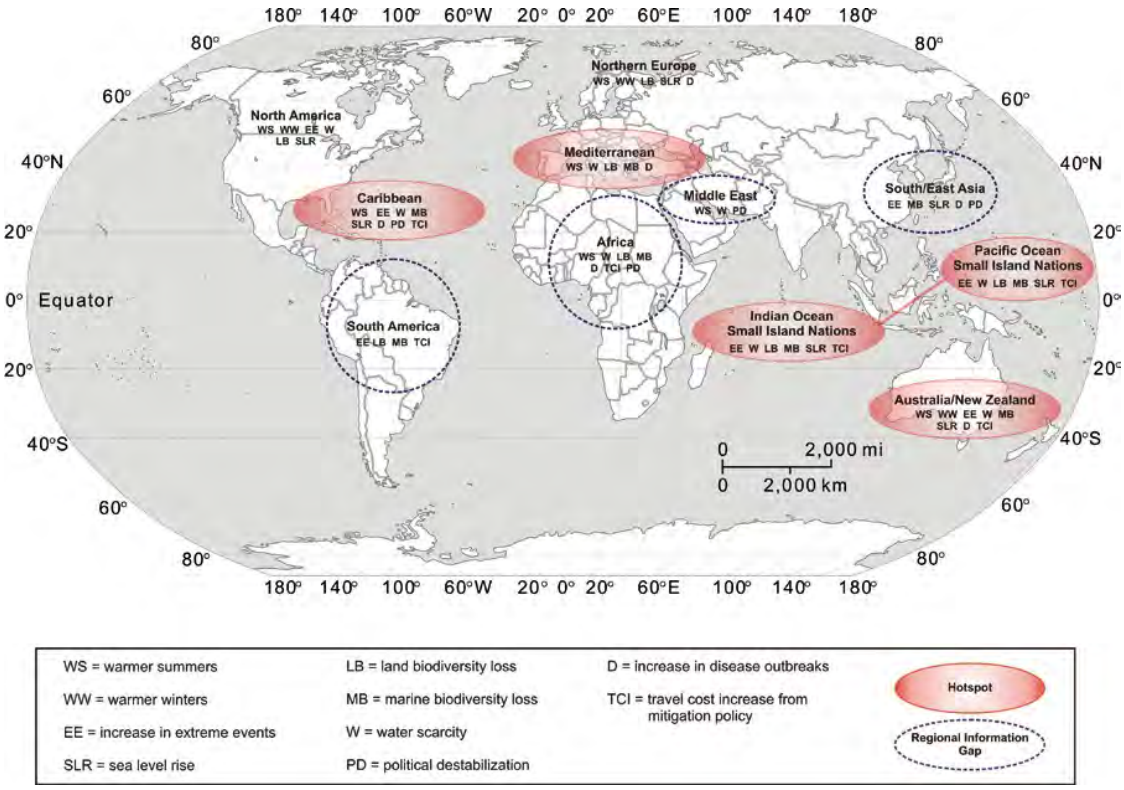

EXHIBIT A.8.2. HOTSPOTS WHERE TOURISM ACTIVITIES ARE VULNERABLE TO CLIMATE IMPACTS.

Source: Simpson et al., 2008.

EXHIBIT A.8.3. DIFFERENCES IN ADAPTIVE CAPACITY AMONG TOURISTS, TOURISM OPERATORS, AND DESTINATION COMMUNITIES.

Adapted from: Simpson et al., 2008.

WHAT ARE THE OPTIONS FOR COASTAL TOURISM?

Many coastal livelihoods are reliant on tourism, which is a vital yet vulnerable part of many coastal economies. A variety of adaptation options can help the tourism economy adapt to climate change.

Option A: Diversify Tourist Activities

Many tourists are drawn to coastal destinations because of warm weather, beaches, and ecotourism. Extreme weather events and other climate impacts may make it more difficult for tourism operators to reliably provide some of these services. For example, operators may find it costly or impossible to ensure the use of beaches, or weather conditions may not be conducive to outdoor activities. To adapt, operators can offer alternative tourist activities that are less weather- and climate-sensitive. For example, tourist locations can:

- ***Support and market cultural attractions.*** Tourist destinations are often home to cultural and historical resources, such as historic sites or museums, which are of interest to visitors. Tourists often seek opportunities to interact with destination-country citizens or experience aspects of the local lifestyle, including unique foods, music, or markets.
- ***Expand eco-tourism activities.*** Eco-tourism includes a wide range of activities in which tourists observe species and ecosystems. It can involve tours or exploration of unique ecosystems, or adventure-based activities such as snorkeling, diving, kayaking, and mountain climbing. Eco-tourism may also be designed for the observation of specific species of plants or animals during specific times of year, such as annual flower blooms or bird migrations. Although these activities can still be weather- or climate-sensitive, they may be less sensitive than typical coastal tourism activities; they may expand the range of seasons for which a destination is attractive to tourists.

