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Practicing Coastal Adaptation to Climate Change: Lessons from Integrated Coastal Management

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The challenges faced in adapting to climate change present themselves with increasing urgency. Nowhere will these challenges be greater than in the developing world where often weak institutions and governance systems struggle to deal with mounting pressures from population growth, inadequate infrastructure, and diminishing or already depleted natural resources. This article synthesizes the many global climate change and other anthropogenic threats to coastal ecosystems and draws on lessons and good practices from global experience in integrated coastal management (ICM) that can be transferred to coastal adaptation to these challenges. The case is made that the process and best practices of ICM are not radically changed by applying a climate lens. For the most part, the good practices of planning and implementation coastal management measures apply equally to climate change as they do to other coastal issues. However, there are some new and important considerations that enter into planning and decision-making with respect to climate change. These considerations include the need for an even greater emphasis on nature-based coastal protection strategies and measures, more pronounced issues of uncertainty in decision-making, the need for a longer planning horizon, and the importance of including in the decision-making equation opportunities to mitigate the sources of climate change with adaptation measures.

Keywords climate change, coastal adaptation, coastal impacts, ICM, lessons learned

Introduction

There is a growing scientific consensus that increases in greenhouse gases in the atmosphere drive warming temperatures of air and sea, and acidification of the world's oceans from

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carbon dioxide absorbed by the oceans. Warming of air and sea induces shifts in precipitation patterns, sea-level rise, and causes more frequent and severe extreme weather events (e.g., storms and sea surge). These effects are already being witnessed in the world's coastal regions and are projected to intensify in years to come, affecting approximately 2.7 billion people, representing over 40% of the world's population.

Climate change can amplify the effect of other existing stresses on coastal areas such as over-exploitation and degradation of resources, water pollution, habitat change, and alteration of freshwater flows. Dramatically increased efforts to combat climate change through mitigation (reducing greenhouse gas emissions, or removing the gases from the atmosphere) must be complemented by urgent actions to assist vulnerable coastal countries to adapt to changes already underway and expected to get worse. Developing countries will be impacted by climate change even greater than developed countries because of weaker adaptive capacities. This is part of what is termed the *climate divide*, meaning inequalities across countries in the responsibility for climate change, impacts from climate change, and capacities available to reduce the effects of climate change. The climate divide highlights the need for developed nations to take steps to transfer knowledge, technology, and other assistance to the developing world if significant dislocations and costs to coastal communities are to be avoided.

The societal costs of inaction may far exceed the cost of being proactive. Proactive adaptation is strategic and aims to address the full range of coastal climate change hazards in ways that meet social objectives. Lessons and good practices will be drawn from global experience in integrated coastal management (ICM) that can be transferred to proactive coastal adaptation to climate change.

A case will be made that the process and best practices of ICM are not radically changed by applying a climate lens. For the most part, the good practices of planning and implementation of coastal management measures apply equally to climate change as they do to other coastal issues. However, there are some new and important considerations that enter into planning and decision-making with respect to climate change. These considerations include: (1) the need for an even greater emphasis on nature-based coastal protection strategies and measures, (2) more pronounced issues of uncertainty in decision-making, (3) the need for a longer planning horizon, and (4) the importance of including in the decision-making equation opportunities to mitigate the sources of climate change with adaptation measures.

What will be presented is based on a recent effort supported by the United States Agency for International Development (USAID) that involved a large number of coastal professionals, practitioners and institutions. The USAID effort was comprised of several international meetings and workshops, interactions with an Advisory Panel, and several global and regional training events. The effort resulted in production of a Guidebook for development planners entitled "Adapting to Coastal Climate Change" (USAID, 2009). The Guidebook is directed at practitioners, development planners, and coastal management professionals. It offers an approach for assessing vulnerability to climate change and climate variability in communities and outlines how to develop and implement adaptation measures at the local and national levels.

This article begins with an overview of the dramatic and wide-ranging challenges facing the world's coastal regions as a consequence of climate change, and its overlay onto existing threats to coastal and marine ecosystems. Best practices for coastal adaptation processes drawn from the USAID Guidebook on Adapting to Coastal Climate Change are then described. These best practices draw from decades of global experience in the practice of ICM. Finally, some of the unique coastal adaptation challenges posed by climate change are identified.

Coasts and Oceans in a Climate Change World

The impacts of climate change on coastal and marine systems are many, and they can be difficult and complex to understand. They are also constantly evolving with growing evidence, knowledge, and understanding. Table 1 provides a summary of observations and trends of the climate and chemical effects of increased greenhouse gases on coastal and ocean systems.

Sea-level rise is usually the first impact to come to mind in thinking about climate change and coasts. Sea level has been rising throughout the 20th century, contributing to increased coastal inundation, erosion and ecosystem loss, posing a severe threat to coastal areas with heavy concentrations of population and economic activity (IPCC, 2007a). Until recently, studies of sea- level rise typically predicted a 0–1 meter rise during the 21st century. For example, the Intergovernmental Panel on Climate Change (IPCC) anticipates that sea level will rise 0.6 m or more by 2100 (IPCC, 2007c). Ocean thermal expansion was expected to be the dominating factor behind this rise. However, new data on rates of deglaciation (the uncovering of land previously covered by glaciers) in Greenland and Antarctica suggest that glacial melt may play a significant role in potentially creating an even greater rise in sea level on the order of 1–3 meter in this century (Dasgupta et al., 2007). A rise of this amount would displace hundreds of millions of people in the developing world, particularly in high population megadeltas (e.g., Danube, Ganges-Brahmaputra, Indus, Mekong, Mississippi, and Nile) (Burkett, 2008).

