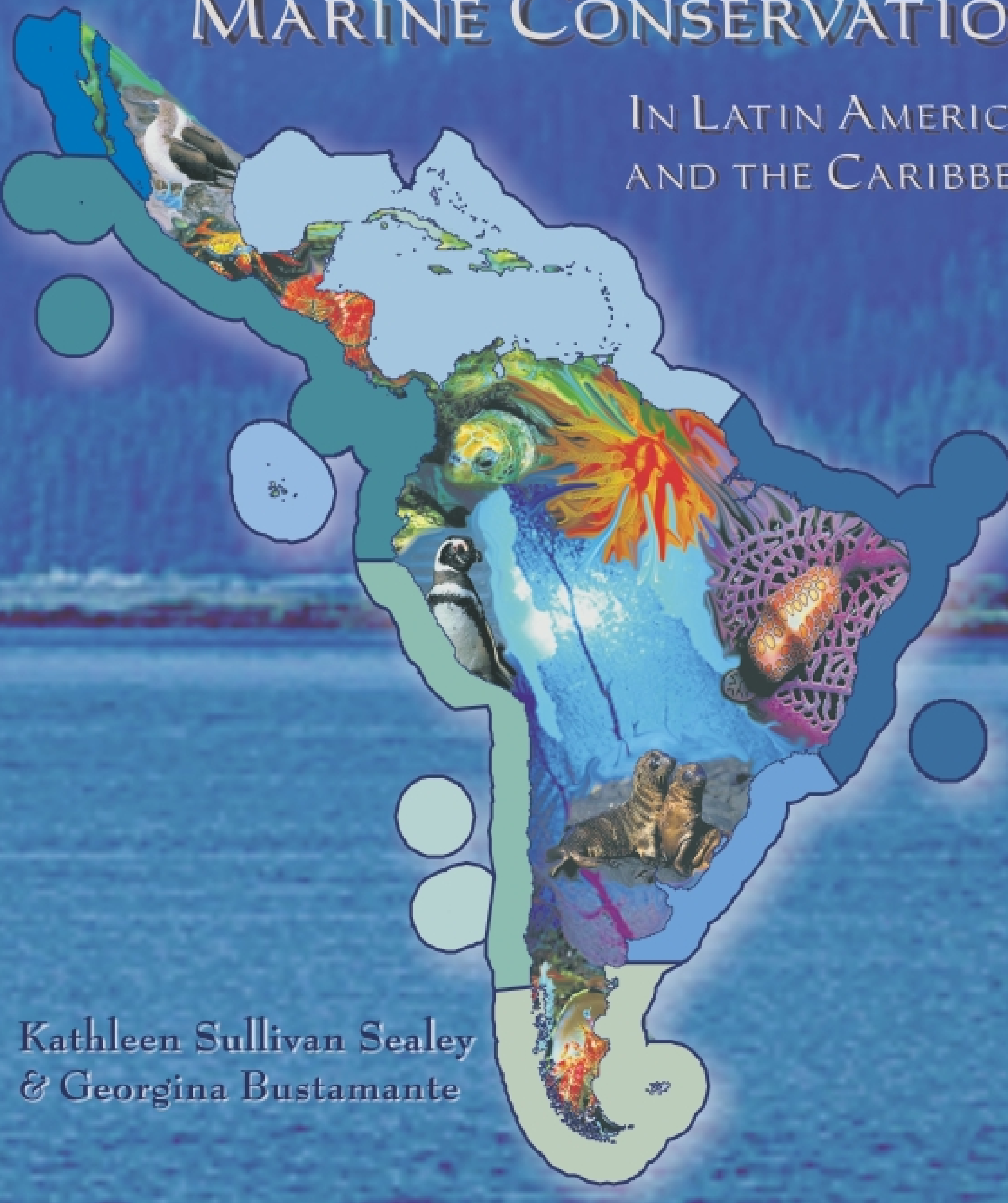
Setting Geographic Priorities for Marine Conservation in Latin America and the Caribbean



Kathleen Sullivan Sealey
& Georgina Bustamante

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By Kathleen Sullivan Sealey and Georgina Bustamante

With

Karl Aiken, Pedro M. Alcolado, Tim Austin, Joaquín Buitrago, Jaime R. Cantera, Juan C. Castilla, Segundo Coello, Omar Defeo, Vallierre Deleveaux, Juan M. Díaz, Domingo Flores, Héctor Guzmán, Ann Haynes-Sutton, Diego Lercari, Richard E. Matheson, Patricia T. Monteiro-Cunningham, José Orensanz, Melquíades Pinto Paiva, Arthur Potts, Enrique Pugibet, Gustavo Riestra, Juan C. Riveros Salcedo, George Sedberry, Luis Sierra, Guillermo Soberón, Carlos Valdés, Vance Vicente, Juan C. Villagrán, Mark Chiappone, John Kelly, Robb Wright, Thomas Hourigan, Carlos de Paco, Roger Sayre, John Tschirky, and Xiaojun Li

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The participants of the project contributed in many ways to develop the methodologies and results herein. However, the authors assume responsibility for any mistakes or omissions. The purpose of this work was to generate, for the first time, a scientifically sound analysis of the geographic priorities for conservation investments in the marine environment of the Latin America and Caribbean region. We examined the biological value and conservation status of the coastal areas, but we recognize the enormous importance of a changing social context in the effectiveness and impact of any conservation action. Collectively, we sincerely hope that this book serves to leverage a significantly larger support for the protection, responsible management, and restoration of the marine resources.

This book is the product of two women deeply gratified with their work, but also grateful to the support that they receive from their partners in life, Neil Sealey and Roger Dooley, both related to the marine science field and sensitive to conservation. Thanks to our men…

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Dr. Georgina Bustamante
and Dr. Kathleen Sullivan Sealey
Arlington, Virginia, and Miami, Florida
November 1999

Executive Summary

EARTH, THE BLUE PLANET. A full three-quarters of its area lies under water yet we continue to regard it in terms of landmass and territory. Throughout the globe, humans represent the greatest threat to the marine environment, degrading marine ecosystems, and reducing the capacity of estuaries and oceans to thrive.

As a result, approximately three-quarters of marine fisheries are in drastic decline due to fleet modernization, over-subsidization and ineffective management regimes. Mangroves, coastal wetlands and estuaries around the world are being cleared for croplands and urban development. Coral reef bleaching is a worldwide crisis that may be a result of increased water temperatures due to global warming. And, many marine species are now considered threatened or endangered due to overfishing, overhunting, habitat destruction and other factors.

Due to the transboundary nature of the marine realm, solutions to these problems cannot be implemented only at single sites. On the contrary, it is increasingly recognized that ecosystem-based approaches are needed to improve the management of water systems that suffer from the problems mentioned above. Yet, while it is widely believed that ecosystem-based approaches are essential for effective marine conservation, all such approaches must depend first on efforts to define and better understand marine ecosystems.

By classifying marine environments, developing methods for establishing geographic priorities and finally, identifying high-priority conservation areas, this report hopes to serve as an initial step in the direction of greater understanding of the marine realm in the LAC region. It is the third and final component of a larger effort undertaken by the Biodiversity Support Program (BSP), a USAID-funded consortium of World Wildlife Fund, The Nature Conservancy and World Resources Institute. The goal of this effort has been to identify high-priority conservation areas in Latin America and the Caribbean. The first priority-setting workshop took place in 1994 and focused on terrestrial ecoregions (*A regional analysis of geographic priorities for biodiversity conservation in Latin America and the Caribbean*, BSP et al., 1995). Participants at that workshop recognized the urgent need to adapt the priority-setting framework they used to aquatic freshwater and marine systems. Responding to this need, USAID provided BSP with funding to carry out priority-setting exercises for freshwater and

marine habitats. The results of the freshwater analysis, undertaken by World Wildlife Fund and Wetlands International, were published in 1998 (*Freshwater biodiversity of Latin America and the Caribbean: A conservation assessment*, Olson et al., 1998).

Methods

This study comprises two parts. The primary study (detailed in chapters I and II), was supported by BSP and USAID and consisted of the following steps:

1) delineating coastal biogeographic provinces
2) delineating coastal biogeographic regions (also called here as marine ecoregions)
3) ranking ecoregions within provinces.

Delineation of Coastal Biogeographic Provinces

To distinguish provinces a number of biological, physical, and geographic characteristics had to be considered, including the features of the continental shelf and ocean currents, the water temperature regime, and the occurrence of upwellings.

Nine provinces were thus delineated along the Atlantic and Pacific coasts of Latin America and the wider Caribbean, including south Florida, the Gulf of Mexico, and the Bahamas (see Figure 1 and Appendix A-2). The provinces and ecoregions are described in detail in Chapter 1.

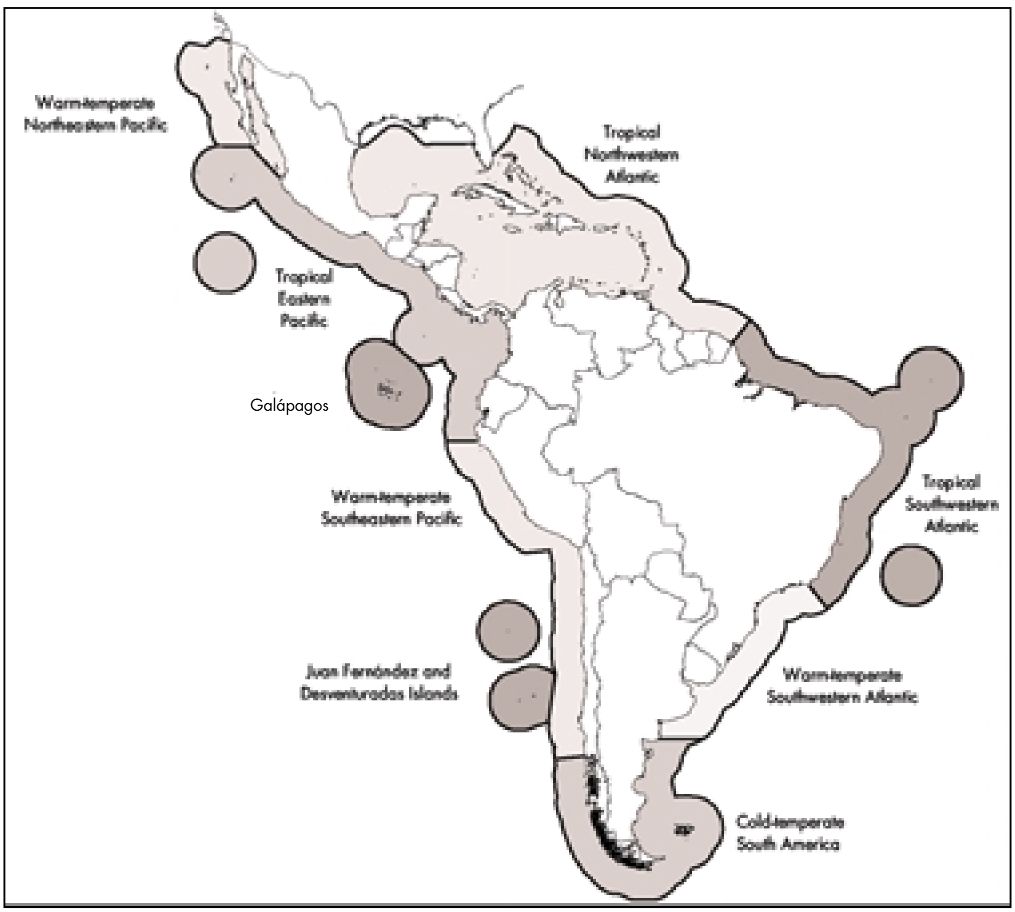


Figure 1 - Coastal Biogeographic Provinces of Latin America and the wider Caribbean

Figure 2 - Coastal Biogeographic Regions (or Marine Ecoregions)

Delineation of Marine Ecoregions

Each large province consists of smaller geographic units called Coastal Biogeographic Regions, or simply Marine Ecoregions. These were defined and delineated according to patterns of ocean circulation, coastal geomorphology, and distribution of major faunal populations (see Figure 2 and Appendix A-3).

Ranking Ecoregions Within Provinces

The study involved ranking ecoregions within each province according to biological value and conservation status. There is no basis for the comparison of ecoregions across provinces as these are very distinct from one another. For example, there is little basis for comparison between an ecoregion in the Warm-temperate Southeastern Pacific and one in the Tropical Northwestern Atlantic.

To establish priorities, four main tasks were carried out.

- Project Design: Indicators were selected as direct and indirect measures of biological value and conservation status. Reviews of the credibility of these parameters as measures of biodiversity, resource abundance, or changes in natural systems were performed.

- Information Compilation: Information specific to ecoregions was compiled from library research, scientists, local naturalists, and technical data sources.

- Expert Assessment: The collected information was evaluated and ecoregions were ranked for biological value and conservation status. The institutional capacity and political commitment to marine resource conservation of each country within the project area were examined, but not used in the ranking of ecoregions.

- Review and Ranking: A workshop was held in Miami from September 11 to 15, 1996. Regional experts and project personnel reviewed the compiled information and decided on which indicators should be used for ranking within each province. The ranking process and criteria were examined to determine the scientific validity of establishing geographic priorities. Indicators of biological value and conservation status were ranked as low (L), medium (M) and high (H), with assigned numerical values (1, 2, and 3 points respectively). Ranks for each indicator in each ecoregion were generated after examining the range of scores across all ecoregions within the province. When quantitative data of important indicators were not available, ranks were produced after a qualitative assessment based on the experts' best knowledge. Overall ranking for biological value/conservation status was obtained by a simple sum of all ranked values. Experts held that this method provided reasonable and scientifically supported results, therefore no attempt was made to use discriminated weighting or grouped indicators. A matrix created by cross-referencing biological value and conservation status made it possible to develop a list of priorities.

Results

No attempt was made to rank ecoregions within the Galápagos, and Juan Fernán-

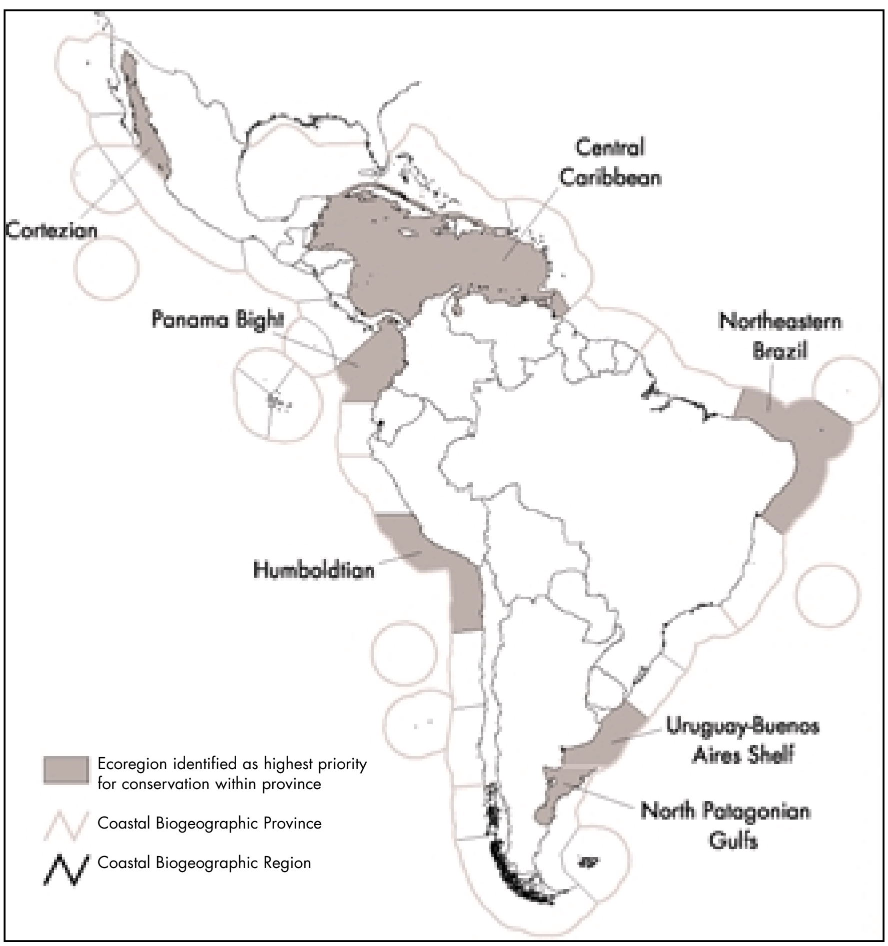


Figure 3 - Coastal Biogeographic Regions (or Marine Ecoregions) designated as highest priority for conservation within each Coastal Biogeographic Province

dez and Desventuradas provinces, due both to lack of information and the small size of the provinces. For the other seven provinces, the priority ecoregions are as shown (see Figure 3 and Appendix A-4).

- **Warm-temperate Northeastern Pacific province**: The Cortezian ecoregion. The ranking indicates the unusual setting of the Gulf of California and its vulnerability, as an enclosed sea, to over-exploitation and land-based sources of pollution.

- **Tropical Eastern Pacific province**: The Panama Bight ecoregion. This ecoregion includes unique coastal communities such as mangroves and coral reefs, several highly productive rivers and estuaries, breeding sites for marine mammals, and an abundance of commercially important fish and crustaceans.

- **Warm-temperate Southeastern Pacific province**: The Humboldtian ecoregion. This ecoregion includes abundant populations of fish, seabirds, and marine mammals. It also has numerous conservation problems, including coastal pollution and over-fishing. Marine pollution from fish processing plants is a real threat to both the Peruvian and Chilean portions of the ecoregion.