Option B: Protect or Relocate Tourist Facilities and Services

Severe storms may damage, destroy, or threaten accommodations, attractions, roads, energy and water infrastructure, ecosystems, and water supplies. Operators may be able to protect or relocate the facilities and infrastructure on which tourists rely.

- *Protect facilities and infrastructure.* A wide range of structural and non-structural actions can protect coastal property, buildings, roads, cultural landmarks, and other infrastructure from damage suffered during extreme weather events, or risks posed by longer-term threats, such as sea level rise. These actions may extend to infrastructure beyond the tourism area itself, and include transportation networks within the broader region. Adaptation Action 3 describes specific options for protecting infrastructure.
- *Relocate facilities and services inland.* Operators can minimize or avoid damage or disruption from severe storms by shifting facilities and services away from shorelines. These relocated facilities and services may be less susceptible to flooding, representing a more attractive investment over the long-term. See Adaptation Action 4 for a more detailed discussion of facility relocation strategies.

Option C: Protect Ecosystems and Ecosystem Services

Nearby ecosystems may provide buffers from flooding, regulate local climate conditions (e.g., reduce heat island effects), or enhance water quality. Because the tourism industry benefits from these and other similar ecosystem services, degradation of these ecosystems can negatively affect tourism. Tourism operators can help to maintain these services by reducing human-caused stresses on ecosystems. For example, restricting land development near sensitive ecosystems can help maintain ecosystem area, connectivity, and function. Changes in waste or pollution management from tourism-related facilities can help maintain clean water and clean air (see Adaptation Action 2).

WATER ADAPTATION IN TOBAGO

Climate change impacts on the island of Tobago are projected to include increasing incidence of droughts and water shortages. Individual accommodation providers and tourism operators are adapting through actions such as rainwater harvesting, using saltwater for non-potable applications, desalinizing saltwater for potable use, and increasing water storage. Lodging providers are also reducing water use for landscaping and pools, as well as educating employees and guests to conserve water (WTO and UNEP, 2008).

Tobago.

Photo credit: NOAA/JSL.

Option D: Improve Information about Climate Risks

More and better information about climate impacts can help inform planning and decision-making by tourism operators and their staff. For example, with advanced knowledge of local climate impacts, facility managers can become more prepared by conserving water resources or expanding water storage and reuse. National or international meteorological services may be able to help provide up-to-date information that meets the needs of the tourism sector. Longer-term climate projections can be provided to tourism operators from many

sources, including reports, news media, conferences and trainings, local trade groups, community organizations, and government.

Option E: Acquire or Provide Insurance

Insurance can help tourism operators recover more quickly from disasters. If insurance products are available, operators can recoup property losses following extreme weather events. The magnitude of the risks associated with tropical storms can be enormous. For example, Samoa lost the equivalent of 37% of its annual gross domestic product following Cyclone Ofa in 1990 (DARA, 2010). Insurance may be critical in providing a source of capital to tourism operators to speed recovery following a disaster. Tourism operators can also offer insurance products to tourists to allow them to manage the risks associated with visits during extreme or inclement weather. These policies are sometimes included within a travel package or can be purchased for a fee. Although some of these products may be costly for operators to provide, it may be viewed as a valuable amenity option by tourists, and serve as a competitive advantage for the destination.

DISASTER INSURANCE IN THE CARIBBEAN

An innovative insurance model is the Caribbean Catastrophe Risk Insurance Facility (CCRIF), a risk-pooling facility whose membership includes 16 Caribbean governments. CCRIF provides its members with short-term cash payments in the event of a catastrophic earthquake or hurricane. By pooling capital into a collective reserve and spreading the risk geographically, the CCRIF provides cost-effective coverage options for its participating governments (CCRIF, 2013).

Caribbean.

Source: http://www.freeimages.com/browse.phtml?f=view&id=774986.

WHAT NEEDS TO BE CONSIDERED FOR IMPLEMENTATION?

Planners and managers need to analyze each potential adaptation option to select the best course of action. Typical considerations for any given adaptation option are in the "Adaptation options considerations" text box; a mix of adaptation options may be used to address specific climate risks to a community, region, or nation.

ADAPTATION OPTION CONSIDERATIONS

- Effectiveness
- Feasibility
- Cost
- Unintended consequences
- Additional benefits
- Implementation timing
- Flexibility
- Robustness

In particular, two considerations are important when pursuing adaptation actions related to tourism. First, the knowledge base is relatively limited. Examples of effective adaptation are just beginning to emerge. Second, the interests of tourists, tourism operators, and destination staff are not always well aligned. Steps that may benefit the destination may raise prices for tourists or reduce the attractiveness of the destination. Finding "no-regrets" strategies that benefit all parties should be a priority. In addition, tourism operators must evaluate and adjust adaptation options to improve resilience to climate impacts. Such evaluation can indicate which

strategies will bolster a region's tourist industry or are cost-effective, ultimately yielding economic benefits to tourism operators and destination communities.