While sea-level rise receives the most attention, other impacts will create challenges along the world's coasts. Rises in marine/coastal water surface temperatures will lead to the further bleaching and widespread mortality of coral reefs. Saltwater will displace or at least intrude coastal aquifers, and estuarine systems will likely become more brackish—altering estuarine ecology with potentially severe impacts on fisheries and marine or coastal biodiversity and overall productivity.

Rising sea level and increased sea surface temperatures are expected to contribute to increased frequency and severity of extreme weather events, such as coastal storms. More intense storms will, in turn, generate larger waves, storm surges, and increased coastal erosion. Annually, about 120 million people are exposed to tropical cyclone hazards alone, which killed 250,000 people from 1980–2000 (IPCC, 2007a). The recent human tragedies of the December 2004 Indian Ocean tsunami, Hurricane Katrina (United States, August 2005), Cyclone Sidr (Bangladesh, November 2007), and the Cyclone Nargis (Myanmar, May 2008) demonstrate that coastal calamities can overwhelm resources and disaster responses of developed and less developed nations alike. Each coastal disaster provides tangible examples of the potential impacts that may unfold during the next century as a result of global warming and associated sea-level rise.

Another physical effect of climate change and climate variability on coastal regions is the pattern of rainfall. Rainfall patterns are changing and the effects of El Niño and La Niña episodes have worsened, resulting in increased cyclones, flooding, and drought cycles. Runoff from more intense precipitation and changes in seasonal freshwater flows in many coastal environments can result in broad ecosystem changes including changes in coastal erosion and sedimentation to which mangroves, estuaries, and coral reefs are particularly vulnerable. Nutrient-rich runoff under conditions of higher sea surface temperature will likely promote coastal hypoxia or seasonal hypoxic events, increasing the spread of marine dead zones. Changing weather patterns affect the distribution and range of species and disrupt the natural balance of many ecosystems, potentially impacting fisheries. When bacteria, viruses, mosquitoes or other disease vectors change their geographical range as a result of global warming, diseases also spread.

In short, climate change is increasing the frequency of natural disasters with overarching impacts on the health and resilience of coastal ecosystems and the global economy. Sea-level rise, more frequent and severe extreme weather events, increased flooding and the degradation of freshwater, fisheries, and other coastal resources could impact hundreds

Table 1
A summary of climate change observations and trends in the coastal zone†

Coastal impact	Observations	Projected trends
Sea level rise	√ For the 20th century, sea levels rose at a rate of 1.7 to 1.8 mm/yr √ In the last decade, the worldwide average rate was measured to be 3.0 mm/yr √ Coastal **erosion** is increasingly observed around the world; it can be related to either sea level rise or subsidence, or both	√ Sea levels are expected to rise by at least 0.6 meters by the century's end; **glacial melt** is expected to increase this rise √ Coastal **flooding** could grow tenfold or more by the 2080s, affecting more than 100 million people per year due to sea-level rise, especially in Southeast Asia √ It is projected that **seawater intrusion** due to sea-level rise could severely affect aquaculture in heavily populated mega-deltas, such as in Southeast Asia √ A one meter rise in sea level could inundate 17% of Bangladesh and completely **flood** the Republic of Maldives, reduce Bangladesh's rice farming land by half and affect millions of livelihoods √ A 2°C increase in temperature could result in the loss of a number of island states
Sea surface temperature change	√ Between 1970 and 2004, sea surface temperatures around the planet rose between 0.2–1.0°C, with a mean increase of 0.6°C √ The Caribbean Sea has warmed by 1.5°C in the last 100 years √ Observations since 1961 show that the ocean has been absorbing more than 80% of the heat added to the climate system √ Changes in water temperature caused wide scale **coral bleaching** in the Asia region, damaging as much as 75–100% of coral in the Philippines in 1998	√ By 2100, temperatures are projected to rise in the tropical Atlantic (2–4°C), Pacific (1.5–3.5°C) and Indian (3°C) Oceans √ Increases in sea surface temperature of about 1–3°C are projected to result in more frequent **coral bleaching** events and widespread mortality √ Studies project that with a 1°C increase in sea surface temperatures, all coral reefs in the Great Barrier Reef, Southeast Asia and the Caribbean could be **bleached**

Table 1
A summary of climate change observations and trends in the coastal zone† *(Continued)*