- **Cold-temperate South America province**: The North Patagonian Gulfs ecoregion. Numerous seabird colonies and abundant fishery resources give the ecoregion a high value for biodiversity and production. The high conservation status score is due mostly to threats such as over-harvesting of mollusk and crustacean populations, numerous ports and oil facilities, and high tourist visitation.

- **Warm-temperate Southwestern Atlantic province:** The Uruguay-Buenos Aires Shelf ecoregion. The Uruguay-Buenos Aires Shelf is a wide platform with high biological productivity, abundant populations of finfish, and numerous colonies of marine mammals and seabirds that feed upon those fish. However, pollution generated from industries and oil facilities, together with the exploitation of coastal mollusks, coastal development, and intensive tourism, have combined to assign this ecoregion the highest rank with regard to conservation concerns.

- **Tropical Southwestern Atlantic province:** The Northeastern Brazil ecoregion. This ecoregion has large numbers of nesting sites and nursery grounds for sea turtles, along with abundant fish and seabird populations. The presence of coral reefs also adds to the ecoregion's conservation value.

- **Tropical Northwestern Atlantic province**: The Central Caribbean ecoregion. The coastlines of this ecoregion are diverse, including large river deltas and estuaries, mangrove forests, complex bays and coastal lagoons, and upwelling areas. A series of coral atolls is located along the western extent of the ecoregion. The ecoregion also has high coastal population densities, a long history of human use of marine resources, and significant land-based sources of pollution associated with oil extraction, port development, and agriculture.

These high-priority ecoregions are discussed in more detail in Chapter 2.

Central Caribbean Marine Ecoregion Case Study

High-priority ecoregions are still generally too large to provide useful guidance to donors and policymakers about investing in specific areas. Consequently, the authors conducted a separate case study to delineate, assess and rank the "coastal systems" that comprise the Central Caribbean ecoregion of the Tropical Northwestern Atlantic province. This

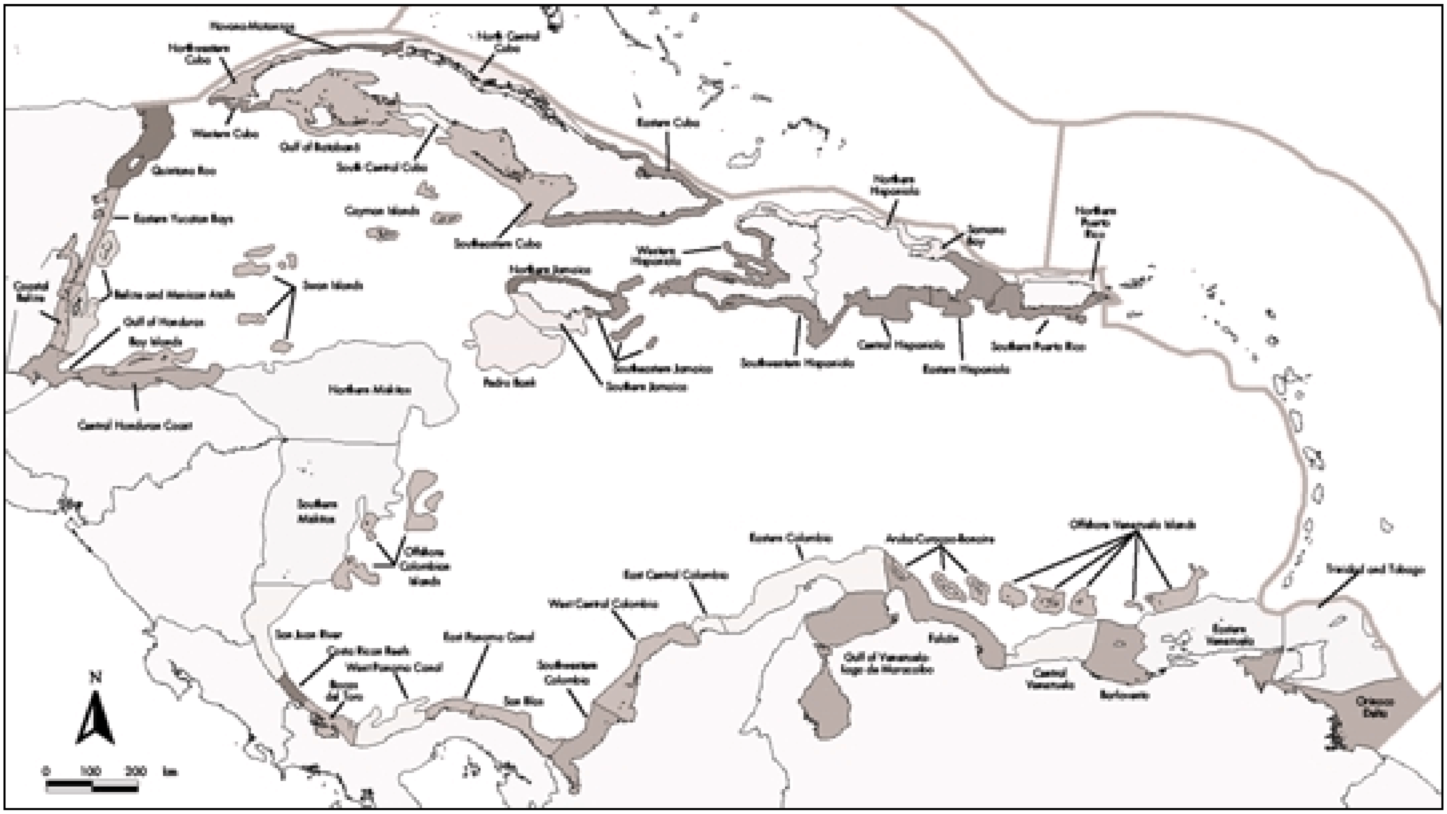


Figure 4 - Coastal Systems of the Central Caribbean Coastal Biogeographic Region (or Marine Ecoregion)

case study was supported by The Nature Conservancy and the University of Miami but due to lack of additional funds, it was not possible to apply this level of analysis to other ecoregions.

This case study (detailed in Chapter 3) created a framework to identify and rank smaller "Coastal Systems" (see Figures 4 and 5 and Appendices A-13 and A-14) based on conservation targets such as natural communities and their geographic location relative to ocean currents. This more detailed process is intended to identify specific sites for marine conservation action and coastal stewardship programs.

The process of setting priorities within ecoregions was carried out in three steps. First, a further classification delineated smaller segments of the coastal shelf. These units, called coastal systems, were defined in terms of coastal morphology, hydrology, geology, and dominant biological features, on a scale that was practical for the collection of information.

The Central Caribbean ecoregion was segmented into 51 coastal systems that extend from coastal wetlands (mangroves) outward to the 1,000-m depth contour (see Figure 4 and Appendices A-13 and A-14). Coastal systems varied in size from a few thousand square kilometers in the Samana Bay to more than 28,000 km^2 in the Orinoco River Delta. The coastal systems are described in Appendix B.

The 51 coastal systems can be grouped into seven types:

- reef-dominated
- seagrass-dominated
- mangrove-dominated
- mixed seagrass-mangrove-reef dominated
- rocky platform dominated
- beach/sand-bottom dominated
- upwelling dominated.

After this process of classification, the second step in the priority setting exercise was to use "scorecard" criteria to evaluate biological value and conservation status of the coastal systems. The process drew less on quantitative data (which did not exist for the scale of coastal systems), and more on expert opinion regarding the diversity and status of the smaller coastal systems. The objective was to identify and locate the "best" reef systems or mangrove forest systems.

The final portfolio of priority coastal systems targeted for conservation action should include the best (or least disturbed) examples of each type of coastal system with some geographic distribution in upstream to downstream positions in the ecoregion. The third step—a review of the feasibility of investing in a particular site—was added to select 25 of the 51 coastal systems as priority sites (see Figure 5 and Appendix A-14).

In each of these 25 coastal systems, conservation of the region's coastal biological diversity should be a critical priority. Some part of the coastal system needs to be in a marine protected area or marine reserve. The hydrological processes linking land and sea need to be intact and coastal habitats and shorelines need to be protected.

Unfortunately, there are many coastal systems of spectacular natural beauty and biological diversity that are already severely impacted by land-based sources of pollution, loss of coastal habitats, and over-harvesting. Based on this method of priority setting, these are not good candidate sites for conservation action.

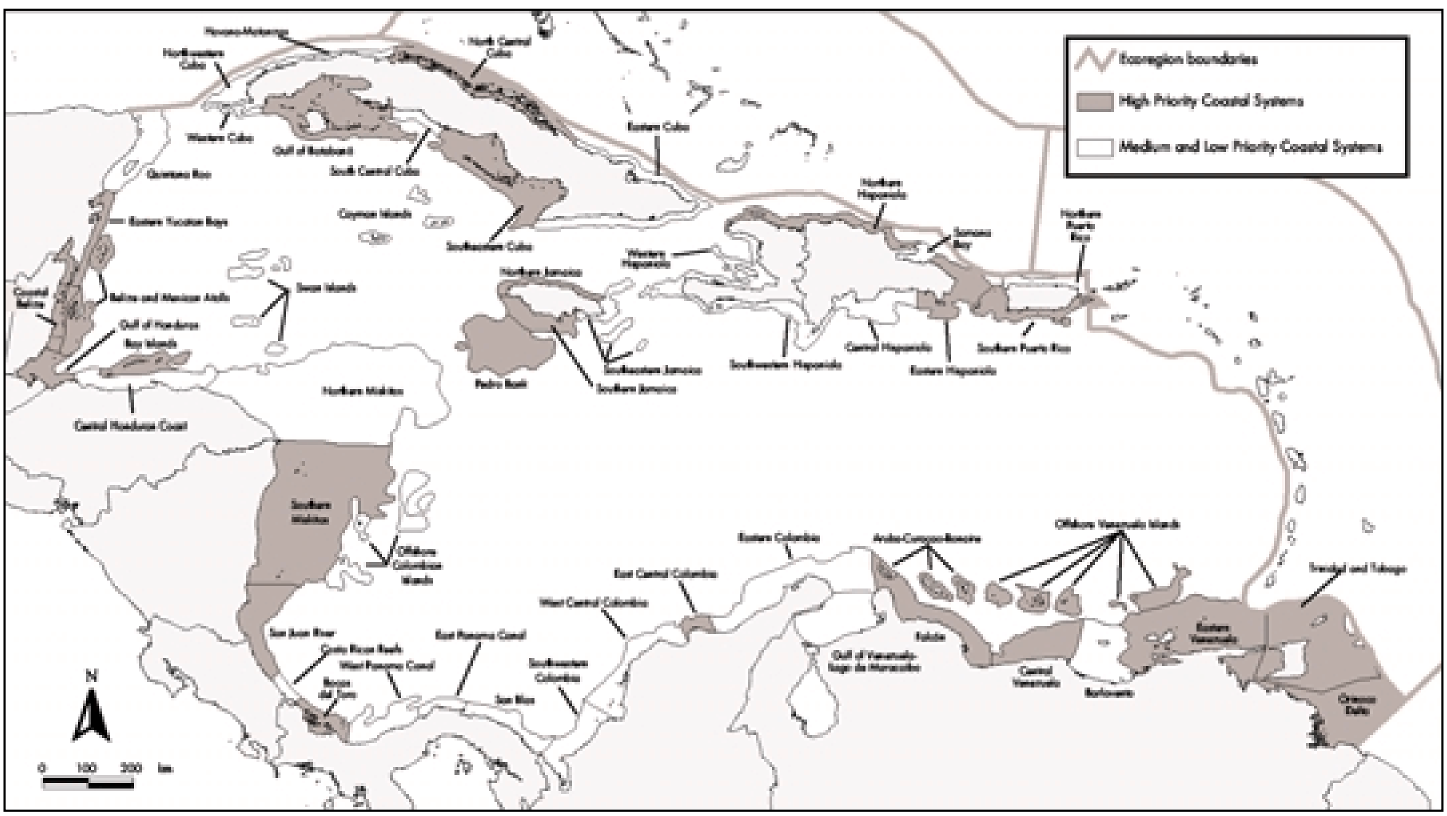


Figure 5 - High Priority Coastal Systems of the Central Caribbean Marine Ecoregion

Conclusions and Recommendations

Once geographic priorities have been established, practitioners and policy makers can develop strategies for marine conservation that aim to keep coastal environments intact and functioning. These may include

- The preservation of natural hydrological and hydrochemical linkages between rivers, streams, and terrestrial run-off to the coastal environment.
- The protection of natural links between land and sea (such as coastal wetlands) to help preserve coastal ecology and productivity.
- The selection and design of "cornerstone sites" (parks, protected areas, or sanctuaries) that are important for productivity, ecological processes, or natural community composition.
- The promotion of grass-roots programs in coastal communities to assume stewardship and protection of sustainable marine resource use.
- The development of methods needed to transfer information to local communities for coastal development, sustainable harvesting, and preservation of the quality of life associated with living at the ocean's edge.

The preservation or restoration of linkages, the selection of special conservation sites, and effective stewardship action all depend on sound scientific information. We hope that this report serves as an initial step in the provision of this information. Conservation donors can then use such analyses to strategically target their investments so that the greatest conservation good is achieved.

List of marine provinces and ecoregions in Latin America and the wider Caribbean

Warm-temperate Northeastern Pacific Province
Mexican Temperate Pacific
Magdalena Transition
Cortezian*
Tropical Eastern Pacific Province
Clipperton & Revillagigedo Islands
Mexican Tropical Pacific
Chiapas-Nicaragua
Cocos Islands
Panama Bight*
Nicoya
Guayaquil
Galápagos Islands Province
Northern Galápagos Islands
Eastern Galápagos Islands
Western Galápagos Islands
Warm-temperate Southeastern Pacific Province
Central Peru
Humboldtian*
Central Chile
Araucanian
Cold-temperate South America Province
Chiloense
Channels & Fjords of Southern Chile
Malvinas/Falklands
Patagonian Shelf
North Patagonian Gulfs*
Warm-temperate Southwestern Atlantic Province
Uruguay-Buenos Aires Shelf*
Río de la Plata
Rio Grande
Southeastern Brazil
Tropical Southwestern Atlantic Province
Eastern Brazil
Trindade and Martin Vaz Islands
Northeastern Brazil*
São Pedro and São Pablo Islands
Amazonian
Juan Fernández and Desventuradas Province
Juan Fernández & Desventuradas Islands
Tropical Northwestern Atlantic Province
Guianan
Lesser Antilles
Bahamian
Central Caribbean*
South Florida
Gulf of Mexico

* denotes high priority ecoregions

INTRODUCTION

The three quarters of the Earth's area covered by water is an environment of extraordinary complexity and extraordinary value. The combined benefits of coastal wetlands and mangroves, estuaries, and ocean ecosystems—both in terms of marine and other resources as well as ecological services—have not been quantified, but are surely worth trillions of dollars each year.

Tragically, human activities are threatening many marine species, undermining the ability of the oceans to provide food resources, degrading marine ecosystems, reducing the capacity of estuaries and oceans to provide ecological services, and possibly threatening the very physical and biological dynamics of ocean ecosystems.

For example:

- The global catch of finfish and shellfish provide close to 10% of the animal protein consumed by people annually, and probably much more in some parts of the developing world. Most marine food resources are taken from the continental shelf which covers only about 8% of the ocean. Yet, due to factors such as fleet modernization, oversubsidization, and ineffective management regimes, some three fourths of marine fisheries are in drastic decline.

- Estuaries, coastal wetlands, and mangrove forests provide a multitude of valuable services. They act to filter land-borne pollutants, provide shelter for the reproduction and growth of many finfish and shellfish, serve as vital habitats for many species of birds, and help reduce coastal erosion. All over the world, however, these ecosystems are being cleared for croplands, urban development, mariculture ponds, and garbage dumps.

- Coral reefs, one of the oldest and richest environments on earth, are threatened by human activities throughout the tropics. Bleaching of coral reefs, which occurs when corals expel their symbiotic zooxanthellae, is a worldwide crisis that may be a result of increased water temperatures stemming from global warming.

- Overfishing, overhunting, habitat destruction, pollution, and other factors have so reduced numerous marine species that many are now considered threatened or endangered. Whales and other marine mammals, giant clams, sea snakes, and many other species are threatened, endangered, or facing extermination. All seven species of sea turtles are endangered. Seabird populations have declined in many parts of the world, partly as a result of overfishing.

- Anthropogenic emissions of carbon dioxide have increased concentrations of CO_2 in the atmosphere. If the global climate is warming, as many scientists believe, the consequences are expected to include substantial sea-level rise and greater frequency of storms. Substantial sea-level rise could have a devastating effect on coastal environments and marine resources. Increased frequency of storms also has many important economic and social impacts. For example, many developing nations already have large populations living in low-lying coastal plains. There is already some evidence that storm damage is rising; the insurance industry incurred $14 billion in weather-related claims in the 1980s, which increased to almost $50 billion in the 1990-95 period.

The Conservation Imperative

The growth of human population and the environmental pressures imposed by economic development pose great challenges to the future health of marine ecosystems, as they do to most other components of the global environment.

On many fronts, however, we can see examples that provide some hope for the future. Global and regional agreements have been established regulating fishing rights, wetlands protection, water allocation procedures, reduction of transborder pollution, and contamination of marine waters. The intent of such agreements (including the UN Convention on the Law of the Sea and the 1995 Global Programme of Action for the Protection of the Marine Environment from Land-Based Activities) is for the global solution to be implemented in site-specific, regional cooperative efforts in areas such as the wider Caribbean.

