The global path of CO₂ emissions already surpasses the worst-case standard emissions scenarios of the IPCC. The current trend may result in a situation that exceeds the direst of anticipated consequences. Although there remain uncertainties, there is high confidence that impacts from climate change—even under significantly more modest emission scenarios—will affect the functioning and integrity of key ecosystems worldwide. These impacts will add to the stress already resulting from local anthropogenic effects; combined, they represent an unprecedented challenge to the global biosphere. While the impacts are being felt globally, some regions will be more acutely affected than others.

Relatively modest amounts of carbon dioxide emissions are generated in the subcontinent. Nevertheless, climate change is likely to have a substantial impact on Latin America and the Caribbean, which is characterized by a substantial—but intrinsically fragile—natural capital and a number of climate-sensitive ecoregions.

The Bank’s Latin America Region has been working on the assessment and implementation of adaptation measures to address the consequences of climate impacts since 1997 and has developed a large portfolio of adaptation measures. The program on adaptation has focused on regional climate hotspots (see Table, at right). Coastal and marine ecosystems are a key area of concern.

Climate Change Impacts on Coastal Ecosystems

The effects of increased atmospheric CO₂ concentrations—such as changes in ocean chemistry—will adversely affect the physical and biological characteristics of coastal systems, modifying their ecosystem structure and functioning. As a result, coastal nations face losses of marine biodiversity, fisheries, and shorelines. Coral reefs, which are among the most biodiverse ecosystems on Earth, are highly sensitive to increases in sea surface temperature. A 2°C increase, associated with CO₂ concentrations of 500 ppm, threat-
ens to destroy most coral reefs. Along with increasing temperatures, more acidic conditions in the ocean associated with dissolved CO₂ from Earth’s atmosphere threaten to transform living reefs into seaweed-dominated mounds of rubble.

Climate impacts will also affect wetlands, which provide many environmental services, including regulation of the hydrological regime; human settlement protection through flood control; protection of the coastal region; help in mitigating storm impacts; control of erosion; conservation and replenishing of coastal groundwater tables; reduction of pollutants; regulation and protection of water quality; retention of nutrients, sediments, and polluting agents; sustenance for many human communities settled along the coast; and habitats for waterfowl and wild life.

Coastal wetlands are already subject to land use changes, mangrove deforestation, pollution, and water diversion, which increase the ecosystem’s vulnerability to expected climate change impacts and exacerbate the impacts. Land use changes increase the vulnerability of these ecosystems and are expected to worsen the climate change impacts on wetlands along the coast. Low-lying coastal areas and associated swamps could be displaced by saltwater habitats, disrupting freshwater-based ecosystems as a result of sea level rise. Such changes may also result in the loss of important brackish water habitats. Migratory and resident birds and fish may lose important staging, feeding, and breeding grounds, which are difficult to replace under competing demands for scarce land. This deterioration of wetland habitat may result in impacts on commercially important fish species, seriously affecting the sustainability of fisheries.

As part of the adaptation portfolio and in combination with the development of opportunities for carbon sinks, the Latin America and Caribbean Region has a number of ongoing or planned activities to build resilience to future climate impacts based on protection of coastal ecosystems and their services. Some of these are presented below.

### Adaptation to Climate Impacts on the Wetlands of the Gulf of Mexico

The wetlands of the Gulf of Mexico have been identified by the National Institute of Ecology / Ministry of Environment and Natural Resources of Mexico as the most critical and threatened ecosystem affected by climate change in the country. The Gulf of Mexico is characterized by a very high exposure to extreme weather events, with populations that live in high-risk areas prone to flooding and other extreme weather events, and the