Coastal impact	Observations	Projected trends
Increased frequency of extreme weather events	√ Increases in category 4 and 5 tropical cyclones, **hurricanes** and **typhoons** during the 20th century have been reported √ Tropical **cyclone** activity has increased since 1970, with a trend toward longer-lived storms and storms of greater intensity √ Mass mortality of mangrove species in the Caribbean has been attributed to the increased frequencies of **hurricanes** in the region √ **El Nino** events have become more frequent, persistent and intense during the last 20 years compared to the previous 100	√ Models project a likely increase of peak **wind intensities** and increased mean and peak near-storm **precipitation** in future tropical cyclones √ The population exposed to **flooding** by **storm surges** will increase over the 21st century, especially in South, Southeast, and East Asia
Precipitation change	√ Precipitation has increased by up to 10% in the Northern Hemisphere and decreased in other regions (e.g., North and West Africa, parts of the Mediterranean and the Caribbean) √ The frequency and severity of **drought** has increased in some regions, such as parts of Asia and Africa √ Very dry areas have more than doubled since the 1970s √ Australia incurred over US$13 billion in **drought** damage between 1982–2003	√ Projections for Latin America show a general year round drop in seasonal precipitation of up to 60% with the greatest effects felt in Mexico and Central America √ Precipitation change is very likely to increase the frequency of **flash floods** and large-area floods in many regions √ In Tarawa, Kiribati, it is projected that **drought** damages could to reach 18% of the gross domestic product by 2050
Ocean acidification	√ Since 1750, an average decrease in pH of 0.1 units has been observed	√ It is projected that the pH of the world's oceans could fall by up to a further 0.3–0.4 units by 2100, resulting in the lowest **ocean pH** levels in 20 million years

†*Source*: IPCC (2007a, b); IUCN (2007).

of millions of people (IPCC, 2007a). This occurs at a time when there is an ever increasing human dependence on coastal resources and growing populations in the coastal zone.

In parallel with climate change, the ocean is becoming more acidic (decreased seawater pH) because of the absorption of atmospheric carbon dioxide (CO_2) by oceans. Ocean acidification has potential widespread effects on marine ecosystems by inhibiting calcification, threatening the survival of coral-reef ecosystems, inhibiting the growth of calcareous algae at the base of the food web, as well as shell-forming marine organisms (such as scallops), and stunting the growth of calcified skeletons in many other marine organisms, including commercial fish species.

Table 2 lists the many ways in which the climate and chemical changes in the coastal and marine zone impact on coastal sectors, human well-being, and goods and services. It highlights the fact that the world's coastal regions are already under assault as a result of coastal development patterns and habitat loss, over-fishing, pollution, and other environmentally damaging activities. The effect of climatic change is to exacerbate the threats already faced by coastal systems.

Transferable Lessons from the ICM Playbook

Table 1 and Table 2 illustrate the need for dramatically stepped up efforts to mitigate climate change complemented by urgent actions to assist vulnerable developing coastal countries to adapt. In this section, best practices for effective adaptation promoted by the USAID Guidebook on Adapting to Coastal Climate Change are described. These best practices emanate from decades of experience with ICM, and as the Guidebook postulates, they are transferable to the new challenges of adapting to coastal climate change. The best practices and lessons learned that emerge from global ICM experience help to make the seemingly overwhelming issues of climate change in coastal regions more manageable.

Adaptation Should be Seen as an Inclusive, Participatory, and On-Going Process

The conceptual framework in which ICM is seen as a management cycle is widely accepted among ICM professionals (see, for example, GESAMP, 1996; Olsen et al., 1999, Olsen, 2003; World Bank, 1996). The cycle includes the following steps: issue identification and assessment (Step 1), program preparation (Step 2), formal adoption and funding (Step 3), implementation (Step 4), and evaluation (Step 5). Similarly, coastal adaptation needs to be practiced as an inclusive, strategic, and adaptive process for assessment of climate change risks, planning, securing commitment and funding, implementation, and evaluation (USAID, 2007, 2009). This common approach, or cycle, to coastal management and adaptation is shown in Figure 1. The coastal adaptation management cycle highlights a central message: the process of coastal planning and action for climate change is not radically changed by applying a *climate lens*. The process and good practices of planning and management, with some modest refinements, apply equally to climate change as they do to other coastal issues. Further, as with the ICM management cycle, a broad range of stakeholders should be engaged in the process to ensure salience and ownership of adaptation interventions, and therefore more effective implementation and sustainability. Political support is an essential condition for successful coastal adaptation.

Use Best Available Knowledge

A fundamental tenet underlying the ICM concept is that decision making should be based on the use of the best information and science available (GESAMP, 1996). Systematic knowledge and understanding plays a major role to guide the wise use of coastal resources, resolve human-induced problems, and improve governance systems. This need for information in planning and decision-making becomes more evident for climate change due to the complexity and uncertainty of climate change impacts.

Table 2
Threats to the coastal environment‡

Sector	Climate change threats	Other human threats
Coral reefs, coastal wetlands, and ecosystems	➢ Loss of coral reefs from **coral bleaching** and **ocean acidification** ➢ **Loss or migration of coastal wetland ecosystems**, including salt marshes and mangroves ➢ Runoff from more intense **precipitation** causing coastal erosion, and sedimentation adversely affecting estuaries and coral reefs ➢ Nutrient rich runoff under conditions of higher **sea surface temperature** promoting coastal hypoxia and marine **dead zones** ➢ Change in the distribution and **abundance** of commercially valuable marine species ➢ Increased spread of **exotic** and **invasive species**	○ 30% of the world's **coral reefs** have been lost as a consequence of overfishing, pollution, and habitat destruction ○ Intense coastal development and **habitat loss** ○ Pollution and marine **dead zones** ○ **Conversion of mangroves** and wetlands for mariculture ○ Disruption of the quantity, quality, and timing of **freshwater inflows** to estuaries ○ Damage to **seagrass beds** from sedimentation, recreational boating, fishing and tourism ○ **Coral mining** for construction and lime making ○ **Oil spills** from shipping ○ Spread of **invasive species** ○ Coastal reinforcement disrupts natural **shoreline processes** ○ Sand and gravel **mining** of riverbeds and beaches
Capture fisheries	➢ Overall decline in ocean productivity ➢ **Eutrophication** and coral mortality leading to reduced fish catch ➢ **Loss or shifts in critical fish habitat** ➢ **Temperature shifts** causing migration of fishes ➢ Extreme events, temperature increases and oxygen depletion reducing spawning areas in some regions ➢ **Temperature changes** affecting the abundance and distribution of marine pathogens ➢ **Ocean acidification** and increases in temperature damaging coral reefs	○ **Over-harvesting** ○ **Destructive fishing** practices (e.g., bottom trawling, dynamite fishing, beach seining) ○ Land-based sources of **pollution** (sewage, industrial waste, nutrient runoff, etc.) ○ **Sedimentation** of coastal systems from land-based sources