It is also increasingly recognized that ecosystem-based approaches are needed for improving the management of transboundary water systems that suffer from overfishing, habitat loss, and biological diversity issues. Yet, while it is widely believed that ecosystem-based approaches are essential for effective marine conservation, all such approaches depend on efforts to define and better understand marine ecosystems.

Context and Objectives

The context for this report is a larger effort undertaken by the Biodiversity Support Program (BSP) to identify high-priority conservation areas in Latin America and the Caribbean.

BSP is a consortium of the World Wildlife Fund (WWF), The Nature Conservancy, and the World Resources Institute (WRI). It is funded by the U.S. Agency for International Development (USAID).

Establishing the location and scale of marine conservation initiatives is the final component of BSP's review of biodiversity protection in Latin America and the Caribbean (see Appendix A-1 for a map of the study area). This research project aimed at setting geographic priorities for marine conservation along the coastal areas of Latin America and the Caribbean by 1) delineating coastal biogeographic provinces; 2) delineating coastal biogeographic regions (also called marine ecoregions); and 3) ranking ecoregions within provinces.

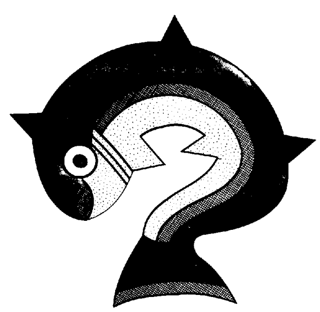
Similar priority-setting exercises assessing terrestrial, mangrove, and freshwater ecosystems are described briefly in Box 1. Taken together, these four studies can serve as a useful framework for investment decisions by donors concerned with biodiversity conservation.

In all four assessments, the principles underlying this geographic priority-setting approach have remained the same:

- Every nation's biodiversity is critical to its own sustainable development. Therefore, biodiversity conservation is important for every country. The recommendations from this exercise will help determine which areas should be priorities for biodiversity conservation at the regional level. The focus is on where to conserve, not on what, how, or why to conserve.

- Biodiversity includes not only diversity of species, but also diversity of biological communities and ecosystems. Since conservation areas cut across national boundaries, the priority-setting analysis should be based on biogeographic units, not country units.

- Biological importance alone is not a sufficient criterion for determining biodiversity conservation priorities at a regional level, since natural habitats have been degraded to varying extents and because national commitment to biodiversity conservation varies. Biodiversity conservation priorities should integrate consideration of an area's biological importance, conservation threat, and institutional feasibility and utility factors.



Box 1. Developing Priorities for Biodiversity Conservation in Latin America and the Caribbean: A Brief History

This report on developing priorities for conservation of marine ecosystems in Latin America and the Caribbean is the third and final report in a series assessing geographic priorities for biodiversity conservation in the region.

These reports were sponsored by the Biodiversity Support Program (BSP) and funded by the U.S. Agency for International Development (USAID). BSP is a consortium of The Nature Conservancy, World Wildlife Fund, and World Resources Institute. It is funded through a cooperative agreement between World Wildlife Fund (WWF), the lead consortium institution, and USAID. BSP is governed by an executive committee comprising representatives of the three consortium partners and managed by a professional staff unit within WWF.

In December 1993, USAID hosted a meeting to explore criteria for setting geographic priorities for biodiversity conservation of terrestrial systems. Participants agreed on four criteria: biological importance, conservation threat and opportunity, political and institutional feasibility, and human utility. Using these criteria, BSP started an effort to develop a priority-setting framework. Five leading conservation organizations were invited—the three consortium partners plus Conservation International and the Wildlife Conservation Society—to serve on a working group to develop a framework for conservation priorities and then apply the framework to Latin America and the Caribbean. The framework was developed early in 1994, data were collected that summer, and in September 1994 leading biodiversity experts held a workshop to review the data and apply the framework.

All of the analyses, with the exception of political/institutional feasibility, were based on biologically and ecologically distinct geographic units, not countries. These geographic units were called Regional Habitat Units (RHUs). Seven RHUs were recommended as highest priority for biodiversity conservation: the Atlantic Forest, Tropical Andes, Cerrado-Pantanal, Mexican Xerics, Patagonian Steppe, Puna, and Mexican Pine-Oak.

In the initial report, the analysis was limited to terrestrial priorities and excluded marine and freshwater ecoregions. In an effort to fill in these gaps, USAID provided BSP with funding to carry out similar priority-setting exercises for freshwater and marine habitats.

BSP commissioned WWF and Wetlands International to undertake a conservation assessment of freshwater ecoregions in LA/C. Regional priorities were assessed at a workshop in Santa Cruz, Bolivia, in the fall of 1995. Workshop participants identified 42 freshwater ecoregion complexes, within which 117 ecoregions were delineated. Integrating biological distinctiveness and conservation status provided a framework for priority-setting. The 10 ecoregions that were given a priority status of 1 (highest priority for conservation action) had biological distinctiveness that was considered globally outstanding and a threat ranking that was either endangered or vulnerable.

A complementary marine analysis of Latin America and the Caribbean, organized by The Nature Conservancy with funding from BSP, was conducted in September 1996, after 10 months of data compilation by project staff and in-country experts. The methodology and identification of preliminary priorities for coastal and marine habitats are available in a separate report (Bustamante and Sullivan Sealey, 1998) and are summarized in this volume.

With funding from The Nature Conservancy and the University of Miami, the same authors also produced a second volume that analyzed one ecoregion—the Central Caribbean—and delineated 51 smaller coastal systems within the ecoregion. The study then used a ranking process to identify 25 of the 51 systems as priority sites for biodiversity conservation (Sullivan Sealey and Bustamante, 1998).

Complementing these studies are two additional reports published by WWF and Wetlands International on mangrove and wetlands ecosystems respectively (Olson et al., 1996; Canevari et al., 1998).

Delineating Provinces and Ranking Ecoregions within Provinces Part 1

Chapter 1 Delineating Provinces and Ecoregions

THE EFFORT TO DISTINGUISH provinces involved consideration of a number of biological, physical, and geographic characteristics, including the features of the continental shelf, sea surface temperature, ocean currents, and the occurrence of upwellings.

The Continental Shelf

The vastness of surface oceans can be initially divided into coastal waters above the continental shelf and offshore waters of the deep ocean (see Figs. 1.1 and 1.2). Coastal oceans are characterized by broad versus narrow continental shelves. Open oceans are further subdivided into surface environments (to a depth of 1,000 m) and deep-sea environments. Each environment has unique abiotic features, such as circulation, temperature, salinity, nutrients, and oxygen content, that control the biogeographic distribution of marine life.

This study used the 200-mile Exclusive Economic Zone (EEZ) to delineate the outer confines of provinces. Although the EEZ has little ecological significance, it allows for a consistent representation of coastal features at the atlas scale. Furthermore, the EEZ delineates those areas in which national governments are responsible for the management of marine resources.

Sea Surface Temperature

Sea surface temperature is an important factor in the delineation of provinces (see Fig. 1.3). Temperatures can range from polar to temperate to tropical. The distribution of most marine organisms is generally limited by provinces. Animals whose distribution ranges across provinces are often rare, very large, and robust swimmers, or animals—such as whales and tuna—that can regulate their own temperature and are indifferent to sea temperature change.

Ocean Currents

All major ocean currents are driven by the wind which is itself driven by heat energy from the sun. Friction between the wind and ocean surface causes the upper layer of water to move while the influence of the Coriolis effect (the deflection of water bodies as a result of the earth's eastward rotation) deflects surface currents 45 degrees to the wind. The combined effect of wind-driven currents and the Coriolis effect produce large oceanic gyres, flowing clockwise in the northern hemisphere, counter-clockwise in the southern hemisphere (see Fig. 1.4). These gyres transport vast quantities of warm equatorial water to the higher latitudes while returning cold polar water to the equator, and therefore have an enormous impact on the climate and biology of the planet. The location of the major surface currents, particularly gyres, define the boundaries of provinces.

Upwellings

Upwelling occurs when the prevailing wind fields of a region blow parallel to the coast and the effect of the Coriolis force is such that the mass transport of surface water is away from shore. Usually occurring on the western coast of continents, upwelling also provides the replacement of warm, nutrient-poor surface water with cold, nutrient-rich water from the ocean depths. In a nutrient-limited system such as the ocean surface, this continual replenishment sustains a vast number of phytoplankton, an abundant food source for larger organisms. The bathymetry (the depth and relief of water basins) of the coastal region is also important, as upwellings are usually located in areas where the continental shelf is very narrow and deep oceanic water is close to shore. In the Americas, upwellings are found off the coasts of California, Peru, and Chile and are associated with the high biological productivity found in these regions. Smaller, seasonal upwellings are located off the coasts of Venezuela and Cabo Frio, Brazil.

Using these characteristics, nine provinces and their ecoregions were delineated along the Atlantic and Pacific coasts in Latin America and the wider Caribbean (see Appendix A-2). The provinces and ecoregions are described below.

Figure 1.1 Typical Pacific coast bathymetric profile illustrating a narrow coastal shelf

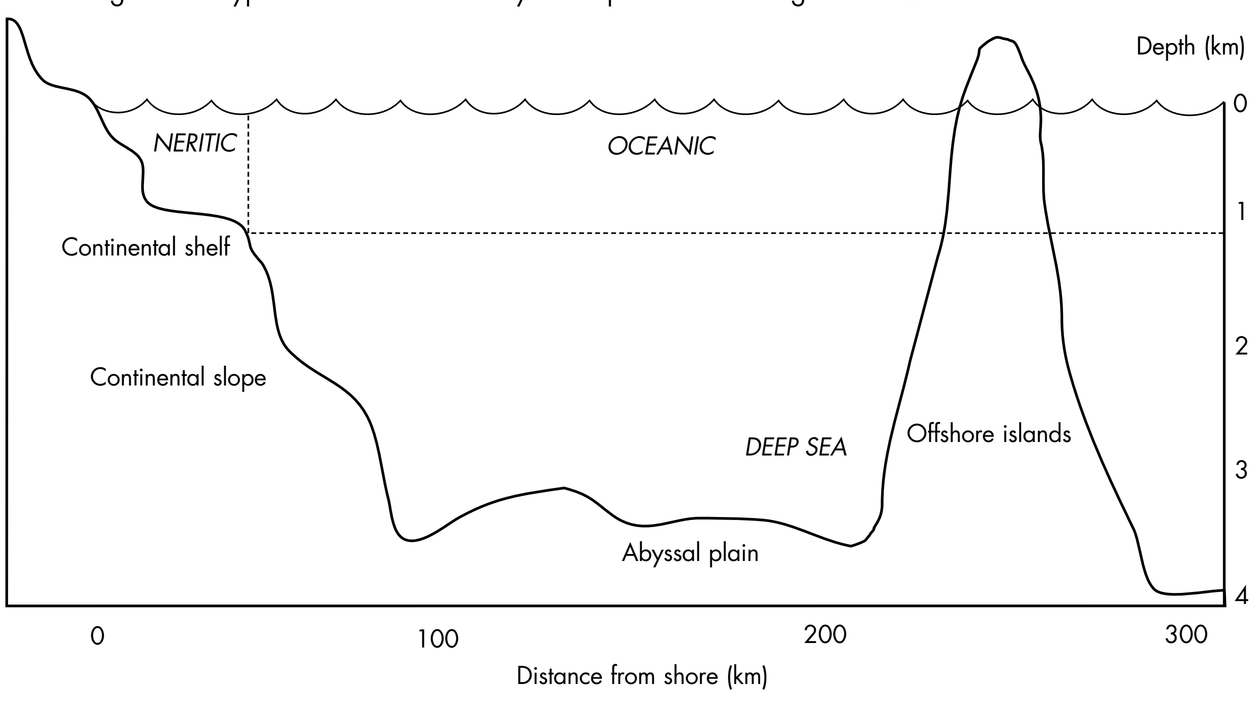
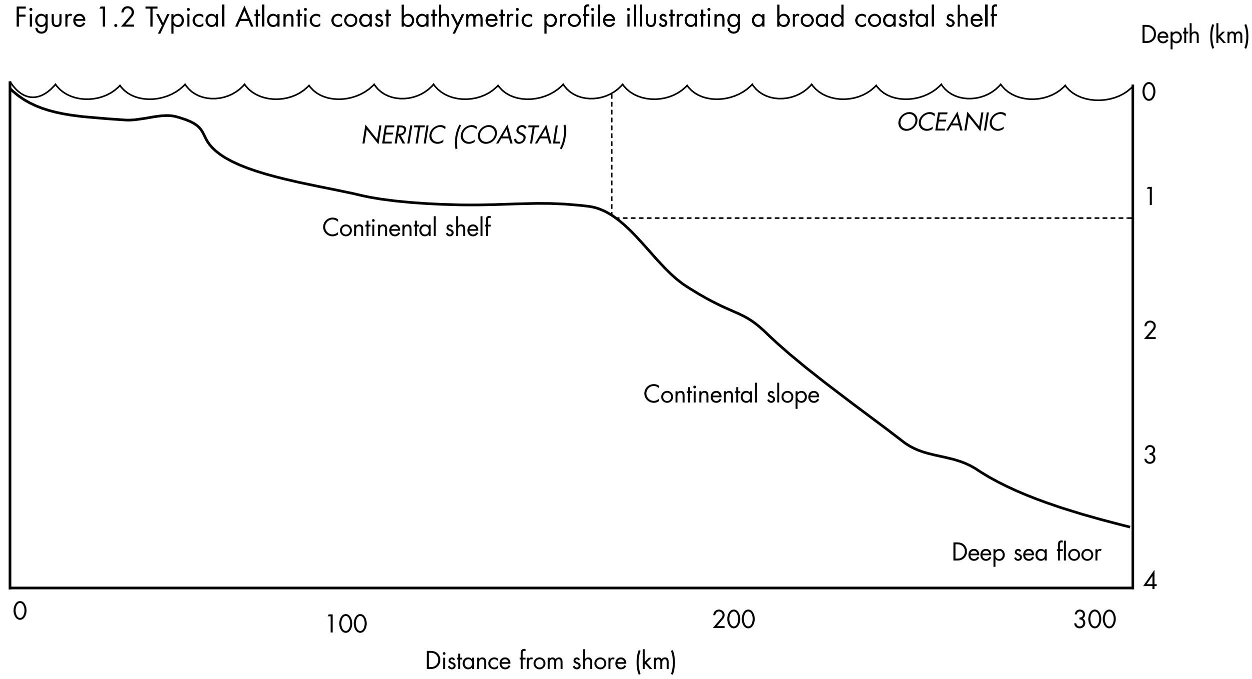


Figure 1.2 Typical Atlantic coast bathymetric profile illustrating a broad coastal shelf



Warm-temperate Northeastern Pacific Province

This province stretches from Point Concepción, California, to Cabo San Lucas, the southernmost tip of the Baja California Peninsula and Cabo Corrientes, Jalisco (Mexico), including the Gulf of California or Sea of Cortez (see Table 1.1 and Appendix A-5). The province includes coastal areas of the Mexican states of Baja California Norte, Baja California Sur, Sonora, Sinaloa, Nayarit, and the northern part of Jalisco to Cabo Corrientes. The province is influenced by extensions of the Equatorial Counter Current and to a lesser extent of the California Current. The abrupt curvature of the coast south of Point Concepción and the presence of the outer islands of the Southern California Bight tend to insulate South California and the coastal area southward from the cooling influence of the California Current. The province is defined as warm-temperate by sea surface temperatures, but some tropical communities occur in the shallower and protected lagoons of the Gulf of California. The climate regime in the province is arid to semi-arid. At about 30°N, an upwelling occurs, seasonally drawing deep water from the California Current to the surface. Waters flow across the mouth of the Sea of Cortez, partially isolating the gulf from the warmer waters flowing northward from the Tropical Eastern Pacific.

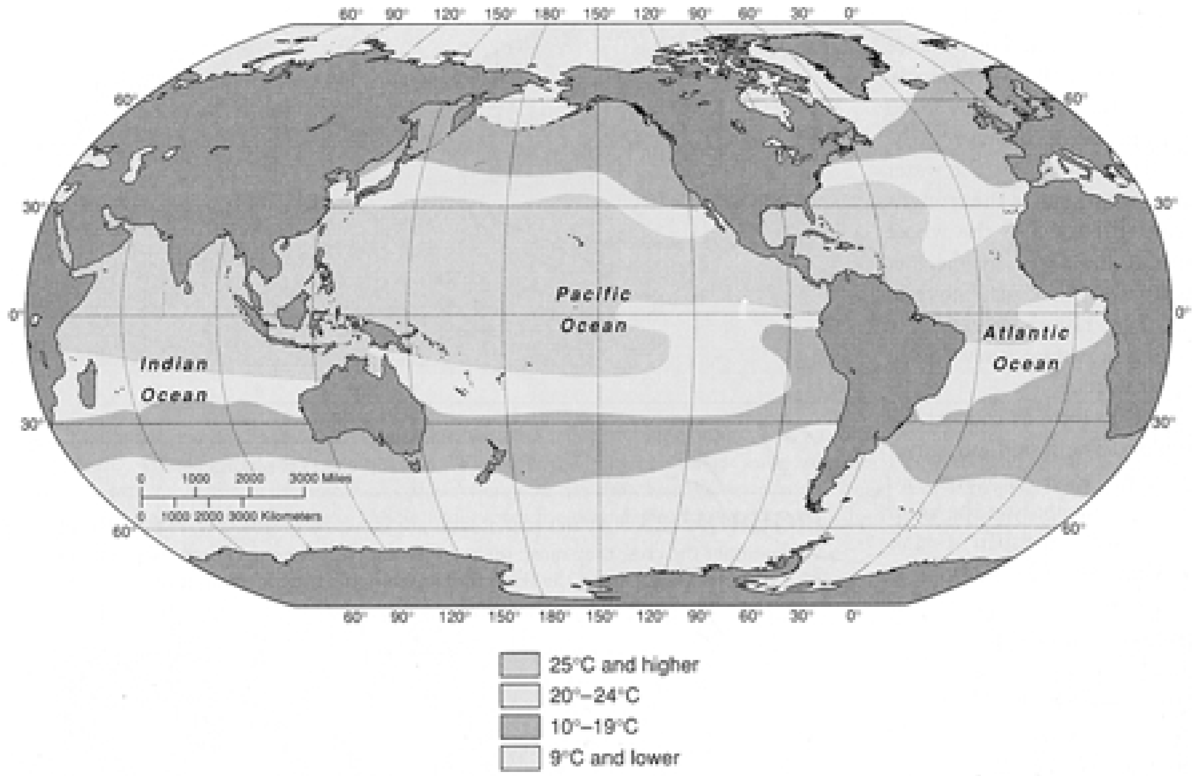
The northern limit of the distribution of coral reefs for the eastern Pacific lies in this province, at the Gulf of California. For many cetaceans, the province represents the southern or northern limits of their range.