<table>
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<th>Climate hotspot</th>
<th>Direct effect</th>
<th>Immediacy</th>
<th>Irreversibility</th>
<th>Magnitude of physical impacts</th>
<th>Economic consequence</th>
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<tr>
<td>Coral biome in the Caribbean</td>
<td>Bleaching and mass mortality of corals</td>
<td>Now</td>
<td>Once temperatures pass the threshold for thermal tolerance, corals will be gone.</td>
<td>Total collapse of ecosystem and wide-ranging extinction of associated species.</td>
<td>Impacts on fisheries, tourism, increased vulnerability of coastal areas.</td>
</tr>
<tr>
<td>Mountain ecosystems in the Andes</td>
<td>Warming</td>
<td>Now</td>
<td>The thermal momentum in mountain habitats will result in significant increases in temperature, leading to major unidirectional changes in mountain ecology.</td>
<td>Disappearance of glaciers, drying-up of mountain wetlands, extinction of cold-climate endemic species.</td>
<td>Impacts on water and power supply, displacement of current agriculture.</td>
</tr>
<tr>
<td>Wetlands in the Gulf of Mexico</td>
<td>Subsidence and salinization; increased exposure to extreme weather</td>
<td>This century</td>
<td>Irreversible sea level rises will submerge coastal wetlands, affecting their ecology.</td>
<td>Disappearance of coastal wetlands, displacement and extinction of local and migratory species.</td>
<td>Impacts on coastal infrastructure, fisheries, and agriculture.</td>
</tr>
<tr>
<td>Amazon Basin</td>
<td>Forest dieback</td>
<td>This century</td>
<td>If rainfall decreases in the basin, biomass densities would also decrease.</td>
<td>Drastic change to the ecosystem, leading to potential savannah.</td>
<td>Impacts on global water circulation patterns, agriculture, water and power supply on a continental scale</td>
</tr>
</tbody>
</table>

presence of important economic sectors such as Mexico’s oil industry and tourism. Three Mexican national communications reports and other studies have documented ongoing changes in the wetlands of the Gulf of Mexico and have raised urgent concerns about their integrity. These wetlands perform very important environmental functions that are critical to economic activity over a wide area of the country.

Located in the lower reaches of the Gulf’s main water tributaries, the Gulf wetlands are considered the most productive ecosystem in Mexico. Changes in the distribution and characteristics of river flows may affect the biological functioning of the wetlands, impacting the economy of coastal areas.

To address these impacts, the government of Mexico is formulating, with assistance from the World Bank, a project to reduce the vulnerability to anticipated impacts of climate change (focusing on integrity and stability) on coastal wetlands and associated inland basins of the Gulf of Mexico. The project will support pilot adaptation measures in four wetlands: (1) Río Panuco Corredor Sistema Lagunar (Tamaulipas); (2) Laguna de Alvarado (Veracruz); (3) Carmen-Pajonal-Machona (Tabasco); and (4) Punta Allen (Quintana Roo), including the coastal coral reefs in the region. These were selected during the formulation phase of the project and respond to the magnitude of the impacts induced by climate change, the value of compromised economic and environmental services, the readiness of local institutional capacity, and the participation of the local community. In addition, the project seeks to identify national policies to address the impacts of climate change on water resources at the national level (global overlay). The total budget is estimated at $25.5 million, with a Bank-GEF contribution of $5 million.

Adaptation to Climate Impacts in Coastal Zones of the West Indies

Also of particular concern are the impacts on the coral biome in the Caribbean. Coral reefs support more than 25 percent of all marine species, making them the most biologically diverse of marine ecosystems and an equivalent, in terms of biomass productivity, to rainforests on land. Corals have been around for over 200 million years and have evolved over time to adjust to relatively stable environmental conditions in tropical seas, defined through a narrow range of temperatures, salinity, and pH. Because of their stable environment, most corals are also very sensitive to changes in environmental parameters. When stressed by rising temperatures, reef-building corals can lose their photosynthesizing symbionts—microscopic algae that live inside the soft coral tissue, converting the sun’s energy and CO₂ into food and giving the coral its color. Loss of these photosynthetic elements leads to coral bleaching and, eventually, death from starvation and disease. Corals also play very important roles for other species, providing feeding grounds and the 3-D structure essential for fish populations and a multitude of other plant and animal species.