Table 2
Threats to the coastal environment‡ *(Continued)*

Sector	Climate change threats	Other human threats
Mariculture	➢ Increases in water temperature reduces culture productivity ➢ Increased sea temperature results in spread of **pathogens** and parasites to cultured organisms in new areas ➢ Overall decline in **ocean productivity** reduces supplies of wild fish used for fish meal for mariculture sector ➢ Changes in weather patterns and extreme weather events reduce **productivity** and damage operations (loss of infrastructure and stock)	○ **Overexploitation** of juveniles and larvae seed stock for fish farms ○ Release of chemicals, nutrients and sediment in pond effluents ○ **Spreading of pathogens** and disease to local ecosystems and neighboring culture operations ○ **Loss of protective habitats from improper siting of mariculture facilities**
Recreation and tourism	➢ **Storms**, **erosion** and **precipitation** damaging infrastructure and causing losses to beaches ➢ Compromised water quality and increasing beach closures ➢ Increases in tourism insurance costs on high-risk coasts	○ **Improper siting** of tourist facilities ○ **Alteration** of the shoreline, coastal processes, and habitat ○ Strain on **freshwater resources** for tourist facilities ○ **Marine pollution** and habitat disruption from recreational boating
Freshwater resources	➢ **Saltwater intrusion** of freshwater sources ➢ Encroachment of saltwater into estuaries and coastal rivers ➢ Waves and **storm surges** reaching further inland, increasing coastal inundation and **flooding** ➢ **Decreased precipitation**, enhancing saltwater intrusion and exacerbating water supply problems	○ Discharge of untreated sewage and chemical **contamination** of coastal waters ○ Unregulated **freshwater extraction** and withdrawal of groundwater ○ Upstream **dams** ○ Enlargement and **dredging** of waterways
Human settlements	➢ Coastal **inundation** causing relocation inland ➢ Building and infrastructure damage from increasing coastal **storm intensity** and flood exposure ➢ **Sea level rise** raising water levels during storm surge ➢ Reduced clearance under bridges	○ Rapid increase in **coastal development** projected to impact 91% of all inhabited coasts by 2050 ○ Inappropriate **siting** of infrastructure ○ Shoreline **armoring** ○ **Habitat conversion and biodiversity loss**

Table 2
Threats to the coastal environment‡ *(Continued)*

Sector	Climate change threats	Other human threats
	➢ Overtopping of coastal defense structures ➢ **Sea level rise**, erosion, and extreme weather events leading to degradation of natural coastal defense structures	
Human health	➢ **Heat stress** from extremely hot periods ➢ Injuries, illness, and loss of lives due to **extreme weather events** ➢ **Malnutrition** and food shortages during extreme events ➢ Increased spread of vector-borne **disease** (dengue fever and malaria), waterborne diseases (diarrhea), and toxic algae (ciguatera)	○ **Pollution** and water contamination
Conflict	➢ **Coastal land loss** leading to coastal land and resource scarcity or loss, and human migration ➢ **Water use** conflicts due to scarcity ➢ Population **migration** to urban areas as ocean productivity and food availability declines and fishers are displaced	○ **Displacement** and loss of shore access resulting from tourism and coastal development

‡*Source*: IPCC (2007a, b); IUCN (2007).

The complexity of climate change and coastal processes is often seen as a barrier to action. However, by integrating the best available knowledge and involving local communities, it is possible to take responsible action in situations where there are uncertainties and imperfect information. Following the *precautionary approach*, actions should not be impeded by an absence of full scientific certainty. A skillful adaptation approach is to look at the trends suggested by existing models along with the trends that are beginning to show themselves in the region in question and to plan accordingly. Trends will continue to change and emerge for generations to come, even should mitigation efforts greatly reduce global greenhouse gas emissions.