Pursuing adaptation options for tourism can also raise equity concerns. In taking action to maintain the viability of tourism in an area, the benefits of these actions potentially may be isolated to tourists, or to a small portion of the local population. Steps should be taken to ensure that the benefits of adaptation are realized broadly across a destination community and not restricted to tourists or to the livelihoods of a small set of individuals.

Finally, some of the adaptation options themselves may suffer negative impacts from climate. In particular, attempts to develop eco-tourism may be hindered by changes in temperature or precipitation, which affect ecosystems. For example, the health of many coral reefs around the world is threatened by increasing temperatures and ocean acidity. Strategies designed to bring tourists to coral reefs would need to assess the longevity of these ecosystems.

Exhibit A.8.4 provides a summary of some major implementation considerations. For each tourism-related action, the table identifies key feasibility challenges in implementation; the cost of implementing the measure, relative to other options included in the table; the level of decision-making typically involved (e.g., national, regional, or local); and the timeframe for implementation.

EXHIBIT A.8.4. IMPLEMENTATION CONSIDERATIONS TO ADAPT TOURISM PLANNING AND OPERATIONS.

Option	Feasibility	Cost	Level of decision	Other considerations
Option A: Diversify tourist activities				
Develop and market cultural attractions	• Depends on presence of existing or potential attractions • May require extension of services (e.g., transportation, accommodations, security, water, electricity) to new areas	• Costs of development are highly variable, depending on accessibility and presence of necessary services • Costs of marketing are likely relatively low • Potential economic benefits if visitation increases	• Local and national governments • Tourism operators	• Development timeframe is highly variable, dependent on the current state of the attraction and the surrounding area • Marketing timeframe could be relatively short
Expand eco-tourism activities	• Depends on presence of nearby ecosystems of interest • Sensitive ecosystems may have restricted access, based on national or international rules/agreements • Potential increase in visitation could degrade ecosystem function and viability • Ecosystem may be negatively impacted by climate change	• Costs of development are highly variable, depending on accessibility, presence of necessary services, and extent of required restoration	• Tourism operators • Potential involvement of local or national government to secure access or rights, especially in protected areas	• Highly variable; activities involving currently existing and accessible ecosystems could be developed immediately; activities involving restoration or creation (e.g., planting of vegetation) could take years or decades
Option B: Protect or relocate tourist facilities and services				
Protect facilities and infrastructure	• Feasibility, constraints, and costs are largely dependent on the methods pursued (see Adaptation Action 3)		• Tourism operators • Local and national infrastructure planners	• Highly variable, depending on the method; construction, armoring, or restoration of natural buffers can take years or decades; policy changes can be made more quickly (months to years)
Relocate facilities and services inland	• Dependent on presence of less-vulnerable areas nearby; for small islands, there may be few options • May require extension of services (e.g., transportation, accommodations, security, water, electricity) to new areas	• Costs of development are highly variable, depending on accessibility and presence of necessary services	• Tourism operators	• Assuming that inland areas are not currently used by tourists, construction of facilities and infrastructure could take several years

EXHIBIT A.8.4. IMPLEMENTATION CONSIDERATIONS TO ADAPT TOURISM PLANNING AND OPERATIONS.

Option	Feasibility	Cost	Level of decision	Other considerations
Option C: Protect ecosystems and ecosystem services				
Protect ecosystems	• Can have significant co-benefits for eco-tourism, environmental health, and water and air quality • Potential conflicts with other industries (e.g., timber harvesting, fisheries)	• Highly variable; dependent on the state of the current ecosystem and level of restoration/ management required	• Tourism operators • Local and national governments • Industrial or agricultural entities that draw on ecosystem products and services	• Restoration activities could have relatively immediate benefits if the loss of such ecosystems represents a loss of ecosystem services • Benefits could require years and decades to become evident if significant restoration is needed
Option D: Improve information about climate risks				
Provide information to tourism operators and destination staff	• May require expertise in technical communications	• Highly variable, depending on the strategies pursued; likely less than infrastructure- or construction-related options	• Tourist agents and organizers • National governments or tourism boards	• Can be initiated quickly or immediately
Option E: Acquire or provide insurance				
Provide insurance to tourism operators	• In locations where risks are high, insurance firms may not offer coverage	• Premiums could be relatively costly for tourism operators	• National governments • Tourism operators • Insurance firms	• Can be implemented almost immediately

REFERENCES AND RESOURCES

Website describes the CCRIF program:

CCRIF. 2013. *About Us*. Caribbean Catastrophe Risk Insurance Facility. Available: http://www.ccrif.org/content/about-us.