This province was divided into three ecoregions: Mexican Temperate Pacific, Magdalena Transition, and Cortezian.

Mexican Temperate Pacific Ecoregion

This is the largest ecoregion within the province by area and includes the offshore Guadalupe Islands. Eighty-seven percent of this ecoregion is over 1,000 m deep and the continental shelf is relatively

Figure 1.3 Sea surface temperature (from Castro and Huber, 1997)



narrow. This ecoregion is characterized by the flow of the California Current along the coast and the onshore movement of the current flowing from the south during the winter. The latter influence makes water temperatures warmer along the Baja California coast than they are to the north. Climate is dry with 500 mm of annual rainfall. Thermal annual fluctuation is low, 3-4°C at the surface. At its upper part, local coastal upwellings occur seasonally drawing water of about 3-9°C from the California Current to the ecoregion. During such events, northern California fish, invertebrates, and algae reappear.

The ecoregion's coast is classified as a collision coast with a narrow continental shelf. It widens to 110 to 140 km at Sebastian Vizcaino Bay and north of Magdalena Bay. Coastal morphology varies from mountainous, cliffed coastline with pocket beaches to mangrove swamps along a coastal plain in the south. The shoreline at this latter area contains sandy pocket beaches and cliffs. Mangrove communities have their northernmost extension in the eastern Pacific at 28-29°N; however, mangroves are not abundant, even in coastal lagoons. The total coverage is only 314 km^2 along 109 km of coastline. This is attributable to the high relief physiography with cliffed and narrow shorelines, steeply inclined coastal plains, and reduced intertidal areas bordered by mountain ranges.

Marine fauna has a double origin: from the Monterreyan region to the north and from the Tropical Eastern Pacific to the south. Here, in contrast to the Cortezian fauna (see below), about two thirds of the non-endemics along the coast are eurythermic temperate species coming from north of Point Concepción; however, endemism is very high.

A small island (Guadalupe) and rocks (Alijos) are located off the coast of Baja California. The Guadalupe Island (35 km long and 6-10 km wide) is situated about 260 km off the coast of northern Baja California. Despite the isolation of the island, which is surrounded by deep waters, mollusk fauna share a high percentage of species with the mainland, south and north of the province. The rate of endemics was not enough to designate it as a separate province. The Alijos rocks barely project from the water and lie about 300 km off Cape Lazardo, Baja California.

Magdalena Transition Ecoregion

This ecoregion stretches from the northern limit of the Magdalena wetland system, south to Cabo San Lucas, along 1,321 km of coastline. Shelf area occupies about one fifth of the whole ecoregion.

This ecoregion is a transitional region between the Eastern Mexican and the Cortezian ecoregions. Here the Equatorial and California Currents mix to generate a transitional zone between the warm-temperate and tropical provinces. It has been defined as a sub-tropical transitional zone.

Magdalena Bay is enclosed by barrier islands. Coastal vegetation is composed of desert flora including sagebrush, with pockets of chaparral. About 1,450 km^2 of mangroves stretch along 811 km of coastline. There is an important mangrove community at Magdalena Bay.

Cortezian Ecoregion

The Gulf of California (also referred to as the Sea of Cortez) is a semi-enclosed sea of 181,000 km^2. The whole ecoregion extends to Cabo Corrientes in Jalisco and occupies 276,606 km^2. About a third of this area is covered by waters shallower than 200 m. The Gulf is separated from the adjacent regions by the Baja California Peninsula. The peninsula attained its present geomorphology at the beginning of the Pleistocene when

Figure 1.4 Surface circulation patterns of the world's oceans (from Castro and Huber, 1997)

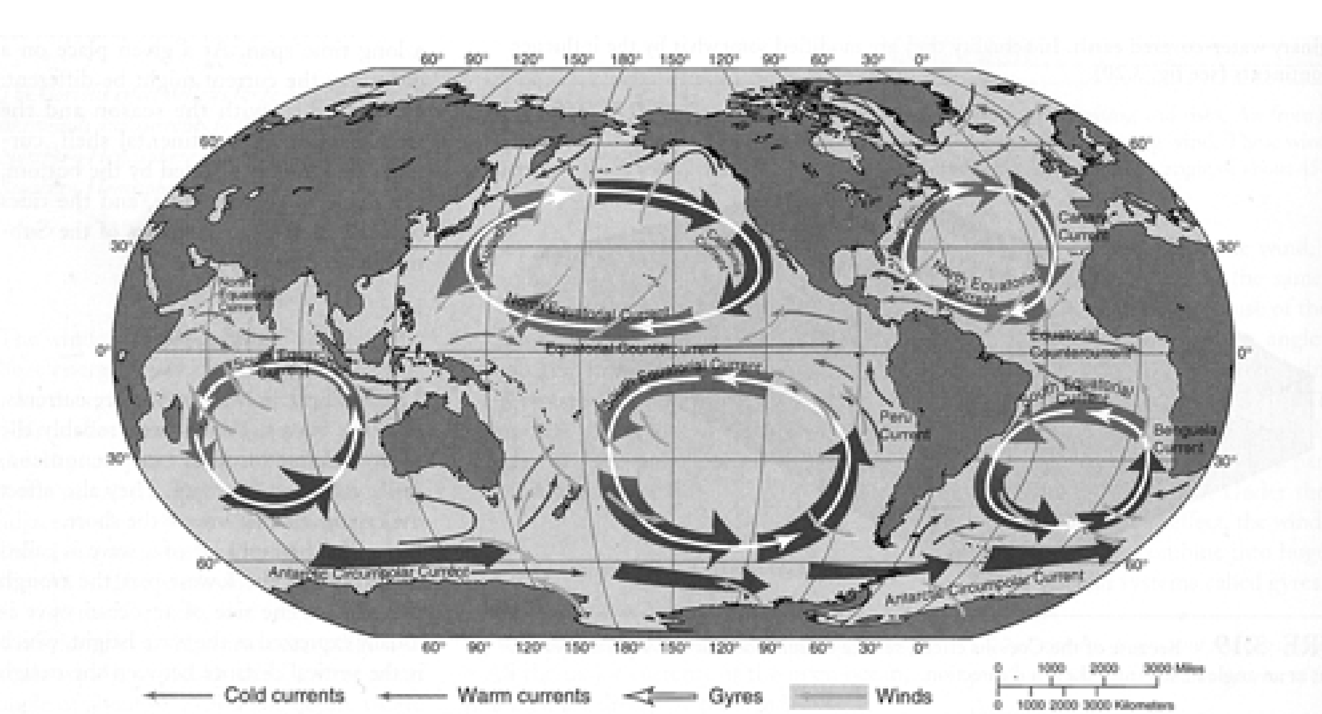


Table 1.1 Geographic indicators of Provinces and Ecoregions

Province / Ecoregion	Area of Ecoregion (km²) and % of Province		Coastline Length (km) and % of Province		Area of Mangroves (km²) and % of Province		Mangrove Coastline Length (km) and % of Province		Area of Bathymetry (km²) and % within Ecoregion: 0 - 200m		200-1,000m		>1,000m	
Warm-temperate Northeastern Pacific														
Mexican Temperate Pacific	527,828	55%	2,063	22%	314.9	4%	109	4%	47,601	9%	21,067	4%	459,160	- 87%
Magdalena Transition	158,974	17%	1,321	14%	1,451.0	19%	811	33%	14,241	9%	19,421	12%	125,313	79%
Cortezian	276,621	29%	6,211	65%	5,820.6	77%	1,515	62%	93,873	34%	66,485	24%	116,248	42%
Tropical Eastern Pacific														
Clipperton & Revillagigedo Islands	1,035,466	29%	118	1%		0%	0	0%	314	<1%	502	<1%	1,034,650	100%
Mexican Tropical Pacific	767,409	18%	1,412	11%	1,510	6%	322	4%	12,144	2%	16,831	3%	738,433	95%
Chiapas-Nicaragua	392,204	12%	2,638	20%	7,306	31%	1,871	26%	84,893	22%	29,256	7%	278,055	71%
Cocos Islands	298,829	9%	26	<1%	a		5-7[b]	7-20%	43	<1%	2,487	1%	296,299	99%
Panama Bight	508,357	15%	4,227	32%	8,719	37%	2,441	34%	54,996	11%	27,150	5%	426,211	84%
Nicoya	330,336	10%	2,756	21%	2,100	9%	1,513	21%	26,242	8%	12,842	4%	291,252	88%
Guayaquil	263,423	8%	2,087	16%	3,727	16%	1,099	15%	31,035	12%	8,441	3%	223,947	85%
Galápagos Islands														
Northern Galápagos Islands	224,673	26%	15	1%	0	0%	0	0%	30	<1%	698	<1%	223,945	100%
Eastern Galápagos Islands	411,657	47%	1,001	70%	0	0%	0	0%	7,157	2%	24,910	6%	379,590	92%
Western Galápagos Islands	240,711	27%	410	29%	0	0%	0	0%	1,932	1%	1,388	1%	237,391	99%
Warm-temperate Southeastern Pacific														
Central Peru	328,220	19%	1,164	19%	0	0%	0	0%	65,686	20%	20,242	6%	242,292	74%
Humboldtian	668,339	39%	2,308	37%	0	0%	0	0%	33,249	5%	30,587	5%	604,503	90%
Central Chile	344,625	20%	1,277	20%	0	0%	0	0%	7,212	2%	11,150	3%	326,263	95%
Araucanian	375,598	22%	1,486	24%	0	0%	0	0%	31,888	8%	20,129	5%	323,581	86%
Cold-temperate South America														
Chiloense	277,646	12%	10,705	19%	0	0%	0	0%	56,860	20%	11,687	5%	209,099	75%
Channels & Fjords of Southern Chile	849,252	38%	39,126	68%	0	0%	0	0%	124,935	15%	30,375	4%	693,941	81%
Malvinas/Falklands	507,118	23%	4,375	8%	0	0%	0	0%	150,930	30%	154,323	30%	201,865	40%
Patagonian Shelf	401,724	18%	1,361	2%	0	0%	0	0%	360,424	90%	31,486	8%	9,814	2%
North Patagonian Gulfs	198,809	9%	1,898	3%	0	0%	0	0%	198,809	100%				
Warm-temperate Southwestern Atlantic														
Uruguay-Buenos Aires Shelf	381,123	36%	1,740	21%	0	0%	0	0%	237,064	62%	26,792	7%	117,267	31%
Río de la Plata	29,499	3%	1,337	17%	0	0%	0	0%	29,499	100%				
Rio Grande	276,629	26%	1,897	23%	0	0%	0	0%	104,237	38%	21,104	8%	151,288	54%
Southeastern Brazil	378,224	35%	3,180	39%	2,923	100%	755	100%	143,631	38%	36,865	10%	197,728	52%
Tropical Southwestern Atlantic														
Eastern Brazil	497,583	17%	2,050	14%	3,215	10%	504	7%	99,667	20%	21,678	4%	376,238	76%
Trindade and Martin Vaz Islands	437,177	15%	8	<1%	0	0%	0	0%	21	<1%	64	<1%	437,114	100%
Northeastern Brazil	1,043,712	35%	2,106	15%	3,940	13%	355	5%	74,082	7%	26,531	3%	943,100	90%
São Pedro and São Pablo Islands	465,415	15%	12	<1%	0	0%	0	0%	7	<1%	23	<1%	465,361	100%
Amazonian	556,062	18%	10,252	71%	23,661	77%	6301	88%	287,516	52%	23,678	4%	244,869	44%
Juan Fernández and Desventuradas														
Juan Fernández & Desventuradas Islands	968,991	100%	116	100%	0	0%	0	0%	445	<1%	2,109	<1%	966,436	100%

a: Present but not quantified; b: Héctor Guzmán, personal communication

Table 1.1 Geographic indicators of Provinces and Ecoregions *(continued)*

Province / Ecoregion	Area of Ecoregion (km²) and % of Province		Coastline Length (km) and % of Province		Area of Mangroves (km²) and % of Province		Mangrove Coastline Length (km) and % of Province		Area of Bathymetry (km²) and % within Ecoregion					
									0 - 200m		200-1,000m		>1,000m	
Tropical Northwestern Atlantic														
Guianan	384,566	7%	1,814	4%	7,067	11%	969	4%	147,820	38%	28,936	8%	207,809	54%
Lesser Antilles	655,092	12%	2,508	6%	314	<1%	369	2%	28,587	4%	52,116	8%	574,389	88%
Bahamian	855,017	14%	7,225	16%	6,299	9%	3,045	14%	123,274	15%	102,236	12%	629,508	73%
Central Caribbean	2,654,945	46%	26,969	59%	38,913	59%	14,940	68%	422,470	16%	295,549	11%	1,936,926	73%
South Florida	27,195	<1%	1,238	3%	1,661	3%	711	3%	22,073	78%	5,123	22%		
Gulf of Mexico	1,186,745	21%	5,616	12%	12,170	18%	1,788	8%	336,407	29%	118,733	10%	731,603	61%

tectonic movements spread the land mass to the west, creating the Baja California Peninsula and the unique gulf. Waters inside the gulf are distinguished from those of the Pacific side due to the high salinity of the upper layer. This higher salinity (34.9-35.9‰, in comparison to 34.6‰ outside the gulf) is the result of the mixing of waters produced by the intense evaporation in the upper gulf and the subsurface waters of the Eastern Tropical Pacific. The funnel shape and the gradual slope of the bottom in the northern part of the gulf create large intertidal areas (up to 5 km wide), and very high tides (up to 9 m), among the largest in the world. A nearshore current system prevails in the gulf as a result of the combination of its shape and tidal regime. In the upper part of the gulf, surface temperatures range between 14°C in February, to 30°C in August, while in the southern part, it only fluctuates from 20 to 30°C. These physical features strongly influence the biotic composition of the region. The upper (shallower than 200 m) and lower parts of the gulf are separated by Midriff Islands. The upper part, the Grandes Islas area, has five deep basins and strong tidal currents that dominate the water circulation. This is the most productive area of the Gulf. The central portion, down to La Paz, has intermediate characteristics, and the greatest depths as evidenced in the Guaymas Basin: 2,000 m deep and 220 km long. Hydrothermal vents have been found recently in this basin. The southern portion, from La Paz to the gulf mouth, is oceanic influenced, but also has basins up to 3,700 m in depth. The deepest seafloor (about 6,400 m) is located in this area near the international border.

Coastal morphology is a mixture of recent volcanic activity along the Baja California coast. On the eastern side, the coast varies from mainly alluvial along the coast of Sinaloa to alluvial with rocky and metamorphic volcanic deposits on the coasts of Sonora. The upper Gulf area includes the Colorado River delta and the Salado Lake. Rocky shores are abundant at the central and lower part. Hundreds of kilometers of sandy beaches, interrupted by rocky headlands are found along the mainland. Both coastlines have numerous embayments bordered by mangroves and salt marshes. Estuaries in the south are fed by rivers, while those in the north are considered “negative” or “esteros” (hypersaline).

The endemic marine fauna of the gulf is derived from the Eastern Tropical Pacific to the south. During the Pleistocene, apparently only tropical organisms had open access to the gulf. The temperature barrier imposed by the cooler California Current flowing outside is the principal reason for the development of a highly endemic fauna and flora. Almost all the non-endemics may be classified as eurythermic tropical species. The small group of species that are also found in the Mexican Eastern Pacific region is mostly distributed in the upper part of the gulf.

Several cetaceans live in the gulf. The porpoise *Phocoena sinus* is endemic in the northern gulf. The gray whale has wintering, breeding, and calving grounds in the gulf. Sea turtles also are present.

Tropical Eastern Pacific Province

The Tropical Eastern Pacific is the second largest province in the study area, spanning the Pacific coasts of southern Mexico and Central America to northern South America. The province area encompasses 3,372,702 km^2 (see Table 1.1 and Appendix A-6.) and is tropical with a wide range of sea surface temperatures. The province supports tropical communities such as coral reefs with maximum monthly mean surface temperatures of 33°C, but sea surface temperatures can drop to 15°C with coastal upwelling. This province is defined by the influence of tropical waters flowing in the North Equatorial Current, the Equatorial Counter-Current, and the South Equatorial Current. These systems flow west from both the northern and southern oceanic gyres as well as exhibit complex topography with the intersections of the Cocos Plate, the Pacific Plate, and the Nazca Plate. Throughout the entire province, the continental shelf is very narrow, the EEZ area is over 95% deep water, with depths over 1,000 m. The province includes two groups of oceanic islands, and five continental regions stretching from Mexico to Peru. Mangrove communities occupy a significant portion of the shoreline along the coasts of Central and South America. The Gulf of Panama area is one of the most complex in terms of its oceanography, topography, and biology.