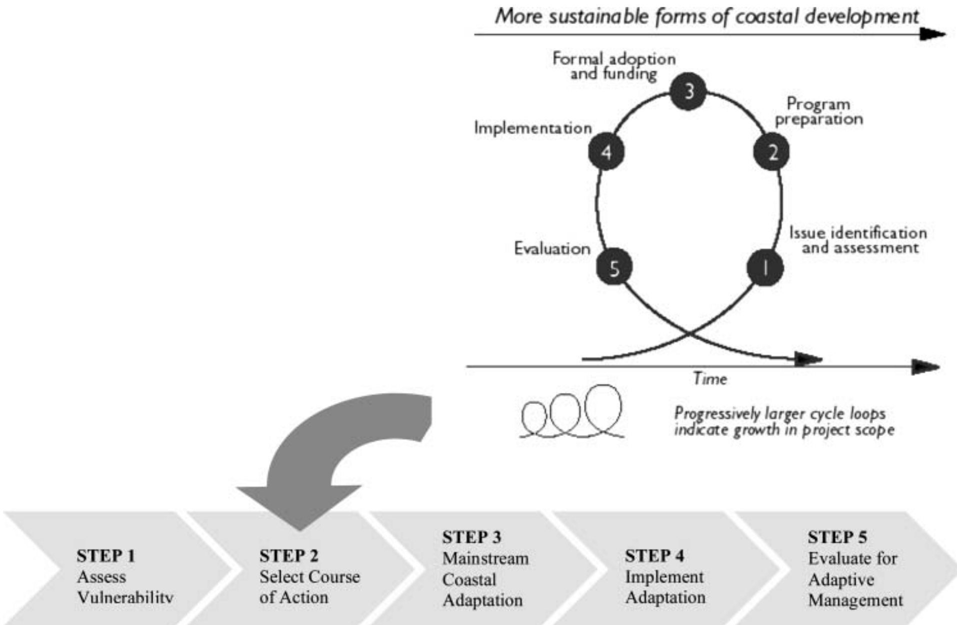

Figure 1. A coastal adaptation roadmap applies a climate lens to the ICM management cycle used by coastal practitioners. Source: USAID (2009).

Larger scale climate change models and projections, such as those of the IPCC, as well as on-line regional mapping tools and downscaling models (e.g., the SERVIR Climate Change Mapping Tool (http://www.servir.net/ and the PRECIS Regional Climate Modeling System http://precis.metoffice.com/) lack the resolution and specificity needed to assess the vulnerability of specific coastal areas. They can, however, provide a broad context from which to overlay local knowledge on past and current climate trends for the specific place. For example, local knowledge can help answer the basic question: “Has the frequency, magnitude, or timing of precipitation, extreme weather events and other climate impacts changed in the last several decades?” A review of historic records for climate variability and hazard events in a specific area can also help validate the projections. Spatial data and maps to visualize biophysical impacts (e.g., shoreline, storm surge, and flooding maps) also aid in this exercise.

Scenarios that reflect a range of low to high degrees of change can be used by stakeholders to assess vulnerabilities and identify issues and adaptation measures. Scenarios can also help move dialogue from a debate about exactly *how* the climate will change to a discussion among key stakeholders, experts, and project staff on the *implications* of the different scenarios (high, medium, low change), and on the degree of risk that society is willing to tolerate before action must be taken.

Strategically Define Priorities, Goals, and Objectives

Other good practice and fundamental features of ICM are to strategically select a limited number of management issues with attention to the nature of the problem, and dimensions of capacity and complexity, and to define early on the goals and objectives of the management initiative (Olsen et al., 1999; Olsen, 2003; Tobey & Volk, 2002).

Similarly, given the scope and multifaceted effects of climate change, coastal adaptation efforts need to choose an initial focus on a limited set of key climate threats and adaptation issues that capture the interest, imagination, and commitment of local residents and the government departments most directly involved. A limited number of climate change issues should be selected strategically with attention to the complexity of the problems, political realities, and available resources to achieve goals. The information needed to set priorities comes from step 1 of the coastal adaptation management cycle. This is the vulnerability assessment that defines what assets are most *sensitive* and *exposed* to climate change, and what are the *adaptive capacities* to address climate change impacts? (USAID, 2009).

Priorities should be selected through an inclusive process that involves the major stakeholder groups and decision-makers. It is their perspectives and interests that will influence the criteria used for judging risk and prioritizing concerns. While there is no formula for determining the most important climate change risks for a specific coastal area, it is possible to draw from the experience of integrated coastal management best practices. This experience suggests the following strategies:

- Identify and involve governmental agencies and other formal institutions, such as universities and user groups, that have an interest in the condition and use of the coastal ecosystems being considered
- Solicit the views of major stakeholder and other groups and, to the extent possible, the general public (e.g., through focus groups and surveys)
- Identify potential leaders and the stakeholder groups who will be involved in the implementation of the adaptation measures
- Ensure the scope and complexity of the climate change issues selected as priorities for adaptation measures are appropriate to the capacity of the institutions involved

Coastal management experience also confirms the importance of clearly defining management goals and objectives in coastal programs. Goals identify the desired endpoint you want to reach. Objectives provide the specific achievements that must be met in order to reach the goals. Successful long-term coastal management programs teach us the importance of setting objectives that are unambiguous and time-bounded for each issue the program chooses to address. Such objectives are best when they specify in *quantitative terms* what will be achieved *by a specified date*. Table 3 lists some of the major categories of management goals and objectives likely to be found in adaptation programs in coastal areas.