Report presents a broad discussion on metrics of vulnerability and costs of adaptation throughout the world:

DARA 2010. Climate Vulnerability Monitor 2010. Available: http://daraint.org/climate-vulnerability-monitor/climate-vulnerability-monitor-2010/.

Brief report discusses how the global tourism market is likely to be affected by climate change, identifying some of the countries likely to benefit and suffer:

Ehmerr, P. and E. Heymann. 2008. Climate change and tourism: Where will the journey lead? Deutshe Bank Research. April 11. Available: https://www.dbresearch.com/PROD/DBR_INTERNET_EN-PROD/PROD0000000000222943.PDF.

Report outlines frameworks and techniques for addressing climate impacts in the tourism sector, presenting many examples from around the world:

Simpson, M.C., S. Gössling, D. Scott, C.M. Hall, and E. Gladin. 2008. *Climate Change Adaptation and Mitigation in the Tourism Sector: Frameworks, Tools and Practices.* UNEP, University of Oxford, UNWTO, WMO, Paris, France. Available: http://www.unep.fr/scp/publications/details.asp?id=DTI/1047/PA.

Report discusses impacts of climate change at tourist destinations, adaptation options and strategies, and implications for tourism demand patterns:

WTO and UNEP. 2008. *Climate Change and Tourism: Responding to Global Challenges*. World Tourism Organization, Madrid, and United Nations Environment Programme, Paris. Available: http://www.unep.fr/shared/publications/pdf/WEBx0142xPA-ClimateChangeandTourismGlobalChallenges.pdf.

Report presents case studies of selected natural and cultural World Heritage sites to illustrate the impacts of climate change and the adaptation measures to protect them:

UNESCO. 2007. *Case Studies on Climate Change and World Heritage*. United Nations Educational, Scientific and Cultural Organization. Available: http://unesdoc.unesco.org/images/0015/001506/150600e.pdf.

ADAPTATION ACTION 9: STRENGTHEN COASTAL GOVERNANCE

Strong governance is important for all adaptation actions in the coastal zone because (a) weak governance frameworks are an obstacle to creating and implementing sustainable adaptation actions, (b) community and country characteristics shape the feasibility and effectiveness of potential climate-related interventions, and (c) adaptation actions present an opportunity to integrate initiatives that strengthen governance and support sustainable development. Adaptation Action 9 focuses on ICZM as an option for building better coastal governance, generating education and outreach to communicate risks, increasing regulatory compliance, and improving enforcement capacity.

Many governance challenges can be difficult and time consuming to address, but opportunities may exist to take action to improve coastal resilience despite poor governance. The importance of understanding governance as part of the adaptation planning process is discussed in detail in USAID's *Governing for Resilience: An Annex to the USAID Climate-Resilient Development Framework* (USAID, Forthcoming).

The remainder of this appendix provides information for coastal planners and managers on how strengthening coastal governance can contribute to climate-resilient development in the coastal zone. We include a menu of potential options for strengthening coastal governance and identify key considerations for implementing these options.

HOW CAN STRENGTHENING COASTAL GOVERNANCE CONTRIBUTE TO CLIMATE-RESILIENT DEVELOPMENT?

In many developing countries, poor governance limits the availability of options for improving coastal zone planning and management and thus enhancing climate resilience. In general, poor governance is evident through the following:

- Weak or ineffective policies and legal frameworks, such as for allocating coastal resource access rights
- Unenforced laws or regulations, for example, restricting development in flood zones
- Weak or ineffective institutions and lack of institutional coordination
- Lack of transparency and accountability in decision-making
- Lack of effective and representative stakeholder engagement in decision-making

These governance challenges are prevalent throughout coastal zones in many countries. Actions that address these challenges will enhance the effectiveness of other adaptation actions in coastal zones and therefore will help increase climate resilience.

WHAT ARE THE OPTIONS FOR STRENGTHENING COASTAL GOVERNANCE?

Strong coastal governance at all levels – from the local community up to the national government – and even across national boundaries – is integral to enhancing climate resilience in coastal zones. Numerous adaptation options at all levels, ranging from institutional and legal reforms to sectoral reforms, support adaptive capacity and can lead to better adaptation outcomes.

Institutional and legal reforms in developing countries can create environments that enable successful adaptation actions in coastal zones, but they can be challenging to implement. For example, in many cases, policies and regulations have been developed without consideration of shoreline processes, coastal hazards, and down shore and upland effects. Such governance frameworks require updating to reflect good practices related to integrated coastal management, disaster risk reduction, and adaptation to climate impacts.

However, the political environment that most coastal planners and managers encounter is often not conducive to such institutional and legal reforms. In addition, many local adaptation options are affected by disconnects between informal (e.g., practices based on custom) and formal (e.g., legal) coastal governance mechanisms. Planners must identify and emphasize reforms that can enhance adaptive capacity, regardless of political, social, and economic conditions, for example, improving the effectiveness of public engagement to ensure the participation of all relevant stakeholders.