This province includes seven ecoregions.

Clipperton and Revillagigedo Islands Ecoregion

This ecoregion consists of the isolated island atoll of Clipperton and the small island group to the north, the Revillagigedo Islands. These islands are isolated and are often described as a stepping stone in the migration of coastal marine species from the western Pacific to the eastern Pacific. They are 1,100 km from the coast of Mexico. Information on the species composition of corals suggests that the islands are more similar to each other than to reefs along the continent. The islands are influenced by the Northern Equatorial Current that moves tropical water from west to east. The shelf area occupies less than 1% of the ecoregion.

Mexican Tropical Pacific Ecoregion

This ecoregion includes the Mexican states of Jalisco (south of Cabo Corrientes), Colima, Michoacán, Guerrero, and a portion of Oaxaca north of Tehuantepec Isthmus. The mountains of Sierra Madre del Sur are located along the coast, except for the lowlands at the Balsas river basin. Offshore, the continental shelf is quite narrow, falling precipitously into the Middle America Trench. Coastal oceanography is influenced by the North Equatorial Current. The area has a relatively dry climate with a coastline broken by 16 coastal lagoon systems stretching along a narrow coastal plain. Mangrove shores occupy about 28% of the whole coastline.

Chiapas-Nicaragua Ecoregion

This ecoregion stretches along 2,638 km of coastline and includes EEZ areas of southern Mexico, Guatemala, El Salvador, Nicaragua, and a small part of Costa Rica. In this ecoregion, the continental shelf widens, occupying 29% of the area. A coastal plain includes seven lagoons, most of them along the Mexican portion, in Oaxaca and Chiapas states. There are numerous cliffs along the coast of El

Salvador, the Gulf of Fonseca, and Nicaragua. Mangroves are extensive and well developed and cover most of the coastline from the northern boundary of the ecoregion to south of the Gulf of Fonseca in Nicaragua. This gulf is one of the most productive coastal systems of the ecoregion. However, mangrove forests, which constitute the major habitat for coastal fauna and fisheries, have been degraded by shrimp-pond construction in many areas. Upwelling of colder nutrient-rich waters occurs off Papagayo Gulf, north of the Nicoya Peninsula, originated by Atlantic winds that blow seasonally across the mountains moving surface water offshore. Tropical cyclones originate in the Gulf of Tehuantepec area and either move directly westward or follow a northwest course parallel to the coastline.

Nicoya Ecoregion

This ecoregion is defined by the presence of the Gulf of Nicoya in Costa Rica and the several bays and gulfs situated southeast to the Azuero Peninsula. The ecoregion extends from the Gulf of Papagayo, Costa Rica (at about 11°30' N) to the Azuero Peninsula, Panama (at about 80°30'W), along 2,756 km of coastline, covering an area of 330,360 km^2. It includes most of the Costa Rican Pacific area and the region offshore of the western half of the Panama coast. One fifth of the coastline is occupied by mangroves. Mangrove forests are extensive along rivers and estuaries in Costa Rica. The continental shelf is relatively wide, and includes numerous gulfs, bays, and coves. A group of eight islands are found in the Gulf of Nicoya, four of which are biological reserves. The North Equatorial Counter Current penetrates the ecoregion and splits north and south off the coast of Costa Rica. Despite the discontinuous occurrence and limited development due to upwellings and river drainage, coral formations have been described off Costa Rica and Panama. There are over 40 coral formations off Costa Rica, and the reef communities are richer in the southern portion, although they are generally small and shallow with few coral species. Despite the huge distance between the Central Pacific and the Eastern Pacific, reef faunas are essentially similar. The main coral areas of the Pacific Central America are found off Panama south of Azuero Peninsula and Coiba Island.

Panama Bight Ecoregion

This ecoregion encompasses 508,357 km^2 and stretches along 4,227 km of coastline (from Azuero Peninsula, at about 80°30'W, to Caraquez Bay, Ecuador) and includes three countries: Panama, Colombia, and the northern portion of Ecuador. The Gulf of Panama and the Pacific coast of Colombia form a bight of significant value. This ecoregion contains the largest mangrove coverage of the whole province (37%). The middle part of the Gulf of Panama ranges from 50 to 100 m in depth. Most of the coast is flat with several river mouths, swamps, and mangroves. Extensive flats are found west, extending to the Panama Canal. Cliff-dominated coasts, with occasional fjords and gorges, are the predominant coastal morphology from the Panama border to Cabo Corrientes, Colombia. From this point to the Ecuador border, large mangrove forests and river deltas are present. River discharge affects reef development along the Colombia coasts. It is important to note that every September, young whales (*Megaptera novaeangliae*) visit the area off Tumaco, Colombia. The most important reef formations of the Pacific Colombia are located at the Gorgona and Malpelo islands. Coral reefs are also present along mainland Ecuador. The deltaic-estuarine system of Mataja-La Tola in northern Ecuador has the most developed mangrove forests of the country. Despite the exploitation of mangroves, this area is considered one of the most conserved coastal areas of Ecuador.

Guayaquil Ecoregion

The Guayaquil ecoregion extends from Caraquez Bay by the equator to Península Illescas, Peru (about 6°S). The ecoregion comprises 263,411 km^2 of area, and stretches along 2,087 km of coastline, half of which is occupied by mangrove forests. The Gulf of Guayaquil is the main feature of this ecoregion. The southernmost extent of the influence of the tropical waters flowing southward, as well as the southern limit of mangroves in continental coasts, is located in northern Peru. Local currents merge with the northward flowing Humboldt Current and deflect westward to the Galápagos Islands.

In Caraquez Bay, most of the mangrove forests along the estuary have been lost due to shrimp-culture facilities. This area, together with the Gulf of Guayaquil, supports abundant shorebird populations. An upwelling area and important pelagic fisheries (mostly sardines and squid) occur off Machalilla (Ecuador). These populations are the main food source for pilot whales (*Globicephala macrorhynchus*). Marine turtles are also abundant in this area, as are seabirds. Sea lions (*Zalophus californianus*) and several cetacean species are sighted in and around La Plata island.

Terrestrial runoff, coastal morphology, oceanic productivity, and habitat diversity make the Gulf of Guayaquil the most important coastal area of the ecoregion. The gulf supports an intricate community by providing habitat for abundant populations of fish, birds, reptiles, invertebrates, and many other ecologically and commercially significant groups. Pond construction, mangrove exploitation, and pollutant discharge in the Guaymas river have severely degraded this highly productive environment.

Cocos Islands Ecoregion

The Cocos Islands comprise only 5,000 ha and are situated about 500 km southwest of Costa Rica. They are of volcanic origin and rise from the Cocos Plate. Strong westward Equatorial Currents wash the islands. Coral formations are found in this ecoregion.

Galápagos Islands Province

This coastal province has an EEZ area of 864,646 km^2. Despite the small size (only 4.6% of the total study area), the Galápagos Archipelago is one of the most charismatic island groups in the world. Unique features make this a special area for terrestrial and marine conservation. The province can be subdivided into three ecoregions (see Table 1.1 and Appendix A-6). This province is unusual in that it falls entirely under one national jurisdiction, that of Ecuador.

The archipelago is situated at the equator, between longitudes of 86°W and 93°W. The Galápagos include 13 major islands and numerous islets and rocks, situated at about 950 km west of South America. The islands are volcanic in origin and are located at the crossing of several ocean currents, warm and cold that flow from east and west. This peculiarity creates a range of marine habitats.

The South Equatorial Current flows westward and meets the Cromwell Current flowing eastward, creating frontal systems around the islands. The Cromwell Current moves across the Pacific just below the surface, typically at depths of 100-400 m. When the cooler water of the Cromwell Current is pushed to the surface, the mixing of cool, nutrient-rich water with the warmer South Equatorial Current water generates high biological productivity in the waters around the archipelago.

The geographic isolation of the Galápagos combined with unique oceanographic conditions results in high biodiversity and endemism. Abundant populations of fish, whales, dolphins, sea lions, fur seals, sea turtles, cormorants, and the Galápagos penguin occur throughout the archipelago. Nesting sites for seabirds and turtles are important. The widely distributed green turtle (*Chelonia midas*) has a major breeding site in the Galápagos. The islands are also home to the only existing true marine lizard of the world, the sea iguana (*Amblyrhynchus cristatus*).

The southernmost limit of the coral reef formations along the Eastern Pacific occurs in the Galápagos. Thirteen hermatypic and 32 ahermatypic (30% of them endemic) coral species are recorded for the islands. The black coral (*Anthipates panamensis*) is endemic. There are also dozens of endemic fish species. Sixteen species of whales and eight species of dolphins are found in the Galápagos Province, while two pinnipeds are endemics: the sea lion (*Zallophus wollebaecki*) and the fur seal (*Arctocephalus galapagoensis*). The rate of endemism is high among marine invertebrates.

The most important conservation issues in the area include: the decline of black coral, which is due to tourist demand for jewelry, overfishing, particularly of hammerhead sharks (*Sphyrna* spp.) and sea cucumber (*Stichopus fuscus*). Asian fishing fleets are a significant and increasing pressure on fisheries resources. Ecuadorian fishermen migrating from the mainland are also a potential threat to marine resources because of their artisanal, non-sustainable methods. Predators (cats, rats, and dogs) of seabirds and marine iguanas have increased in numbers. Tourist visitation has increased in the last 20 years, leading to a corresponding increase in pollution.

This province was divided into three ecoregions. There are clear biogeographic differences across ecoregions within the archipelago due to differences in oceanographic conditions. These regions vary in size, area of coastline, and shelf area.

Northern Galápagos Islands Ecoregion

This ecoregion extends around the northern islands of Darwin, Wolf, Pinta, Marchena, and Genovesa. The EEZ area of this ecoregion covers 226,017 km^2. The ecoregion has the shortest coastline (15 km) of the province. There is a 728 km^2 shelf area (less than 1% of the EEZ extension), surrounded by warm waters (about 28°C). True coral reefs are only found in the northernmost islands, Darwin and Wolf, because of the warmer water temperatures.

Eastern Galápagos Islands Ecoregion

This is the largest ecoregion, and comprises the coastal area of the islands Santiago, Pinzón, Santa Cruz, and Santa Fé. This ecoregion has cooler oceanic waters (about 24°C). Altogether this group of islands form a 403,591 km^2 EEZ, making up 47% of the whole province. This is the ecoregion with the largest coastal area (33,067 km^2) in relation to the whole EEZ extension (8%).

Western Galápagos Islands Ecoregion

The Isabela and Fernandina Islands are influenced by waters from the Cromwell Current which are even cooler (about 14°C) and are associated with a significant upwelling. The coastline is 410 km long, and the platform area is 3,320 km^2 which constitutes only 2% of the total EEZ area of the ecoregion.

Warm-temperate Southeastern Pacific Province

The Warm-temperate Southeastern Pacific Province stretches, from north to south, over 36 degrees of latitude covering 6,235 km of coastline (see Table 1.1 and Appendix A-7). The province area is 963,423 km^2, but just 27% of it is occupied by continental shelf waters. The province stretches from Península Illescas, in north Peru at 6°S, to the Chacao Channel at the Chiloé Island, Chile, located at 40°30'S. The northern limit of the province is determined by an abrupt change of climate and consequential shift in fauna. South of Península Illescas, ocean waters are notably cooler; the maximum sea surface temperature is 18-19°C. This is three to four degrees cooler than areas of northern Peru because the influence of the Humboldt Current brings colder water from the south. Mangroves and other tropical fauna have a southernmost limit in the eastern Pacific at 5°S.

At this southern limit of the tropics, the coastal morphology, oceanography, climate, and biota change notably. A narrow continental shelf and deep oceanic trenches are the dominant features in the province, thus most of the area within the EEZ is deep oceanic water. The Peruvian coast has a number of small near-shore islands. The Chilean coastline is continuous without indentations or embayments. The oceanic archipelagos of Juan Fernández and Desventuradas, 600 km off the Chilean coast, are not included in this province because of their unique climatic, faunal, and floral features.

The climate of the province ranges from warm-temperate in the north to cold-temperate in southern Chile. The Andes Mountains stretch along the entire coast of this province, and combined with the prevailing winds, determine the coastal rainfall regime. Winds blowing from east to west bring arid conditions to the coast in the northern sector. In central Peru, mean annual rainfall is low (from 15 to 31 mm) and variable: desiccation is intense between occasional rains. At this latitude, coastal waters are abnormally cool due to the upwelling of cold waters from oceanic depths.

The coasts of Peru and Chile are directly influenced by two surface-water masses that converge in this area: Antarctic waters and subtropical surface waters. The West Wind Drift makes the cold and nutrient-rich waters of the Antarctic Circumpolar Current approach the southern tip of South America from the west at around 45 to 50°S. The Antarctic waters branch at this point and the Humboldt (or Peru Coastal) Current moves north from this divergence point while the Peru Oceanic Current heads south. The two currents are separated by the warm, south-flowing Peru-Chile Counter Current.

Oceanographic features from north Chile to Peru suffer considerable modifications at irregular intervals during the El Niño Southern Oscillation (ENSO) events. As a result of this planetary-scale climatic event, warmer waters penetrate further south, altering the dynamics of the circulation patterns, water mass characteristics, and biota. Abnormal, high temperatures (23-29°C) and low-salinity waters spill southward. During these periods, water temperature can rise to 30 or 40°C, and precipitation increases to three to ten times the normal average. Upwelling is reduced and downwelling is increased close to shore. The geographic influence of this phenomenon is variable in time and space.

One of the most productive fisheries of the world is found in this province and is based mainly upon hake, sardine, and anchovy. The annual catch off Peru of anchovy (*Engraulis ringens*) ranges from one to twelve million metric tons, with great fluctuation due to the impact of climatic changes and fisheries exploitation. The top trophic level carnivores are marine mammals and seabirds whose immense populations inhabit islands and coastal promontories. The northern limit of the South America fur seal (*Arctocephalus australis*) is located south of Callao, Peru.

Seabirds are abundant, with some species being endemic to the Peru-Chile current system. Important breeding sites for seabirds are located along the shore and in islands off Peru: Lobos de Tierra, Lobos de Afuera, Macabí, Diego Martín, Pescadores, and Santa Rosa, located between 6 and 16°S. This area includes important nesting sites for the penguin (*Spheniscus humboldti*).

As for biodiversity and endemism, reports indicate that 6% of the species of marine macroalgae, approximately 40% of littoral bivalve mollusks and 70 species of marine perciform fish, are endemic. Most of the cetacean species of the world have been sighted in this province.

The Warm-temperate Southeastern Pacific Province was divided into four ecoregions according to climatic, oceanographic, and coastal morphological conditions, as well as some biological features.

Central Peru Ecoregion

This ecoregion extends from Península Illescas (6°S) to the San Lorenzo Island area (12°S, north of Callao) along 1,164 km of coastline. Although this ecoregion has a relatively short coastline extension, it has the broadest continental shelf area in the province; 20% of the EEZ area is covered by waters shallower than 200 m. This is in contrast to the remaining ecoregions of the province where shelf areas are less than 8%. The southern boundary of the ecoregion is defined as the northern distribution limit of kelp forest communities (*Lessonia nigrescens* and *Macrocystis pirifera*).

Cliffs and a few pocket beaches are found along the coast. Several rivers are present, but their effluent is primarily seasonal. No deltas, coastal wetlands, or lagoons are found in this ecoregion. High coastal dunes are present south of Diego Martín. The shelf width in this ecoregion averages 80 km. Oceanic islands are abundant and include the islands of Lobos de Tierra, Lobos de Afuera, and Macabí. The most intense upwelling associated with oceanic productivity occurs in this ecoregion, mostly north of 9°S. At its southern boundary, the warm counter current flowing from the north diminishes. Salinity is higher than 34.5‰. The average sea surface temperature maximum is 18 to 19°C.

The influence of El Niño Southern Oscillation events is not as strong at the southern part of this ecoregion. The consistent upwelling supports large numbers of guano-producing birds. To the north, anchovies are exploited by the local fisheries and remain an important forage base for seals and birds.

Humboldtian Ecoregion

This is the largest in the province, extending from 12°S (in Peru) to 25°S (south of Antofagasta, Chile), for some 2,308 km^2 of coastline. The continental shelf is narrow (63,836 km^2 within the 1,000-m contour). The Andean foothills approach and intersect the coastline, and there are little or no coastal plains. Frequent earthquakes have produced coastal uplifts and subsidence. The coastline is solid, with few geographic accidents, forming almost a straight line on a macroscale. It is exposed to surge and wind, with some pocket sand beaches, and scarce sheltered embayments. Towering cliffs with narrow beaches are abundant. Throughout this ecoregion, only the northern side of the rocky points and islands form sheltered coastal habitats. The continental shelf is fairly narrow at the southern end of the ecoregion. Rain is scarce with few seasonal rivers (exclusive of Río Loa, with 1.5-2m^3/s) that originate in the Andes and disappear or percolate underground.

The oceanographic regime is determined by the cold waters of the Humboldt Current. Off Peru, the sea surface temperature maximum is 16 to 17°C. Winds cause surface waters to flow offshore, generating local upwellings of cold nutrient-rich waters. The most intense upwellings of the Humboldt Current occur in this ecoregion and are associated with abundant finfish stocks. The predominant fish are anchovy (*Engraulis ringens*), sardines (*Clupea benticki* and *Sardinops sagax*), and jurel (*Trachurus murphy*).