Tailor Coastal Adaptation to Local Conditions

For effective ICM efforts, the complexity of the management issues tackled in a given place must be tailored to the capacity of the institutions involved (Tobey, 2000). Complexity is related to aspects such as the certainty of the solution; the scope of change associated with the proposed management actions; the scale of change in terms of the geographic area and number and diversity of organizations and stakeholders involved; the stability of the policy environment; and the degree of user conflicts. Key dimensions of capacity include traditions of and existing mechanisms for integrated management, leadership, the strength of government institutions and procedures, awareness of coastal issues and public support for ICM, and willingness of government, civil society, and stakeholders to act on coastal management issues. Every coastal place is different.

Similarly, countries or coastal areas may share the same climate change issues, yet each has different circumstances in terms of natural resources, infrastructure, technological state, economy, and governance, so the responses to those climate change issues will vary.

Table 3
Examples of adaptation goals and objectives for coastal climate change

Illustrative goals and objectives for coastal adaptation to climate change
1. **Functioning and healthy coastal ecosystems**
• **The natural shoreline is ecologically sound and functioning as a dynamic system.** Strengthened natural defenses protect people and nature from future hazards. Sand dunes, sea grass, mangroves, and beaches are physical buffers.
√ Mangrove forest area is expanded by 30% in any given coastal lagoon through community-based replanted efforts
• **Extraction and use of natural resources do not compromise the sustainability of vital coastal ecosystems**. Reducing or eliminating non-climate stresses and unfavorable trends helps achieve functional ecosystems that are more resilient to climate change and variability. Resilient, healthy systems can better withstand all types of perturbations than can systems that are unbalanced or at the edge of their survival.
√ Illegal sand and gravel mining in coastal riverbeds and beaches is stopped in one year's time
• **Marine fisheries are healthy and resilient to climate change.** Reducing overfishing and destructive fishing will reduce or eliminate non-climate stresses and non-climate trends helps strengthen fish populations and restore fish habitat.
√ By 2015 industrial fishing vessels will have been eliminated from operating within 15 km of the coast and inshore artisan catches will have been restored to the levels that existed in 1990.
• **Coastal and marine ecosystems are functioning and healthy**. Functional ecosystems provide goods and services that are important to human society in the face of climate change (storm protection, flood mitigation, shoreline stabilization, erosion control, water storage, groundwater recharge, and retention of nutrients, sediments, and pollutants).
√ By 2010, the estuary areas of the river basins that are forested with mangroves will have increased by 35 percent as measured against the year 2000 baseline
• **Key climatic refugia that will likely experience less change are reserved to "bank" ecosystem services for future climate changes**. Identifying locations that are more stable during periods of global climate change can be useful for conservation. In the marine environment, for example, these sites may have strong currents, upwelling or other oceanographic features that make them less prone to thermal fluxes.
√ Coral reef areas that are more resilient to climate changes are identified by end of 2009 and selected areas designated as a reserve by 2011 to protect climate change resilient reef systems
• **Freshwater supplies and access to freshwater for human uses continue to be available.** Proactive adaptation measures can reduce or avoid the undesirable impacts of climate change on access to freshwater supplies for meeting both growing human demand and environmental flow requirements.
√ Water User Associations in three Districts prepare water management plans and approve the plans by September 2009
2. **The built environment is less exposed and less vulnerable to damages from natural hazards.** Reduce human injury, loss of life, and damage and loss to public and private infrastructure with measures that protect, accommodate or avoid the impacts of climate change on the built environment.

Table 3

Examples of adaptation goals and objectives for coastal climate change *(Continued)*

Illustrative goals and objectives for coastal adaptation to climate change
√ A District management plan in a given District that defines coastal development setback rules is completed and formally adopted by local government in a two year timeframe
3. **Governance, policy, and planning capacities for planned adaptation are strengthened**. Vigilance, planning, and continually renewed political commitment improve adaptive capacity and reduce society's vulnerability to climate change impacts.
√ National Adaptation Plan of Action prepared by national working group in 2009 and recommended implementation actions initiated in 2010
4. **Livelihood opportunities are maintained or strengthened in the face of climate change impacts.**
√ Community savings and loan mechanisms are established in three coastal districts in 2009 to increase community resilience and opportunities for fishing households to diversify their livelihoods
5. **Impacts of climate change to human health and safety are minimized.** Disaster risk management and preparedness reduce the risks to human health and safety from natural hazards.
√ Flood hazard maps for all coastal provinces are completed in one year and at the same time pilot disaster risk management plans completed in five communities

Source: USAID (2009).

Coastal adaptations must be *tailored* to the local context through an inclusive process that matches the climate change issues with the technical capabilities and the capacity of the institutions and community stakeholders of the place. Key questions include: What is the preexisting degree of awareness and salience of climate change impacts? What is the locus of decision-making power? What is the capacity to address coastal issues? What is the country's *readiness* to tackle accelerated climate change?

Capacity to respond to climate change issues will grow with time, experience, and the positive reinforcement that comes with success. Early successes of adaptation may begin with establishing setbacks and buffer areas, for example, in undeveloped areas or areas proposed for future development that are exposed to flooding and erosion. More complex adaptation measures might include those that involve infrastructure development and maintenance.

Population density and infrastructure are other key considerations in selecting measures. For example, in heavily developed areas facing potential increases in erosion, sea-level rise, or flooding, the favored adaptation option may be structural shore protection (to stabilize the shoreline) versus retreat. In underdeveloped areas, the opposite (a strategy of retreat) may be more appropriate. Retreat refers to a series of measures that would remove the population and development by "retreating" landward (i.e., away from the potential risk).