The remainder of this section describes options to improve coastal governance. The potential effectiveness of options for strengthening coastal governance varies across countries because of location-specific environmental, political, social, and economic characteristics (e.g., differences in governmental processes and cross-governmental cultural norms). Nevertheless, the following options can generally be considered when strengthening coastal governance; they may also be modified, as necessary, to address local conditions.

Option A: Emphasize Integrated Planning and Management Strategies

Because of the high degree of interconnectedness among activities and resources in the coastal zone, decisions that are economically and environmentally sound for one coastal sector or use can at the same time have detrimental effects on others. For example, proposed seaside developments might promise job creation and affordable housing, which would support the local economy, but they might also have significant impacts on natural resources and might be vulnerable to climate change.

One of the most important ways in which coastal governance can be strengthened is through integrated planning and management of coastal resources (GWP, 2013). This is often accomplished through an ICZM approach. An ICZM approach promotes the compatibility and balance of coastal uses, cooperation between decision-making bodies and stakeholders, the use of preventive and precautionary approaches that limit coastal development in unsustainable areas, and an awareness of the economic and environmental costs and benefits of coastal management strategies. Long-term planning, facilitated by ICZM, is necessary to avoid investing in actions that harm the coastal environment, exacerbate climate impacts, and put more people and coastal property at risk.

KEY STAKEHOLDER GROUPS TO INVOLVE IN COASTAL MANAGEMENT

Effective coastal management involves engaging with a wide range of stakeholders and providing them with opportunities to participate. These stakeholders can include populations and institutions that:

- Live, work, play, or worship at or near a coastal resource (e.g., businesses, residents)
- Are interested in a coastal resource, its users, its uses, or its non-uses (e.g., interest groups, businesses, residents)
- Are interested in the processes used to make decisions about coastal resources (e.g., interest groups, NGOs, government)
- Pay for coastal management (e.g., residents, businesses, government)
- Represent citizens or are legally responsible for public coastal resources (e.g., government)

Adapted from: Meffe et al., 2002; NOAA, 2007.

The coastal zone has multiple managing entities, such as municipal planners, natural resource and fisheries managers, emergency planners, and others. Coordinating across these multiple entities can be challenging. Additionally, coordinating across multiple levels of government with different jurisdictions or multiple municipal or regional governments to reach objectives in the coastal zone is complex. These entities at varying levels within the government can have overlapping or misaligned mandates in the coastal zone. With these challenges in mind, specific considerations for adopting integrated planning and management strategies, such as ICZM, include the following:

- ***Develop cross-sector coordination mechanisms.*** Effective coastal zone management involves cross-sector coordination to ensure that all coastal resource uses, such as food consumption, nature, tourism, and industry, are included in planning and decision-making (World Bank, 2010). An important aspect of ensuring cross-sector coordination is establishing and supporting mechanisms through which the different sectors can share input and ideas. These coordination mechanisms may include inter-agency task forces to link sector- or use-specific agencies or regular public meetings that convene stakeholders of all types (USAID, 2009). In addition to being useful for developing plans that are based on multiple-use principles, supporting cross-sector coordination can also lead to more efficient information collection and analysis. For example, coastal planners and managers can more easily assemble and coordinate information about economic and environmental factors that affect coastal development by facilitating collaboration between local economic development and environmental protection authorities.

- ***Integrate coastal rivers and catchments in coastal zone planning and management strategies***. Coastal zones depend on fresh water, which often arrives via estuaries. Protecting estuaries – which are vulnerable to a range of climate impacts, such as salinization and soil degradation – is therefore an issue of critical importance for coastal zones. Integrating catchments and estuaries into coastal management strategies can help ensure that potential changes in those resources are anticipated and protected against.

- ***Explicitly address climate change in planning and management strategies***. Coastal zone planning and management strategies should explicitly account for climate change and its impacts on coastal resources (World Bank, 2010). It is especially important for coastal planners and managers to build adaptive approaches (e.g., ICZM) into their plans; these approaches will enable planners to review and revise their plans based on new and better quality climate data in the future (USAID, 2009).

- ***Clarify institutional, national, state, and local roles and responsibilities***. Coastal planners and managers should be sure to coordinate with all levels of government to ensure that institutional, national, state, and local authorities understand their role in coastal zone management and that they are participating in coastal zone governance frameworks (e.g., by assisting in facilitating cross-sector coordination). In many situations, coastal planners and managers must support bottom-up, integrated approaches to resources management, meaning approaches that go from the local level up to the national level. Implementing such approaches, however, can be challenging; in many developing countries, it is customary for strategic planning to rely on a more top-down approach. For this reason, integrated planning requires a considerable measure of outreach to local and national government stakeholders, as well as other stakeholders who can influence government authorities to help change mindsets.