Gradual and consistent increases in sea surface temperatures have yielded increasingly frequent bleaching events (1993, 1998, 2005), the latest of which caused wide-scale bleaching throughout the Caribbean Region. Under conditions anticipated by the Intergovernmental Panel on Climate Change, increased temperatures in the Caribbean are likely to lead to a collapse of the coral biome during this century.

In the wake of coral collapse, major impacts on fisheries, tourism, and coastal protection are anticipated, as well as severe loss of biodiversity and species extinction and impacts on ecosystem integrity. One-third of the more than 700 species of reef-building corals worldwide are already threatened with extinction. It is estimated that between 60 and 70 endemic species of corals in the Caribbean also are in danger; extinction risks are increasing due to more frequent bleaching events experienced in recent years and expected in the future due to climate change. The cost of adapting corals to anticipated environmental conditions in the Caribbean, as well as protecting and recovering affected
populations, is unassessed but likely to be very high.

With Bank assistance, the region is implementing a project to support efforts by Dominica, Saint Lucia, and St. Vincent and the Grenadines to implement specific, pilot adaptation measures addressing the impacts of climate change on their natural resource base, focused on biodiversity and land degradation along coastal and near-coastal areas. As part of the effort, work is planned for the assessment of alternatives to conserve and adapt the coral ecosystem in the region. The project has a budget of $5.5 million, with a Bank-GEF contribution of $2.1 million.

Restoration of the Nariva Wetland in Trinidad and Tobago

Coastal wetlands, in particular mangroves, also provide a coastal protection function. Mangroves have a natural buffering capacity to wind and storm surges, thus providing protection against extreme weather events. Wetlands have been shown to reduce the impact and intensity of wind in inland communities during hurricanes and tsunamis. The natural buffering capacity also provides a cushion against inland flooding. The protection and restoration of these coastal ecosystems can be seen as an adaptation measure to the likelihood of intensified storms in the Caribbean basin.

The Nariva RAMSAR wetland targeted by the proposed project has the most varied vegetation of all wetlands in Trinidad and Tobago, with distinct zones of swamp forest, palm swamp, herbaceous swamp, and mangrove woodlands of distinct global biodiversity value. It is especially important for large numbers of waterfowl, including migratory species, and is the major wetland in Trinidad that still sustains anacondas (Eunectes murinus), blue and golden macaws (Ara ararauna), and manatees (Trichechus manatus).

On the basis of these characteristics, the Trinidad and Tobago government has declared the highest level of protection available in the nation to Nariva, incorporating the wetlands in the “Nariva Environmental Sensitive Area” (Nariva ESA). This protected area covers 15,568 hectares of one of the most important natural habitats in Trinidad and Tobago. The wetlands, as a landform, cover approximately 7,000 ha. The remainder is mostly covered by upland forest, which surrounds the wetland and could be interpreted as a buffer/protection belt to the inland areas. Nariva ESA has a very rich mosaic of vegetation communities, including tropical rain forest, palm forest, mangroves, swamp forest, and swamps.

The Bank is supporting efforts to restore and conserve the Nariva wetlands through the recognition of the services it provides as a carbon sink and a biodiverse ecosystem. This will be done through actions designed to restore and conserve about 1,160 ha of its associated forest stands. The restoration of the wetlands will result in additional environmental benefits, including reduction of GHG emissions and the conservation of endemic species in the area.

Effective restoration and protection of Nariva will also provide for recovery of the protection and storm buffering character of the wetland. The project was approved with an estimated carbon sink and GHG mitigation asset valued at $2.1 million. Carbon finance will be used to credit the accumulated biomass resulting from the activities of the project, as well as the anticipated reduction in greenhouse gas emissions from the wetland once it restores its hydrological balance.

Looking forward, there is a need to consolidate and expand initiatives to protect these valuable coastal and marine ecosystems, particularly to combine traditional conservation efforts with adaptation to climate impact and carbon sink programs. The combination of these resources will increase the ability to respond to the immense challenges and provide a practical example of linkage between the biodiversity and climate change agendas in the region.

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