Coastal managers, stakeholders, and decision-makers can use a range of criteria in deciding the best adaptation option within a given local context. Criteria include:

- **Technical effectiveness:** How effective will the adaptation option be in solving problems arising from climate change (i.e., might some measures be more beneficial than others)?
- **Costs:** What is the cost to implement the adaptation option and what are the benefits? Is one approach both cheaper and more effective? Is the measure a *no-regrets* measure—that is, would it be worthwhile regardless of climate change (e.g., protecting/restoring coastal ecosystems that are already vulnerable or of urgent concern for other reasons)?
- **Benefits**: what are the direct climate change-related benefits? Does taking action avoid damages to human health, property, or livelihoods? Or, does it reduce insurance premiums? Are there any greenhouse gas reduction advantages that could be valued according to the market price for carbon credits? Other benefits include increased ecosystem goods and services and positive contributions to economic value chains.
- **Implementation considerations:** how easy is it to design and implement the option in terms of level of skill required, information needed, scale of implementation, and other barriers?
  - Some measures require sophisticated information and specialists that are not available
  - Flexible, adaptive approaches require more knowledge and judgment than a simpler, rule-based policy
  - A standardized setback for a shoreline area is technically simple compared to a detailed scientific study of oceanographic, geological, or other landscape-scale parameters
  - Working with a resort developer in a particular case to make adjustments may be easier than creating a broad-reaching policy that deals with all business owners in a tourism district who unwittingly made investments and physical alterations to the shore that expose them to increasing hazards from climate change

The USAID Guidebook on Adapting to Coastal Climate Change (USAID, 2009) lists 18 adaptation measures and for each provides summary information on common themes, such as, relevance to climate change and design and implementation considerations.

The best adaptation response will rarely involve a single, stand alone measure. Responding to the wide array of climate change impacts requires a combination of measures working together in a complimentary fashion. In selecting the best combination, it helps to look for interdependencies between individual measures and the benefits of those measures not only to climate change, but to good coastal management.

Build Reinforcing Linkages among the Many Possible Adaptation Entry Points (Sectoral Institutions, National Policy, and Place-Based Action)

Integrated coastal management requires coordination of effort across different levels of government and sectors. Overcoming the policy and functional fragmentation and overlap that occur in the governance of coastal areas is a central goal of ICM. Experience shows that both national mandates for ICM and incentives that encourage appropriate action at lower levels in the governance hierarchy are needed (Robadue, 1995; Olsen, 2003).

In the climate change field, this kind of coordination is called "mainstreaming." Mainstreaming means integrating climate concerns and adaptation responses into relevant policies, plans, programs and projects at the national, sub-national, and local scales (USAID, 2009). Mainstreaming is what gives adaptation the funding and authority to take place. For mainstreaming to be successful there needs to be reinforcing linkages between the different vertical and horizontal entry points. Government, together with nongovernmental partners, must play a pivotal role in fostering the connections across national, sectoral, and place entry points. Examples include:

- *Creating enabling policy, finance, and legal frameworks*. This includes prioritizing adaptation in national planning and budgeting; harmonizing sectoral policies; creating national coordination committees, chaired by a ministry with power; and providing the financial and technical support necessary for adaptation measures to succeed.
- *Capturing local experience*. Coastal adaptation in a specific place or area builds practical experience and a sense of ownership for those living and working there. This experience can be shared among different actors at the national level to build capacity. Linkages between local communities and government strengthen community voice in planning and national policy-making for coastal adaptation to climate change.
- *Public awareness*. Awareness raising and education campaigns help convey information about the impacts of climate change and gain consensus on adaptation options. Governments need to engage more actively with the scientific community and provide easily accessible and up-to-date climate change information relevant to the needs of coastal sectors.

Evaluation and Adaptive Management

Good ICM practice tells us that it should maintain a strategic focus throughout program formulation and implementation by continually defining and redefining the issues—the problems and opportunities that are the management focus, based on broadly based input and deliberation (Tobey & Volk, 2002; Olsen, 2003). This kind of strategic and learning based management is precisely what is needed in climate adaptation.

Once coastal adaptation measures are implemented, there will be considerable interest in how they perform and policymakers will be keen to demonstrate that the measures are beneficial to the citizenry. They will want to assuage stakeholders who have borne some of the costs associated with the measures. The public will seek assurances that the measures afford them as much protection as possible from the impacts of climate variability. All parties will expect the measures to be adjusted if they do not perform according to expectations. As evaluation results become available, policymakers, stakeholders, or the public may be motivated to press for changes in the choice of adaptation measures, their design, or their implementation. The process of reflecting on these changes based on evaluation results is referred to as adaptive management.

New Features of Coastal Adaptation

The experience of the USAID initiative to produce a Guidebook on Adapting to Coastal Climate Change demonstrated that there is much to learn from successful experience in ICM that can be transferred to coastal adaptation. But, it also highlighted some features of climate change and adaptation that require special consideration. For example, issues of uncertainty are more pronounced; a longer planning horizon must be taken into account; arguments can be made for an even greater emphasis on nature-based coastal protection strategies and measures; and opportunities to mitigate the sources of climate change with adaptation measures should be part of the decision-making equation.