GOVERNANCE IN THE CORAL TRIANGLE

The Coral Triangle Initiative in Indonesia, Malaysia, Papua New Guinea, the Philippines, Solomon Islands, and Timor-Leste is a transnational partnership to protect the region's rich marine and coastal resources. With support from USAID, WWF, and other partners, the initiative works on several strategic goals. These include improving fisheries management, establishing MPAs, and improving coastal resilience to climate change. Since the partnership began in 2007, it has achieved several notable accomplishments, including the development of one of the largest MPAs in the world and the development of a Region-wide Early Action Plan for Climate Change Adaptation.

Sources: USAID, 2013; CTI, Undated.

Subsistence fishing.

Photo credit: Aulia Rahman, WWF.

Option B: Improve Coastal Zone Decision-making Efficacy

Even with strong legal and regulatory frameworks for protecting coastal zone resources, there can still be challenges within those frameworks that lead to poor decision-making about how those resources are managed. There are a number of ways in which coastal zone decision-making capacity can be made more effective, including:

- ***Support decision-making at the appropriate level of governance.*** It is important that local authorities have a clear and substantial role in coastal zone decision-making. In many areas, decisions about coastal resources are made at the state or national level. This can be problematic because local interests – the ones that are likely to be most directly affected by the decision – are often not considered. It is also important that decision-making not be restricted to the local community level because the implications of coastal management decisions can extend beyond local political boundaries (USAID, 2009).
- ***Develop participatory and democratic decision-making processes.*** Participatory opportunities, such as public workshops for stakeholders, can provide a means of soliciting input from key stakeholder groups and can provide government with a venue for educating the public about key issues and challenges related to coastal zone management.
- ***Improve information collection and analysis capacity to support decision-making.*** Effective decision-making about coastal zone management issues requires having access to quality data about factors that can influence those zones. Compiling information on environmental, social, and economic factors that influence coastal zones and their vulnerability to climate change (e.g., demographic changes, projected changes in temperature and precipitation, economic costs) is a critical step in adapting to climate change. In some cases, initial or additional data collection may be needed to inform decision-making. This could include monitoring key coastal resources or ecosystems to better understand their response to climate stressors. Downscaled climate data for a particular coastal zone or coastal watershed can also be valuable (World Bank, 2010). These data can be analyzed to improve understanding of the implications of these

factors for climate change in coastal zones, particularly with respect to existing governance arrangements and capacities (USAID, 2009).

- *Improve stakeholder access to information.* In addition to collecting and analyzing information about factors that can influence coastal zones for planning and management purposes, it is important to provide stakeholders with access to relevant, current information. Strong stakeholder participation requires that the stakeholders know about vulnerability to coastal zone changes (e.g., the sea level rise anticipated in the next 10, 25, or 50 years). Stakeholders will be more likely to participate and contribute valuable input if they have more information. Providing timely information in easy-to-understand forms to targeted audiences is a key aspect of improving stakeholder access to information. Information should be shared with stakeholders throughout the adaptation process.

USING PARTICIPATORY WORKSHOPS TO DEVELOP A NATIONAL ICZM STRATEGY IN ALGERIA

As part of its effort to develop a national ICZM strategy, the national government of Algeria organized a series of participatory workshops to integrate input from a wide range of stakeholders. The workshops included participants from numerous economic sectors, local communities, NGOs, and the media. In addition to serving as a forum for gathering input from stakeholders, the workshops served as opportunities for the national government to introduce key issues related to coastal zone management.

Source: MedPartnership, 2013.

Option C: Enhance Education and Outreach Activities to Communicate about Risks

Lack of awareness about coastal resource vulnerability and the effects of coastal decision-making on those resources can significantly hinder adaptation efforts. Studies show that many individuals and stakeholder groups have difficulty perceiving and responding to information about the risks associated with climate change in coastal areas. For many individuals, risks are difficult to understand, even when they are quantifiable. In addition, many people are reluctant to take action, even when they do understand the risks. For example, coastal populations are often reluctant to move in response to learning that their private coastal residences are at risk from rising sea levels and the increasing prevalence of extreme events (e.g., Burby, 2006; Bin et al., 2008; Peloso, 2013).

Enhancing public education opportunities and engaging in stakeholder-specific outreach activities can help strengthen coastal governance by improving the efficiency with which people receive and act on information about coastal resources management. Examples of public education activities can include door-to-door engagement; public meetings; demonstration projects (e.g., planting vegetation along coastal riverbeds); and communications through posters, flyers, radio, television, and other forms of media. Activities for reaching out to key stakeholder groups can also involve integrating education programs into school curricula, meeting with local chambers of commerce, and coordinating with local tourism organizations to co-host events.

Some communication and outreach materials are particularly effective at conveying risks to the public, businesses, local officials, and other stakeholders that play key roles in coastal zone management. For example, inundation maps showing sea level rise can be particularly effective at demonstrating the potential risk of developing coastal lands (Peloso, 2013). It is important to tailor messages and communications vehicles to the target audience.