Fisheries and land-based sources of pollution are the main threats to marine resources in Chile. No reports on overfishing exist; however, there is insufficient knowledge of the status of marine fish stocks.

Central Chile Ecoregion

This ecoregion extends between 25°S, north of Antofagasta, to near Navidad (33°26'S), covering 1,277 km of coastline. The coastal range is composed primarily of granitic rock, and has elevations with medium-size marine terraces interrupted by few open sandy beaches. The continental shelf here is among the narrowest in the province (5%) and there are isolated upwelling foci along the coast (e.g. off Valparaíso and Coquimbo). In contrast to the Humboldtian ecoregion, the pelagic ecosystems are much less productive. Rivers are more numerous and permanent rather than seasonal. The El Niño Southern Oscillation influences are moderate. This ecoregion can be considered as a transitional zone between the Humboldtian and the Araucanian ecoregions, which show very distinctive biotic and bioeconomic characteristics.

Disturbance of the coastline due to coastal development, the presence of over-exploited populations (e.g. finfish and mollusks), and the impact of coastal pollution from industries and ports seem to be the main conservation issues.

Araucanian Ecoregion

The ecoregion extends from Navidad (33°26') to Chiloé (41°30'S) along 1,486 km of coastline. The Coastal Cordillera is formed by low metamorphic rocks that generate more extended terraces. Climate is humid-temperate and rainfall is greater than 1,500 mm annually. Rivers drain both melted snow from the Andes and rainwater which is increasingly abundant southward. The more important effect of these two kinds of terrestrial runoffs is local dilution of water salinity and input of sediments and terrigenous material to the coastline. Several important estuaries (e.g. Valdivia) and extensive mud flats are found in this ecoregion. There are highly productive salt marshes at 35-41°S. Sea temperature ranges from 11.5 to 13.5°C. Spring tide amplitude is 2 to 10 m, with 8 to 12 m at Chiloé Island. There is a distinctive demersal fishery in this ecoregion. The influence of ENSO is low.

The main conservation issues are related to the overfishing of the mollusk *Concholepas concholepas* and some crustaceans. Petrel populations are abundant and there is thought to be a high number of endemic marine flora and fauna in this area.

Juan Fernández and Desventuradas Islands Province

Situated respectively about 600 and 900 km from South America, the Juan Fernández (at 33°40' to 33°45'S) and Desventuradas (26°17' to 26°20'S) Islands constitute a unique biogeographic unit (see Table 1.1 and Appendix A-7). The Archipelago of Juan Fernández is composed of three islands and several cays. The Desventuradas Islands are made up of two small island groups: the San Felix Islands and San Ambrosio Islands, separated by 16 km. Altogether, they comprise about 300 km^2 of emerged land and 116 km of coastline. Less than 1% of this area (2,544 km^2) is covered by shelf waters.

Average precipitation in Juan Fernández is about 1,000 mm of rainfall. Mean annual temperature is 15.2°C, with a 6.3°C amplitude between February (summer) and July (winter). Minimum air temperature never drops below 3°C, and the maximum rarely exceeds 25°C.

Superficial waters surrounding the Juan Fernández Islands are of subtropical origin in summer and subantarctic in winter. The Desventuradas Islands are more influenced by subtropical waters than the Juan Fernández Islands. Water from the surface to 200 m ranges from

0-19°C, with salinity between 34.0 and 43.2‰. The ocean circulation around the islands at 75-78°W falls under the influence of the strong northward flow of the Humboldt Oceanic branch (the Peru-Chile Current). Currents at 78-90°S (a strong southward flow, corresponding to the Peru Oceanic Counter Current), and beyond 81°S (a current flowing northward with low velocity and small volume transport), has been recorded.

Both the Juan Fernández and the Desventuradas Archipelagos are volcanic in origin. Sandy coastal areas are small. Separated from continental Chile by the Humboldt cold current, which flows between them, these two archipelagos are as old as the Galápagos and, like those islands, have remarkable cases of speciation and endemism. Among the examples of endemism are the Juan Fernández spiny lobster (*Jasus frontalis*), a subspecies of a gastropod mollusk locally called "loco" (*Concholepas concholepas*) and the sunstar (*Heliaster helianthus*). Despite relatively little information about marine flora and fauna, endemics are abundant in almost any invertebrate and fish high taxonomic group. Several species of cnidaria endemics are recorded at between 37 and 73 m in depth. Marine fish endemism is reported to be about 20%.

An estimated 32 species of seabirds are present in the islands; 22 species are visitors and the rest nest in either one or both archipelagos. There are two endemic subspecies (*Pterodroma externa* and *P. coki defilippiana*).

The Juan Fernández fur seal (*Arctocephalus philippii*) is an endemic species of these islands. Some individuals have been recorded in Peru, but there does not appear to be a regular settlement of this species outside of the Juan Fernández Islands. This is the only part of Chile where the species is fully protected (see Castilla, 1987). Other fur seals are present in the province, but in low numbers: *Arctocephalus tropicalis, Hydrurga leptonix,* and *Leptonychotes wedelli*. The sea lion (*Mirounga leonina*) is recorded in the islands as well.

There are 120 marine macroalgae inhabiting the Juan Fernández and Desventuradas Islands; 29% are endemic to both archipelagos. The similarity of the marine flora with other areas (South Pacific, South America, Tropical East Pacific, etc.) demonstrates the relative isolation of these islands with respect to the South American continent. Furthermore, it has been suggested that the archipelago could be considered a source of algae species for continental South America. Some evidence suggests that strong El Niño Southern Oscillation events should be able to reach the islands and thus play an important role in the dispersal and gene flow of some algal species, reducing the survival potential of some cold-water species and contributing to the low species richness reported in the area. Alternatively, it may accelerate the differentiation of the animal population in the islands, thus speeding the speciation process.

No attempt was made to divide this province into ecoregions. The small size of the Juan Fernández and Desventuradas Archipelagos suggest that any conservation effort would have to include the whole province. Despite its low marine biodiversity, the biological importance of these islands is high due to their high endemism, and their position as a center of geographic dispersal and speciation of marine biota.

Experts consider the Juan Fernández Islands to be badly managed and overdeveloped. The historical use of the islands as penal colonies led to deforestation (burns) for agriculture and road construction. Loss of vegetation impacted the nesting habitat and success of petrels (Procellariformes). The introduction of cats and other predators has likely affected the seabird colonies.

The exploitation of fur seals started in late 1600s, after the discovery of the islands by the Spanish navigator Juan Fernández in 1554. Fur seals ("lobos finos") were hunted for their fur and melting grease. Historical records indicate that millions of fur seals used the islands as rookeries up to the early 1700s. The indiscriminate harvesting of fur seals led to a decline of their population. Sixty-five years after the Juan Fernández fur seal was considered extinct, a survey recorded the presence of two hundred individuals. The 1969 census generated an overall number of 459 individuals for two islands, Robinson Crusoe and Alejandro Seikirk. Two juveniles were observed in the Desventuradas Islands in 1970 after more than a century of absence. Between 1984 and 1985, scientists recorded 1,578 individuals in 28 sites distributed on the Robinson Crusoe and Alejandro Seikirk Islands.

In 1929, a ban on the taking of fur seals was established. In 1950, a total ban on harvesting of pinnipeds was enacted. The species *A. philippi* is listed in Annex 2 of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES), which was signed by Chile in 1975. However, in 1976, a law regulating hunting of fur seals affected the total ban enacted previously for *A. philippi*. Due to Chilean scientists' efforts to reform this law, all species of otarids (sea lions and elephant seals) were protected (total ban for hunting) in 1978.

At present, the fisheries exploitation in the Juan Fernández Islands is focused mostly on the endemic rocky lobster (*Jasus frontalis*), and to a lesser degree, on the cod or rocky bass *Polyprion* (*Hectoria*) *oxygenerios*. The rocky lobster dwells at 2 to 200-m depths in caves and rocky bottoms. Despite the existence of fisheries regulations concerning this species, a decline of the stock has been attributed to overfishing.

Cold-temperate South America Province

The Cold-temperate South America province includes the coastal areas under the jurisdiction of three countries: Chile, Argentina, and the United Kingdom (the sovereignty of the Malvinas/Falkland Islands is disputed with Argentina). The province has diverse coastal morphology types and shelf contours along 57,466 km of coastline (see Table 1.1 and Appendix A-8). This province, together with the nearby Warm-temperate Southwestern Atlantic, have the largest continental shelf area—the Argentina shelf—in the western hemisphere. The northern boundary of this province on both sides of the southern cone is situated at a similar latitude: 41°30'S in the Pacific and 41°S in the Atlantic. Both are washed by northward flowing cold currents fed by the Pacific West Wind Drift. The southern limit is in Cape Horn, Argentina.

The boundary between the Warm-temperate Southeast Pacific and the Cold-temperate South America provinces is associated with the greatest faunal change. For example, the diversity of fish fauna declines from north to south: 79 families of teleosts (with 179 species) in the Araucanian Ecoregion of the Warm-temperate South-eastern Pacific, but 63 families (with 135 species) recorded for the two ecoregions of southern Chile combined. At the Atlantic side of the province, the Falkland Current flowing northward upon the shelf area of Argentina is responsible for the dispersion of the flora and fauna along the coastal area of Argentina. The marine biogeography of this coastal province (named at that time Magellan-Falkland by several authors) has been the focus of discussion after the compilation of data on the distribution of some taxonomical groups such as fish and isopods. The taxonomical and systematics studies revealed high endemic rates for echinoderms, pelecypod mollusks, isopods, and fish.

An intricate array of channels, fjords, and passages facing a narrow shelf dominates the coastal geomorphology along the southern coast of Chile, in comparison with the extensive platform of the Argentinean portion, including the Malvinas/Falkland Islands.

On the Patagonian coast of Chile (from about 45°S to 50°S), fjords and straits excavated from granitic and metamorphic rocks form an intricate coastal topography related to structural lineaments and faults eroded by water and ice. At this zone, the depression between the Coastal Cordillera and the Andes is submerged. From 40 to 48°S, river drainage is abundant. Further south, from 48 to 52°S, the large fjords have an ice crust that reaches sea level; the ice formation changes the salinity pattern in the sheltered embayments. Glaciers reach the coastline of Patagonia at several places south of 46°30'S. Waves, substrate type, salinity, and temperature differences between the open coast and the channels south of parallel 42° generate a high habitat diversification in comparison with the coastline of the central and northern part of Chile.

The tip of South America extends almost 20° farther south than any of other continental mass reaching the Circum-Antarctic region. This means that a considerable portion of its coast is directly exposed to the West Wind Drift. A minor portion of this oceanic current is deflected northward along Chile's coast (contributing to the Humboldt Current), but the major branch flows through Drake's Passage between South America and the Antarctica. Another branch of the Falkland Current turns northward to run between Tierra del Fuego and the Falkland (Malvinas) Islands. This current flows slowly along the Argentina coast up to the mouth of Río de la Plata, and then turns eastward and rejoins the West Wind Drift.

The Falkland Current is stronger along the outer edge of the continental shelf, with a speed of about two kilometers per hour. Upwellings occur at the edge of the platform. The huge continental shelf is covered by nutrient-rich waters that support extensive kelp beds in coastal areas as well as abundant biological populations. There are huge colonies of penguins, sea lions, sea elephants, fur seals, and seabirds along the Patagonian shores, with many breeding areas. Two marine mammals and three seabirds are endemic for the ecoregion.

According to climate and biological features of the marine fauna, the Cold-temperate South America Province can be divided into five ecoregions. Off Argentina, the ecoregion divisions were delineated based on dominant fishery resources, oceanographic features, and the influence of major rivers.

Chiloense Ecoregion

Between 41°30'S (Chacao Channel) and 47°S (Taitao Peninsula) exists an intricate array of inner passages, channels, fjords, and archipelagos stretching along 10,705 km of coastline. Twenty-four percent of the EEZ area is occupied by the shelf area, so the shelf/coastline ratio is fairly high (5.6 km^2 per km). This is the so-called "Chiloé's Inner Sea" (between Chiloé Island and the continent) where the maze of channels is characterized by a wide tidal range (up to 8 m) and abundant freshwater inputs from copious precipitation. Offshore, a system associated with the West Wind Drift splits into a northward flowing branch (which gives origin to the Humboldt Current) and a southward flowing branch, known as the Cape Horn Current. The diversity of benthic macroalgae of this ecoregion and the one described below (totaling altogether 60 families of macroalgae, including 212 species of Rhodophytes) is substantially higher than on the Chilean coasts to the north (respective figures are 47 and 97 for the Araucanian Ecoregion of the Warm-temperate Southeastern Pacific). By contrast, isolated to the south by the Taitao Peninsula, and to the north by the end of the channel landscape, the Chiloense ecoregion contains a still poorly known endemic fauna and flora, some of whose components are Weddellian relicts with closely related forms in the southwest Pacific (e.g. the Chilean oyster, *Tiostrea chilensis*, is closely related to a species from New Zealand).

This ecoregion, with a strong tradition of artisanal fishing, has in recent years seen the explosive development of a technologically advanced aquaculture industry, mostly oriented to salmon production. In the inner waters of Chiloé, the farming of introduced Pacific and Atlantic salmon may cause water quality deterioration. Eutrophication caused by food supply is a major threat to the coastal environment. Potential impact on sea lions (*Otaria flavescens*), fur seals (*Arctocephalus australis*), and some cetaceans are reported. The presence of salmon in the natural ecosystem has been reported already. The ecological consequences of this introduction has not yet been examined. The Chiloé National Park is only terrestrial and has no marine component (there are no marine parks in Chile). The area surrounding Guamblin Island has been proposed as a marine park.

Channels and Fjords of Southern Chile Ecoregion

From the Taitao Peninsula (47°S) to Cape Horn there is an extremely complex system of fjords, sounds, channels, and islands that define a unique ecoregion, somewhat comparable to the system that extends through the northeastern Pacific from British Columbia to the Alaska panhandle. The intricate coastline totals 39,126 km, the largest of all the ecoregions in the study area and even longer than the coastline length of other provinces (exclusive of the Tropical Northwestern Atlantic). The Argentinean southern portion of Tierra del Fuego and Isla de los Estados (Staten Island) are included in this ecoregion. All together they comprise an EEZ of 849,251 km^2, 82% of which is beyond the shelf area. The fjord systems end in either seaward-moving glaciers, which cut the Andes Mountains, or numerous small rivers. The coastline and islands delineate a fringe about 220 km wide and more than 1,000 km long. Rocky shores, with some sandy beaches, small estuaries, very high cliffs, and salt marshes are the main geomorphological features along the coastline. Mean annual temperatures decrease from 11° to 4-5°C at Cape Horn. Rainfalls exceed 1,500 mm (mean annual). Surface water temperatures range from 4-11°C in summer to 2-7°C in winter.

While the biota of the southern end (Magellan Straits and areas to the south) had been intensively studied by scientific expeditions during the 19th century and the first half of the 20th century, much of the ecoregion is poorly known. The *Macrocystis* kelp forests are a dominant feature in this area.

Malvinas/Falklands Ecoregion

Located in the southwestern Atlantic, 480 km off the coast of southern South America (51° to 52°30'S), these islands are at the center of the extensive Malvinas/Falkland Shelf. Their coastline stretches 4,375 km, and the EEZ extends for 507,117 km^2; about 60% is occupied by the shelf. The shelf of the Burdwood Bank, to the south, is also included. The Malvinas/Falkland Archipelago consists of two large islands (East and West) with a total area of 1,300 km^2, and 200 to 300 nearby small islands and islets of variable size, in addition to the more isolated Beauchene Island to the southeast. The islands consist largely of Paleozoic sedimentary material. Air temperature is low year round (averaging 9°C during the summer and 7°C during the winter) and strong winds are characteristic (mean over 30 km/h). There are no true rivers or estuaries. The most distinctive subtidal community is a kelp forest composed principally of *Macrocystis* (but also *Durvillea* and *Lessonia*). The marine climate is under the influence of the West Wind Drift (WWD) system, a splinter of which gives origin to the Malvinas/Falkland Current flowing northward along the continental slope off South America. The current has two branches: one (weaker) flowing to the west and the other (stronger) to the east of the islands. The temperature of the cold-temperate surface waters rarely exceeds 10°C.

Some 78 species of fish are reported for this ecoregion. The most important is the Nothothenid family, which has the highest (17) number of species. Four species of fish (*Salilota australis, Micromesistius australis, Macruronus magellanicus,* and the nothothenid *Patagonotothen guenteri*) are commercially significant. Two mollusks and the king crab also are caught. Three macroalgae are exploited for agar (*Gracillaria*) and carrageenan (kelp *Macrocystis*). Other species are potentially significant, but have not yet been exploited.

There are two main groups of seabirds: pelagic species, widespread at subantarctic islands and usually in southernmost South America (some species of Macaroni Penguin, Black-browed Albatross, and King Shag) and coastal species otherwise confined to southern South America (Magellan Penguin, Rock Shag, Dolphin Gull, South American Tern). Up to 24 bird species may still nest in the islands.

Twenty-two species of marine mammals, including 16 toothed whales, 2 baleen whales, and 4 pinnipeds are reported to inhabit the island waters. The Malvinas are the main nesting habitat for several marine birds as well as a refuge for pinnipeds.

Some 59 species of seabirds are present, 17 of them nesting, together with 23 shorebirds and 3 marine ducks. Estimated population for the Rockhopper penguin reaches two million individuals. Shearwaters and petrels are also very abundant. Dozens of seabird colonies have been sighted.