Nature-based adaptations can help people and communities deal with climate change impacts by protecting mangroves, coral reefs, estuaries, seagrass beds, dune communities, and other systems on or near shorelines and the benefits they provide, such as protection from storms; mitigating floods; controlling erosion; providing water storage and groundwater recharge; and retaining nutrients, sediments, and pollutants. Functional ecosystems are also critical to natural resource–dependent livelihoods and biodiversity conservation. When coastal ecosystems are weakened and unhealthy, they are less resilient to the effects of climate change and variability and are less able to provide the goods and services that are important to human society in the face of climate change.[1]

Coastal practitioners must also be cognizant of adaptation efforts being taken in related sectors and ensure that those actions do not result in increased impacts on coastal ecosystems. This is especially true for the water sector, where allocation, management, and adaptation efforts can easily affect downstream ecosystems, including the all-important timing, volume, and quality of freshwater inflows to estuaries. Such changes can dramatically alter estuarine health and productivity, and in turn signal major declines in fish and shellfish abundance, migratory waterfowl, and other estuarine-dependent species. In such cases, coastal practitioners and stakeholders may find that their greatest priority is to begin serious dialogue and engagement with those responsible for water resources management (Olsen et al., n.d.).

Building resilience in coastal and marine ecosystems depends on: (1) spreading risk to manage for uncertainty by protecting replicates of critical habitats (i.e., mangrove forests, coral reefs) over a large geographic range; (2) identifying and securing sources of marine larvae that are critical for maintaining and restoring healthy populations; (3) protecting corals that grow in areas naturally resistant to bleaching, including reefs in upwelling zones (that reduce thermal stress) and those located in turbid environments (where suspended organic material reduces light stress); (4) maintaining connectivity between habitats by creating refugia from other stresses, such as overfishing; and (5) managing resources effectively by controlling other threats and pressures (i.e., sedimentation from land-based sources).

Nature-based adaptation also means favoring ecosystem and living shoreline approaches over hard structures to stabilize the shoreline. Living shoreline approaches address erosion by providing for long-term protection, restoration, or enhancement of vegetated shoreline habitats. Priority should be given to these approaches because they are "no regrets" measures (beneficial even in the absence of climate change).

Another important consideration when selecting coastal adaptation measures is finding opportunities to mitigate the sources of climate change. Many measures can be designed in a way that reduces the production of greenhouse gases or removes the gases from the atmosphere (sequestration) such as through ecosystem conservation and restoration, coastal forest management, and alternatives to fuel wood consumption. Although wetlands cover 6% of Earth's land surface, they store 10–20% of its terrestrial carbon. Preserving or restoring wetlands helps protect the shoreline and the community from climate risks and also mitigates greenhouse gas concentrations.

Concluding Comments

Taken together, the changes brought by climate change are likely to result in significant alteration of natural habitats, coastal ecosystems, coastal hazards, and lifestyle changes for fishers, coastal resource users, waterfront property owners, and coastal communities. These have far-reaching impacts on a range of challenges for coastal resource managers.

Efforts explicitly directed at coastal adaptation are only beginning. In the United States, coastal programs from around the country are developing policies to address issues such as the siting of public and private infrastructure, wetland conservation and restoration, shoreline building setbacks, and alternatives to shoreline hardening for erosion control. Internationally, The United Nations Framework Convention on Climate Change (UNFCCC) provides support to the 50 least developed countries (many of which are coastal) to plan, mainstream, and implement climate adaptation. The National Adaptation Programme of Action (NAPA) process carried out through UNFCCC has led some developing countries to examine several facets of climate change and the need for adaptation measures. Many countries have started their NAPA, however, only a few are in an early stage of implementation (Jallow & Downing, 2007). A number of climate adaptation initiatives are funded by the Global Environment Facility, including: The Special Climate Change Fund, the Community-based Adaptation Program, Adaptation to Climate and Coastal Change in West Africa, Climate Change Adaptation Africa, and the Mainstreaming Adaptation to Climate Change project in the Caribbean. A new multi-donor, country and international conservation group initiative—the Coral Triangle Initiative—in the Indo-Pacific Region, has adopted a nature-based approach to coastal adaptation. In addition, other bilateral and multilateral coastal adaptation efforts are being established in coastal developing countries around the globe.

As these investments unroll, it is critical that they move beyond planning, overcome the "implementation gap," and demonstrate concrete benefits. Practitioners are looking for roadmaps to coastal adaptation to ensure successful and effective adaptation processes with stakeholders, users, communities and government. Many guidance documents for climate change adaptation have been prepared, some specifically targeting coastal adaptation (e.g., New Zealand Climate Change Office, 2008; Sea Grant, 2007; SPREP, 2006; Tyndall, 2005; USAID, 2009; and USEPA, 2008). The USAID Guidebook on Adapting to Coastal Climate Change (2009) has a specific focus on developing countries and builds on global experience and lessons learned from ICM. This and other practitioner guidebooks will no doubt be expanded and refined as the tools, knowledge, and skills for coastal adaptation grow.

It is our hope and expectation that ten years from today, the testing and application of coastal adaptation techniques in specific country and local contexts around the globe will be greatly advanced and new lessons learned and best practices will have emerged, be shared among a community of practice, and utilized to strengthen society's ability to sustainably conserve and use its invaluable coastal and marine ecosystems.

Note

1. Ecosystem resilience is the ability to resist shock or recover quickly from stress.

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