INCREASING STAKEHOLDER CAPACITY IN BANGKOK, THAILAND

In Bangkok, Thailand, several NGOs play key intermediary roles in strengthening coastal zone governance by linking government authorities with local stakeholders. For example, the SEA-START initiative coordinates with local stakeholders through workshops, training sessions, and other capacity-building activities, and serves as a neutral source of climate- and coastal-related information. Because of its neutral position between the government and local stakeholders, it is viewed as a trusted source of information.

Sources: Hickman, 2012; SEA-START, 2013.

Option D: Increase Compliance Assistance and Enforcement Capacity

Communities sometimes lack capacity to comply with coastal resource laws and regulations. For example, local or national regulations might limit the harvest of a certain coastal resource, such as fish. However, local populations dependent on these resources might lack the financial capacity to change their harvesting practices or they may lack the technical capacity to understand new regulations for allowable practices and technologies. Enhanced technical training and targeted outreach can often help affected stakeholders comply with new or strengthened laws or regulations pertaining to coastal resources.

In addition, in many developing countries, insufficient capacity among national and local governments leads to poor enforcement of coastal laws and regulations, often in the form of insufficient or inequitable compliance inspections. Citizen education efforts, public relations campaigns, financial support for expanding enforcement personnel, and training of enforcement personnel are all potential solutions to increase compliance.

WHAT NEEDS TO BE CONSIDERED FOR IMPLEMENTATION?

Planners and managers need to analyze each potential adaptation option to select the best course of action. Typical considerations for any given adaptation option are in the "Adaptation options considerations" text box; a mix of adaptation options may be used to address specific climate risks to a community, region, or nation.

ADAPTATION OPTION CONSIDERATIONS

- Effectiveness
- Feasibility
- Cost
- Unintended consequences
- Additional benefits
- Implementation timing
- Flexibility
- Robustness

Exhibit A.9.1 provides a summary of some of the major implementation considerations for coastal governance. For each option, the table identifies key feasibility challenges in implementation; the cost of implementing the measure, relative to other options included in the table; the level of decision-making typically involved (e.g., national, regional, or local); and the timeframe for implementation. Note, however, that governance is a very complex issue that may require location- and issue-specific considerations. Because of that, we have provided only general considerations for implementation here. Please see USAID's *Governing for Resilience: An Annex to the USAID Climate-Resilient Development Framework* (USAID, Forthcoming) for a more thorough discussion of implementation considerations for governance-related issues and adaptation actions.

EXHIBIT A.9.1. IMPLEMENTATION CONSIDERATIONS TO STRENGTHEN COASTAL GOVERNANCE.[a]

Option	Feasibility	Cost	Level of decision	Other considerations
Option A: Emphasize integrated planning and management strategies	• Entities must be willing and able to work across specialization areas and jurisdictions	• Staff time is the largest cost	• All levels of government	• Initial steps can begin immediately; consensus building and implementation could take years
Option B: Improve coastal zone decision-making efficacy	• Improving access to information or data quality could be challenging	• Staff time and data collection or modeling could be significant costs	• All levels of government	• Initial steps can begin immediately; consensus building and implementation could take years
Option C: Enhance education and outreach activities to communicate about risks	• Communities must be able to synthesize information and present it effectively	• Relatively low cost	• All levels of government	• Initial steps can begin immediately and should continue into the future
Option D: Increase compliance assistance and enforcement capacity	• The various jurisdictions must be willing and able to enforce the outcomes of the integrated planning efforts	• Costs will vary depending on the scale of enforcement	• All levels of government	• Initial steps can begin immediately and should continue into the future

a. See USAID's *Governing for Resilience: An Annex to the USAID Climate-Resilient Development Framework* (USAID, Forthcoming) for more detail.

REFERENCES AND RESOURCES

Journal article presents information on private residents' lack of response to coastal risk:

Bin, O., J.B. Kruse, and C.E. Landry. 2008. Flood hazards, insurance rates, and amenities: evidence from the coastal housing market. *Journal of Risk and Insurance* 75(1):63–82.

Journal article describes private residents' lack of response to coastal risk:

Burby, R.J. 2006. Hurricane Katrina and the paradoxes of government disaster policy: Bringing about wise governmental decisions for hazardous areas. *Annals of the American Academy of Political Science* 604(1):171–191.

Website summarizes the Coral Triangle Initiative:

CTI. Undated. About CTI-CFF. Coral Triangle Initiative.
Available: http://www.coraltriangleinitiative.org/about-us.

Plan provides a wide range of resources on water management and climate change-related activities:

GWP. 2013. Coastal Zone Management Plans. Global Water Partnership.
Available: http://www.gwp.org/en/ToolBox/TOOLS/Management-Instruments/Plans-for-IWRM/Coastal-zone-management-plans/.