Much of the coastal zone physiognomy was defined in the past by the presence of tussock grass (*Poa flabellata*), which may live up to 300 years. The tussock grass community has been greatly damaged by human disturbance (mostly fires), and survives only in isolated pockets. These intentional fires may have heavily affected nesting sites of birds. Egg-taking has been a common practice in the Malvinas Islands, although its current significance is unknown. Predators such as cats and dogs may also have affected seabird colonies. There is no data available for marine mammal abundance in the ecoregion.

An important international fishery has developed in the Malvinas/Falkland Shelf and adjacent areas, targeting mostly short- and long-fin squid. The offshore fishery of hake makes this species a serious candidate for overfishing.

Offshore oil exploration is likely to start soon, creating the single most important anthropogenic risk for the ecological integrity of the southwestern Atlantic.

Patagonian Shelf Ecoregion

The Patagonian Shelf ecoregion includes the Atlantic coast of the Argentinean provinces of Santa Cruz, Tierra del Fuego, and the adjacent shelf north of the Le Maire Strait and Isla de los Estados (Staten Island). It occupies 401,724 km^2 and is bound to the east by the Malvinas/Falkland ecoregion and to the north by the shelf break. The northern boundary, north of 47°S, follows the 100-m depth contour that runs close to the coast south of 47°S and close to the slope north of 41°S. Between 47° and 41°S, the isobath runs diagonally across the shelf, roughly defining the average transition zone between two major ecosystems. The zones are dominated by anchovy and Argentina hake to the north, and to the south by the Fueguian sprat, hoki, blue whiting, and southern hake. This boundary partition is also associated with fish assemblages and benthic communities. The ecoregion has a total area of 401,723 km^2; 90% is less than 200 m deep, which has great significance for resources management.

Climate in the ecoregion is cold and annual rainfall decreases southward from 1,100 to 600 mm. In the south, the climate is dry and arid or semi-arid (in Patagonia western winds are responsible for rain in the Andes). The coastal landscape is dominated by long, high cliffs of Cenozoic marine sediments. There is only one major river, the Santa Cruz, plus smaller rivers such as the Deseado, Coig, and Gallegos. The hydrology of coastal waters is influenced by the strong southwesterly winds. A low salinity zone ("tongue") over the intermediate shelf is a very characteristic feature and has been erroneously interpreted as evidence of the existence of a "current" originating from the Magellan Strait, the so-called "Patagonian Current." The low-salinity region results from diffusion of low-salinity water from the straits; its orientation is influenced by the Coriolis effect. A still poorly known frontal system occurs seasonally off Bahia Grande (51 to 52°S). Towards the north, the coastal ecosystem is characterized by extensive *Macrocystis* kelp forests.

While the number of fish families is similar from the Fuegin area to the Patagonian Gulfs (34-36), they become more speciose: from 65 in Tierra del Fuego to 82 in this ecoregion. This is probably due to the increase in shelf width and subsequent habitat diversity. On the contrary, macroflora diversity decreases northward: from 326 species of macroalgae in the channel and fjords to 178 species in the Patagonian shelf. Two baleen whales, 17 toothed whales (seven are dolphins), and three otarids (sea lions and elephant seals) are recorded for this ecoregion.

As for conservation threats, three projects for the construction of a power plant are proposed for the basin of the only large river (Santa Cruz) draining into this ecoregion. This construction might affect the coastal ecology due to river damming.

While no fish stock collapses have been documented, the offshore fishery of hake makes this species a candidate for overfishing. Overfishing is one of the highest threats for marine conservation in this ecoregion (including illegal fishing by foreign fleets).

Seven species of dolphins are caught in fishing operations. In recent years, the use of monofilament nets increased dolphin mortality which was estimated to be over 100 dolphins per year in the Tierra del Fuego ecoregion alone. The impact of the surimi fleet on marine mammals has not been well recorded. Some marine mammals are known to be captured for use as bait in king crab pot fisheries. While the relationship has not been properly documented, it is supposed that fisheries compete with marine mammals and birds for food resources. Additionally, hake and squid overfishing is one of the most serious conservation issues in the southern Atlantic.

Plans for introducing exotic oysters have apparently been halted. However, if such plans were to continue, they might threaten the native, and commercially valuable, *Ostrea puelchana*, which is susceptible to the disease bonomiasis.

Oil extraction and transportation is a potential threat to this ecoregion. At the Magellan Strait, there are about 50 Chilean and 6 Argentinean oil platforms connected by pipelines with the Punta Arenas or Punta Loyola terminals. At Punta Loyola, at the entrance of the Ría Gallegos (20 km from town), crude oil is loaded from docks with no containment buoys. Offshore oil exploration and exploitation in the Patagonian Gulfs and the Malvinas are perhaps the most important threat to marine biodiversity in the entire southwestern Atlantic. In addition, gold mining is expected to begin soon at San Julián. The potential impact of this project has not been assessed.

North-Patagonian Gulfs Ecoregion

This ecoregion stretches along 1,898 km of coastline, and has 198,808 km^2 of EEZ less than 100 m deep. Between 47° and 41°S, the coastal zone of eastern Patagonia is characterized by a series of prominent gulfs, from south to north: San Jorge, Nuevo, San José, and San Matías. All of them have an inner basin deeper than the adjacent shelf. They range in shape from the wide-open San Jorge to the semi-enclosed San José Gulf. The latter, together with the Nuevo Gulf and the Valdés Peninsula, form a coastal system of remarkable importance from the viewpoint of marine conservation. The coastline is primarily formed by Cenozoic marine sedimentary terrain, which develops in long stretches of uninterrupted cliffs. Freshwater inputs are meager; precipitation is around 250 mm per year. The only river, the Chubut (which is dammed), drains to the sea, but does not form an estuary. Coastal circulation is driven by tides (tidal range reaches eight meters in some areas) and the strong southwesterly wind. Several important frontal areas develop recurrently: two thermohaline fronts (in the San Matías and San Jorge gulfs) and a well-studied frontal system off Valdés Peninsula which develops during the spring at the boundary of well-mixed coastal water and offshore stratified water.

Kelp forests are sparse and patchy between 42 and 44°S. Coverage from Punta Lobos to Punta Marqués is about 2,160 ha.

The area is highly significant for marine mammals and seabirds such as penguins and cormorants. The San José Gulf (an important breeding area for southern right whales) is the only marine park in Argentina. Other cetaceans, elephant seals, sea lions, and fur seals are common and abundant.

Some 178 species of macroalgae are found in this ecoregion while 73 species of fish grouped in 44 families (65 species are bony fish) compose the ecoregion's fish fauna. One shark and 17 bony fish have commercial significance. In addition, seven mollusks and three crustacean species are harvested. The macroalgae genera *Gracillaria* is harvested for agar extraction and *Gigartina* is harvested for carrageen extraction.

Major spawning/nursery grounds exist for hake (Isla Escondida) and shrimp (southern San Jorge Gulf). Some important fisheries target stocks (e.g. hake, shrimp, scallops) are fully contained within the boundaries of the ecoregion. The blue mussel (*Mytilus edulis*) and the Tehuelche scallop (*Aechipecten Tehuelche*) fishery grounds were closed due to decline of their populations. The king crab or centolla (*Lithodes antarctica)* population was overharvested. In addition, kelp forests are sparse and patchy between 42 and 44°S. Coverage from Punta Lobos to Punta Marqués is about 2,160 ha.

Warm-temperate Southwestern Atlantic Province

The Warm-temperate Southwestern Atlantic province is defined to the south by the Valdés Peninsula 41°S to Cabo Frio, Brazil at 23°S (see Table 1.1 and Appendix A-9). This is one of the smallest provinces (1,065,474 km^2) of the study area, with 8,154 km of coastline length. About 56% of the area is occupied by the continental shelf. This province corresponds to (but does not coincide exactly with) the Eastern South American Faunal Province proposed by Hayden et al. (1984). The province enjoys a warm-temperate climate that constitutes a transition between the Cold-temperate South America province and the Tropical Southwestern Atlantic province.

The distribution of marine biota led experts to locate the southern limit of this province at 41°S (around Matías Gulf/Valdés Peninsula). The delineation of this limit is consistent with many biogeographic studies which found a rapid biotic transition in coastal assemblages that occurs near this latitude. Several criteria were used for locating the southern limit:

- Most of the biota from the coastal zone and inner shelf of the Province of Buenos Aires (Argentina) between Río de la Plata and 41°S have warm-temperate, rather than cold-temperate affinities.

- Coastal communities off Río de la Plata are characterized by the absence of the typical cold-temperate south Atlantic forms such as *Macrocystis* or *Aulacomya*, the absence of significant invertebrate predators from the rocky intertidal zone (e.g. *Trophon, Anasterias*), and the presence of a community dominated by the yellow clam (*Mesodesma*) in exposed sandy beaches.

- Estuarine communities in the ecoregion of Río de la Plata are clearly of the type found in the north.

- Fisheries resources in the common Fishing Zone of Argentina and Uruguay (the "Frente Marítimo Común") are different from those found in the rest of the Argentina shelf.

The northern limit of the province is determined by the influence of the Falkland Current (which can be felt north to Rio de Janeiro), and the beginning of the presence of mangroves (around 27°). Mangrove forests cover only 2,923 km^2 along 755 km of coastline, yet the extension is only 2% of the total mangrove coverage of the study area. North of this point, at the Abrolhos Bank, the southernmost extent of the Caribbean coral species may be found. The province has 599,191 km^2 of shelf area and more than half of the total EEZ (1,065,474 km^2). The coastal areas of Argentina, Uruguay, and Brazil are included in the province.

The coastal geomorphology of the province is diverse. The Brazilian section of the coastline runs southwestward and consists of wide sandy barrier formations enclosing major lagoon systems, Lagoa Mirim and Lagoa dos Patos, with associated salt marshes and sedge swamps. The coastal plain in Rio Grande do Sul is up to 120 km wide with extensive dunes driven by predominantly southerly winds. Broad sandy beaches extend along the coast for 640 km, with ridge systems and coastal dunes reaching 25 m in elevation. The area's shelf width is relatively narrow (about 200 km) in comparison with the rest of northern part of the country, but south from Mar del Plata, Argentina, the shelf broadens noticeably.

The Uruguayan coastline extends for 600 km and includes the northern shore of the Río de la Plata and the section facing the Atlantic Ocean. Characterized by uplifts, highlands, coastal lagoons, and river estuaries, the coast is exposed to a southeasterly ocean swell east of Espinillo Point (modified by the circulation at Río de la Plata) and storm waves mainly from the southeast and southwest. The mean spring tide ranges from 0.4 to 0.6 m, with southeasterly winds producing storm surges between 1.9 m (at the mouth of Río de la Plata), 21.7 m (Montevideo), and 3.7 m (Colonia). Together, southern Brazil and northern Uruguay, form an extensive chain of approximately 60 coastal lagoons, separated from the ocean by sandy barrier islands.

Most rivers have strong drainage into estuarine lagoons with sea entrances blocked by sand deposits carried in by storms. Swampy shores with salt marshes (containing *Juncus* and *Spartina* grass) occupy the more sheltered parts of the coast between Montevideo and Arazati.

At Río de la Plata, the Paraná River forms a large 15,000-km^2 delta. From Buenos Aires south to Punta Rasa's Samborombón Bay, an extensive low area of the Pampas Plain is occupied by Holocene marine and estuarine deposits. A brackish marsh and an extensive mud flat are present at Samborombón Bay, while open marine coastline with dunes and beaches are typical near Punta Rasa south. At Mar Chiquita (about 38°S), coastal lagoon, estuarine, and marine deposits are well developed. Immediately south of the inlet, Mar Chiquita's beaches are being severely eroded. Southward, the Mar del Plata coastline is principally made up of cliffs. From this point to Monte Hermoso (near 39°S), the cliffs of the Pampa Interserrana are located.

The oceanic circulation regime of the province is characterized by the meeting of the north Falkland Current, flowing northward, and the warm southwesterly Brazilian Current that meet along that country's coast and becomes progressively weaker. The meeting of cold and warm waters varies both seasonally and yearly. The influence of the Falkland Current can be felt as far north as Rio de Janeiro. An upwelling also occurs off the coast of Cabo Frio.

A reported 43 species of bony fish are present in the Río de la Plata and northern Argentina, 29 of them inhabiting the continental platform. Some 26 marine mammals are reported to be present in the area: two toothed whales, seven baleen whales and dolphins, and three pinnipeds (*Arctocephalus australis, Otaria flavescens,* and *Mirounga leonina*). Both the *Arctocephalus australis* and *Otaria flavescens* breed at Isla de Lobos and Isla de Castillos.

It is estimated that 97 species of seabirds and shorebirds are present. There are more than 100 seabird and shorebird breeding sites in islets, estuaries, and wetlands along the coast, some of which are heavily impacted by egg extraction in Argentina and Uruguay.

Uruguay-Buenos Aires Shelf Ecoregion

Extending from the Brazil-Uruguay border (about 34°S) to the latitude 41°S (San Matías Gulf, at the Valdés Peninsula, Argentina), this ecoregion roughly follows the Uruguayan-Argentinean Common Fishing Zone. It is the province's largest ecoregion (36%), with a coastline extension of 1,740 km, and an EEZ of 381,123 km^2, 69% of which is occupied by the shelf. The most prominent oceanographic feature is the confluence of the Malvinas and Brazil Currents. The Malvinas Current moves northward along the slope, encountering the south-flowing Brazil Current at a latitude that varies seasonally. As a result, the biota is distinguished from the adjacent ones (e.g. Río de la Plata, North Patagonian Gulfs, Patagonian shelf, and Rio Grande). It contains pelagic species that are absent southward along the slope, such as the Spanish mackerel (*Scomber japonicus*) and the white croaker (*Micropogonias furnieri*). The ecoregion's northern limit is characterized by a high number of species and a very important multi-species nursery area defined by the confluence of the Malvinas and Brazil Currents during the austral summer.

Barra del Chuy, a barrier coastal lagoon on the northern limit, is defined as the southern limit of disintegrating beaches (sensu) characterized by a gentle slope of approximately 3 degrees, fine to very fine well-sorted sands, high wave environments, wide surf zones, and large eolic tide ranges (minimum astronomic tides of 0.5 meters). The beaches south of Chuy are also characterized by high primary production represented by surf diatoms and are hence defined as semi-enclosed ecosystems. Approaching the Río de la Plata ecoregion, marine macroinfauna is replaced by eurihaline species.

Conservation issues and threats are found in coastal pollution from rice plantation fertilizers and domestic waste as well as in habitat deterioration due to the use of tractors and shovels for harvesting. This has led to the decline of some mollusk populations (e.g. *Mesodesma mactroides*, *Donax hanleyanus,* and *Mytilus edulis*) on the Uruguayan coast. No finfish stock appears to be overfished. The mass mortality in 1994 of the yellow clam *Mesodesma mactroides*, due to a toxic microalgae bloom, impeded the reopening of the fisheries season in the Argentina-Uruguay Common Fishing Zone. Blue crab populations have been on the decline since the 1970s; the causes of stock fluctuations are still unknown.

Yellow scallop (*Mesodesma mactroides*) and blue mussel (*Mytilus edulis*) fisheries were closed due to overfishing. The polychaete *Ficopomatus enigmaticus*, introduced in the 1930s, forms extensive calcareous reefs in Mar Chiquita Lagoon—an important regional coastal environment of this ecoregion. Introduced in the early '70s, the barnacle *Balanus glandula* has developed a barnacle belt along the rocky shores and most of the components of the fouling communities remain exotic species.

Several ports, including Mar del Plata, Quequén, and Bahía Blanca, are potential threats to the coastal zone, as are oil terminals, refineries, and petrochemical industries. It is estimated that the incidental catch of dolphins fluctuates between 50 and 300 porpoises per year (Corcuera et al., 1994), most of them franciscana.

Río de la Plata Ecoregion

Río de la Plata (34° to 36°20'S and 55° to 58°30'W) has a 1,337 km coastline and a total area of 24,499 km^2. The width varies from 38 km at the upstream end to 230 km in the mouth, between Punta Rasa and Punta del Este. The major tributaries are the Paraná and the Uruguay rivers, with annual average discharges of 16,000 and 6,000 m^2/s, respectively. The Río de la Plata drains the second largest basin in South America and, with an area of 3.1 x 106 km^2, extends through Argentina, Bolivia, Brazil, Paraguay, and Uruguay. Variations in physio-chemical characteristics allow the definition of the existence of a clearly differentiated system. High turbidity values, with suspended sediment concentrations from 100 to 300 mg/l resulting from the discharge of the Paraná and Uruguay rivers and the strong gradient of decreasing salinity from the outer to the inner part, constitute remarkable features of the system. Suspended sediments carried by the river make up an important factor in bottom formation, turbidity, and primary production variability. The estuarine zone of the river was estimated at 18,000 km^2, with a depth of range of four to eight meters. The Río de la Plata constitutes a natural barrier for many benthic species distributed along the Atlantic coasts of Uruguay and Argentina. This, in turn, determines a marked predominance of freshwater species towards the inner section of the river, followed by an increasing predominance of euryhaline species close to the river's mouth. Moreover, several fish species temporarily inhabit the estuary (e.g. Samborombón Bay, Santa Lucía zone), particularly for the purpose of reproduction (e.g. the important commercially exploited white croaker *Micropogonias furnieri*). Trawl surveys yielded up to 150,000 tons of fish biomass, or about 8 g/m^2 fish density. Some demersal fish, such as common hake, are very important.