Study includes a case study of environmental governance in the coastal region of Bangkok:

Hickman, A. 2012. Sink or Swim: Environmental Governance in Southeast Asian Coastal Cities. Dissertation, University of California, Irvine.

Website presents an example of national-scale ICZM activities:

MedPartnership. 2013. Towards Good Governance in Integrated Coastal Zone Management in Algeria.
Available: http://www.themedpartnership.org/med/pfpublish/p/doc/e3de5bc60dd5def41fe0e39f97a4792b.

Study identifies key stakeholder groups to engage in coastal participatory activities:

Meffe, G., L. Nielsen, R. Knight, and D. Schenbom. 2002. *Ecosystem Management: Adaptive, Community-Based Conservation.* Island Press, Washington, DC.

Guidance document for coastal management professionals describes approaches to engaging different stakeholder groups:

NOAA. 2007. Introduction to Stakeholder Participation. National Oceanic and Atmospheric Administration.
Available: http://coast.noaa.gov/digitalcoast/publications/stakeholder.

Web site serves as a clearinghouse of information, resources, and data for coastal zone management in North America:

NOAA. 2013. Coastal Services Center. National Oceanic and Atmospheric Administration.
Available: http://coast.noaa.gov/.

Guidance document provides an overview of the ICZM process and includes an annex on integrating climate change into ICZM:

PAP/RAC. 2012. The ICZM Processes: A Roadmap towards Coastal Sustainability.
Available: http://www.pap-thecoastcentre.org/pdfs/ICZM%20Process.pdf.

Draft guidelines provide information on preparing national ICZM strategies:

PAP/RAC. 2012. National ICZM Strategies. Guidelines for the Preparation of National ICZM Strategies required by the Integrated Coastal Zone Management (ICZM) Protocol for the Mediterranean. DRAFT. Available: http://www.pap-thecoastcentre.org/pdfs/National ICZM Strategy Guidelines_0712.pdf.

The Priority Actions Programme/Regional Activity Centre (PAP/RAC) website provides resources for ICZM:

PAP/RAC. 2013. The Coastal Management Centre. Available: http://www.pap-thecoastcentre.org/about.php?blob_id=21&lang=en.

Paper addresses issues with coastal zone governance in areas vulnerable to sea level rise:

Peloso, M. 2013. Governance Challenges in Adapting to Sea Level Rise. Panel Paper, APPAM Annual Fall Research Conference. November 7–9, 2013.
Available: https://appam.confex.com/appam/2013/webprogram/Paper6476.html.

Website provides an example of local initiative for coordinating multi-stakeholder capacity building for coastal governance:

SEA-START. 2013. SEA-START Regional Center. Available: http://www.start.or.th/.

Position paper describes climate impacts and adaptation actions in Mediterranean coastal zones:

Travers, A., C. Elrick, and R. Kay. 2010. Position Paper: Climate Change in Coastal Zones of the Mediterranean. PAP/RAC. Available: http://pap-thecoastcentre.org/pdfs/CC%20POSITION.pdf.

Database developed to support coastal management in Latin America provides data on present and future coastal climate impacts, coastal dynamics, climate variability, and coastal vulnerability (database in Spanish):

UN-ECLAC. 2013. Database on Climate Change Adaptation in Coastal Zones.
Available: http://www.c3a.ihcantabria.com/.

Guidance document describes ICZM in the Mediterranean:

UNEP. 2001. Good Practices Guidelines for Integrated Coastal Area Management in the Mediterranean. United Nations Environment Programme. Available: http://www.pap-thecoastcentre.org/pdfs/Good Practices Guidelines.pdf.

Website provides general resource for coastal governance information:

UNEP. 2013. Coastal Zone Management. United Nations Environment Programme.
Available: http://www.unep.org/regionalseas/issues/management/mngt/default.asp.

Document presents key guidance for development planners:

USAID. 2009. *Adapting to Coastal Climate Change: A Guidebook for Development Planners*. United States Agency for International Development. May. Available: http://pdf.usaid.gov/pdf_docs/PNADO614.pdf.

Resource discusses improving governance for climate resilience:

USAID. Forthcoming. *Governing for Resilience: An Annex to the USAID Climate-Resilient Development Framework*. United States Agency for International Development.

Website provides information and resources from the Coral Triangle Initiative:

USAID. 2014. U.S. Coral Triangle Initiative. United States Agency for International Development. Available: http://www.usaid.gov/asia-regional/fact-sheets/us-coral-triangle-initiative.

Report describes climate risk assessments and adaptation option evaluations in key Asian coastal megacities:

World Bank. 2010. *Climate Risks and Adaptation in Asian Coastal Megacities*. Available: http://siteresources.worldbank.org/EASTASIAPACIFICEXT/Resources/226300-1287600424406/coastal_megacities_fullreport.pdf.