The main conservation concern in this ecoregion is the highly populated urban center of greater Buenos Aires (both city and province), with approximately 12 million inhabitants. The ecoregion has the highest area to coastline length ratio (22 km^2/km) of all ecoregions and, as a result, land-based sources of marine pollution are an important issue. The discharge of pollutants to the river and estuary from numerous industries reaches gargantuan proportions in the Argentinean Province of Buenos Aires. The cleansing of the river is a high priority for the Department of the Environment, but no results are yet visible. Two ports, five refineries and four petrochemical industries are located in greater Buenos Aires.

Aggregations of the fish papamoscas (*Nemadactylus bergi*) were wiped out in Province of Buenos Aires during the '60s: overfishing was attributed to the Soviet fishing fleet. The papamoscas developed into the basis of a small fish meal industry. At present, it has low significance; the status of the stock is poorly documented.

Large sectors of the Río de la Plata estuary have been strongly modified by urban development, dredging of navigation channels, etc. Further coastal development of Buenos Aires is a potential threat to coastal lagoons and dunes.

The deterioration of habitat is eliminating important seabird nesting sites in Province of Buenos Aires. Impacts include the disappearance of wetlands due to intense tourism in Mar del Plata.

Rio Grande Ecoregion

The northern limit of this ecoregion is Cabo de Santa Marta Grande (28°S); the southern limit is Barra del Chuy (34°S). The ecoregion stretches along 1,897 km of coastline with numerous large coastal lagoons and extensive salt marshes (*Spartina* spp.). The Patos Lagoon (985,000 ha) and the Mirim Lagoon (230,000 ha) are the South Atlantic's largest coastal lagoons. These lagoons, together with those in northern Uruguay, form a major habitat for highly diverse communities of migratory birds coming from North America and the Antarctic. The EEZ area covered by the ecoregion is 276,629 km^2, of which 125,341 km^2 (46%) is occupied by the shelf. Rivers discharge directly into the lagoons, not into the ocean. Sedimentation is the primary conditioning feature. Shelves are generally wide with a gentle slope. The circulation pattern is determined by the seasonal position of the sub-tropical convergence.

Coastal development is the main conservation issue in the coastal area. The input of freshwater to these lagoons is affected.

Southeastern Brazil Ecoregion

This ecoregion's northern limit is Cabo Frio (23°S); the southern limit is Cabo de Santa Marta Grande (28°S). It is characterized by the presence of numerous coastal lagoons, embayments, and estuaries along 3,180 km of coastline. Sedimentation dominates coastal geological processes. The southern extent of the mangrove distribution range in the South Atlantic is located here. About 755 km of coastline have mangroves which cover 2,923 km^2. This ecoregion corresponds with the Mangrove Complex Unit of the same name delineated by WWF. The ecoregion has an EEZ of 378,224 km^2 and a 125,341-km^2 continental shelf composed of sand and mud. There is an absence of major river systems draining into the ecoregion (in comparison with those to the north), but the coast is dominated by numerous rivers, including the São Sebastião, Grande, and Santa Catarina. The encounter of the Malvinas Current with the Brazil Current can reach this area, creating a subtropical convergence. This supports high primary productivity due to local upwellings off Cabo Frio.

Conservation problems in this ecoregion are related mostly to the presence of highly dense populations. Rio de Janeiro lies in the northern part of the ecoregion's coastline, while São Paulo is located at a 50-km distance from the coast. Anthropogenic impacts to the coast include coastal development, domestic and industrial wastes, and port activities. The conservation status of mangroves was assessed as endangered by WWF.

Tropical Southwestern Atlantic Province

The Tropical Southwestern Atlantic province exists entirely in Brazil, extending from the Brazil-French Guiana border (4°N) to Cabo Frio (23°S) (see Table 1.1 and Appendix A-10). The coastline is long (14,419 km); 17% of the EEZ (2,999,950 km^2) is occupied by shelf waters (533,244 km^2). Nearly one quarter of the total mangrove area of the study zone is located in this province.

The province has a great variety of coastal formations, from the Amazon River and the reefs in the north, to coastal lagoons (and associated barrier islands), sand dunes, and cliffs along the shore.

The climate is typically tropical, with July air temperatures ranging from 25-30° at the northern limit, to 20-25°C in the south. Precipitation is abundant and mean annual rainfall ranges between 1,000 and 2,000 mm in the south and 1,000 and 4,000 mm near the mouth of the Amazon River. The northeast area is dry with only 250 to 1,000 mm of mean annual rainfall.

The coastal morphology of this massive province is diverse. Three different sectors can be distinguished: the northern portion, dominated by the Amazon River and its sediment and water drainage, the narrow coastal margin fringing the Brazilian shield, and the barrier islands and rear coastal lagoons to the south.

From Cabo Frio, the first major feature is the deltaic protrusion at the Paraiba do Sul river which is followed by several deltaic river mouths. From 30 to 27°S, the shelf broadens to form the Abrolhos Banks. The Abrolhos Archipelago is settled over a broad bank and is composed of islets and banks of calcareous reef sandstone that emerged in the Holocene. Most coral species are endemic; some Caribbean coral species have their southernmost extent in this location. North of Itacaré, the coastline becomes indented with rías and embayments, the largest of which is Todos os Santos Bay. Northward, beyond of the influence of the Falkland Current, the climate is increasingly warm and wet with estuaries and rias fringed by mangroves.

North of Salvador Peninsula, the straight coastline is bordered offshore by beach rocks and calcareous reef sandstones, some of them cemented dune sands (eolian calcarenites). Coastal terraces are two to eight meters high and tidal range increases to three to four meters.

Humid tropical conditions dominate the coastline from Recife to Natal (annual rainfall ranges from 1,000 to 2,000 mm). Here the coastal morphology is simple, with beach-ridge plains, nearshore sandstone reefs, and some cliff areas. At Calcanhar Cape, the coastline abruptly changes its orientation to west to northwest, and is dominated by beach ridges and dunes alternating with lagoons, swamps, and salt deposits. The dry season is lengthy.

Tidal range increases westward and the coastline at this equatorial sector is indented with islets and estuaries bordered by mangrove swamps and alternating with by small sedimentary rocky-cliffed sectors. The Pará and Amazon rivers are separated by the deltaic island of Marajo. Both have an intricate channel topography and numerous mangrove-fringed alluvial islands which are highly variable in configuration as a result of the interactions of waves and tidal-fluvial currents.

The massive drainage of water and sediment from the Amazon produces an accretion at the coastline, especially northward, as the result of tidal movements of the longshore Guiana Current. At this sector, climate is perennially hot and wet with more than 2,000 mm of annual rainfall and luxuriant vegetation. Coastal waters are turbid due to sediment suspension. The discharge of the Amazon River strongly influences the composition and abundance of coastal flora and fauna. In the rest of the province area, the oceanographic conditions are determined by the presence of the Brazil (flowing southward) and the Guiana (flowing northward) Currents. Both originate from the branching of the warm South Equatorial Current which flows westerly from the Atlantic Ocean.

Biodiversity and productivity in the coastal ecosystems of the Tropical Southwestern Atlantic province are highly influenced by the nourishment coming from terrestrial runoff. Therefore, main areas of high productivity are associated with estuarine and mangrove formations.

More than 30 species of marine mammals are reported to occur in Brazilian waters. The southernmost limit of the Antillean manatee (*Trichechus manatus*) is currently situated at northeastern Brazil (as far as the Bahia State). The Amazonian manatee (*T. inunguis*) is also found in this area. Thousands of green turtles (*Chelonia midas*) are reported to nest along the coastline from Maranhão to Espirito Santo States. The other four species of turtles also occur and nest in some areas of Brazil. Fisheries resources have been intensively exploited and overfished in most cases.

Five ecoregions (three at the continental shelf and two around offshore islands) were delineated within this province.

Eastern Brazil Ecoregion

The northern limit is Salvador (13°S) and the southern limit is Cabo Frio (23°S). This ecoregion is characterized by tropical forests and restingas close to land masses. The shelf is generally broad (121,244 km^2, 24% of the ecoregion area), but gets narrower in the northern portion. The coastline length is similar to that of Northeastern Brazil and stretches along 2,050 km. About 7% (504 km) of the coastline is fringed by mangroves which cover 3,215 km^2. Well-developed biogenic formations rest on a volcanic substrate. Coastal sediments are highly variable with granitic and gneiss components. Macrophyte banks are common throughout the ecoregion to a depth of 10 m. This ecoregion corresponds to Unit 12c of the Northeastern Brazil Mangrove Complex delineated by WWF.

Several important rivers drain into this ecoregion. Water circulation flows southwesterly due to the presence of the tropical, nutrient-poor Brazil Current. Temperature gradients become influential near Cabo Frio and an important upwelling occurs here. At Cabo Frio, the Brazil Current changes from a southerly to southwesterly direction.

The Archipelago de Abrolhos is an important area for humpback whale breeding and calving. The southernmost limit of Caribbean coral species occurs here. Mangroves are under endangered conservation status.

Trindade and Martin Vaz Islands Ecoregion

These small volcanic islands have a total coastline length of about 8 km. Influenced by the Brazil Current returning to the deep Atlantic, they form the farthest extent of a submarine mountain range extending out from the coast. These small islands, with a very narrow shelf (30 km^2), are relatively unknown.

Northeastern Brazil Ecoregion

The northern limit is the Parnaiba River (3°S); the southern limit is Salvador (13°S). This is the largest ecoregion of the province with 2,106 m of coastline fringed by 355 km of mangroves, covering 3,904 km^2. The total ecoregion has an area of 1,043,712 km^2 (35% of the whole province). Of this total, 100,613 km^2 are occupied by shelf waters, including the insular platforms of Atol das Rocas and the Fernando de Noronha Islands. This is the driest area of Brazil, with 250 to 1,000 mm of mean annual rainfall. The coastal morphology is characterized by an indented coastline of calcareous origin with dunes and some mangroves. This ecoregion corresponds with the Northeastern Brazil Mangrove Complex (units 12a-b) delineated by WWF. Some reefs and many banks are found off the northern sector with substantial presence of macrophytes up to the 10-m depth. Coastal lagoons dominate the southern portion of the ecoregion.

Primary production is extremely low due to limited nutrient input from the lack of rivers and the low-productivity influence of the oceanic current. Rivers are typically coastal in origin, not draining from inland. The northern portion has some ephemeral rivers with seasonal discharge. The São Francisco is the major river system.

Water temperature and salinity are high. Limited thermoclines constrain nutrient turnover and availability. The warm South Equatorial Current impacts the continent near Natal and splits into a southerly and westerly branches.

The Archipelagos Fernando de Noronha and Atol das Rocas are situated off the Calcanhar Cape. The latter lies about 200 km northeast of the coast of Rio Grande do Norte State. It is an almost circular atoll reef. The former is a volcanic archipelago of one principal 17-km^2 island and 18 islets, lying 350 km northeast of Cape São Roque. Both archipelagos have a similar flora and fauna and lie on the same shelf.

Regarding conservation threats, Atol das Rocas is known for its abundant seabird nesting colonies and great variety of marine fauna. Fernando de Noronha Archipelago is an important habitat for dolphins. The mangroves in the ecoregion are in relatively stable condition.

São Pedro and São Paulo Islands Ecoregion

These small islands, with just 12 km of coastline, are situated in the Atlantic Ocean about 500 km northeast of Fernando de Noronha. Both islands are influenced by the northern boundary of the North Equatorial Current. The islands have a narrow shelf surrounded by deep ocean waters with typical pelagic fish species (tuna, etc.).

Amazonian Ecoregion

This ecoregion's northern limit is French Guiana (4°30'N); its southern limit (3°S) is the Parnaiba River. The coastline length is 10,252 km; EEZ area is 556,062 km^2. More than half of this area is occupied by continental shelf area (211,194 km^2). Mangroves cover 23,6761 km^2 along 6,301 km of coastline. They comprise 77% of the province's total mangrove area.

Extensive pristine mangroves, numerous large river discharges (Amazon), broad shelf, humid tropical climate, coastal geology of Pleistocene origin, and sedimentary formations are the main coastal features of the ecoregion. Large quantities of sand, silt, and clay are accumulated along the shore. The Amazon delta forms a huge system of inlets, islands, mangrove forests, brackish lagoons, and swamps that provide shelter, nourishment, and breeding habitat for fish, invertebrates, and shore birds. The large wetland areas, mangroves, and estuaries at the Maranhão (São Luis)

Gulf constitute the habitat for over 100 species of shorebirds. Here, extensive dune formations associated with lagoons, extend several kilometers inland. This ecoregion corresponds with the Brazilian portion of the Amazon-Orinoco-Maranhão Mangrove Complex (units 11c-e) delineated by WWF.

The shelf relief is relatively smooth. Primary production is relatively high, and levels of suspended materials are high. The ocean circulation is dominated by the northerly flowing warm Guiana Current. Benthic communities are rich and pelagic biota are relatively scarce. Depositional and erosional processes are extremely influential. This ecoregion includes a notable submerged bank (Manuel Luis).

Tropical Northwestern Atlantic Province

The Tropical Northwestern Atlantic (TNWA) is the largest province in the western hemisphere and extends from the tropical waters of the Gulf of Mexico and South Florida to the French Guiana-Brazil border (see Table 1.1 and Appendix A-11). The province encompasses a complex tropical area of shallow seas, banks, atolls, continental, and island coastlines.

The province is popularly referred to as the "wider Caribbean" and is most known for the extensive coral reef development, both fringing coastlines and at shallow platform margins (barrier reef systems).

This province is remarkable for a number of reasons. It is the largest province overall, at 5.7 million km^2, and encompasses more than 28% of the entire study area. It has the largest area of shallow coastal shelf, both by percent area of the province, as well as total area. It has the largest number of islands and largest island area within a province as well as the most diverse and largest inclusion of enclosed seas, bays, and gulfs.

The entire province extends from the northeastern corner of Brazil to the coast of east Texas and then to south Florida. The area includes not only shallow water resources, but also several large deep basins included within the Caribbean Sea and the Gulf of Mexico. The ecoregion is tropical in surface water temperature, with monthly means ranging from 24-31°C. The average surface temperature is 27°C typically with about 4°C annual variability.

The oceanography of the province is dominated by western boundary currents of the Atlantic that span a scale of thousands of kilometers. The Equatorial Current of the Atlantic turns north at the coast of Brazil and becomes the Guiana Current, running offshore to the eastern Venezuelan shelf. At the shelf, mixing with the vast effluent of the Orinoco River, the current runs to the west and north through the Caribbean Basin, forming the Caribbean Current. Part of the Equatorial Current remains windward of the Lesser Antilles and later the Bahamian Archipelago to form the Antillean Current. Waters that have moved west and north through the Caribbean, up the coast of Central America, and through a "loop" in the Gulf of Mexico, funnel abruptly back to the east through the straits of Florida.

Antillean Current and Florida Straits water combine to form the powerful Gulf Stream moving up and across the northern Atlantic. This large-scale gyre moves water clockwise through the northern Atlantic and carries warm tropical water from the equator throughout the province to exit at the Gulf Stream. This general circulation pattern found throughout the province controls macroscale phenomena such as propagule distribution and climate. The large-scale features are generally well understood. Deeper water circulation is restricted by shallow sills between the deeper basins; throughout the area, an average ocean depth is recorded at almost 2,200 m, with a maximum depth in the Cayman Trench of 7,100 m.

The entire province is influenced by the development of tropical storms and hurricanes that usually start as tropical waves west of the Cape Verde Islands. The occurrence of these disturbances can vary throughout the province and influences the ecology of shallow-water coastal systems. The development of hurricanes corresponds to seasonal increases in rainfall. Throughout the province, seasonality is punctuated by rainfall patterns from approximately May through November. There are latitudinal and longitudinal gradients in climate throughout the province. The eastern half of the province tends to be drier; the western half tends to have higher rainfall.

The marine resources of this province include coral reefs, mangroves, seagrass meadows, and tropical coastal fisheries. The most important commercial fisheries throughout the entire province are spiny lobster, reef fish (snapper and grouper), shrimp, and queen conch.

This province may also have the distinction of being the most threatened by anthropogenic changes. There are well described threats that apply to coastal systems throughout the Tropical Northwestern Atlantic. Tropical shallow water systems are particularly susceptible to changes in coastal hydrology and water quality. Nearshore marine communities are impacted by large-scale changes in coastal landforms, resulting in both acute and chronic sedimentation of coral reefs and hard-bottom communities. The practice of dredging shallow water areas for the development of ports and harbors results not only in sedimentation, but loss of habitat for many species. Much concern has been raised throughout the province over the input of inorganic nutrients to a tropical oligotrophic system. The process known as "eutrophication" results in changes in nearshore productivity and alters ecological balances responsible for maintaining coral reefs. Changes in coastal water quality, due primarily to organic nutrients, but also to contaminants such as polycyclic aromatic hydrocarbons (PAHs), has raised regional concerns about the continued degradation of nearshore marine communities from land-based sources of pollution.

These water quality and sedimentation threats may increase the susceptibility of organisms such as corals to disease. Diseases that are a natural part of the organisms' biology are apparently becoming more frequent and more severe with natural climatic cycles such as El Niño Southern Oscillation (ENSO) events. ENSO events tend to result in elevated surface temperatures throughout this province; there is anecdotal information on the occurrence of coral bleaching, white band, and black band disease in stony corals as well as cellular proliferative disorders (neoplasm or hyperplasm). Water quality changes result from rapid changes in coastal land use accompanied by loss of mangroves and loss of seagrass beds. The province has the highest coastal population density in the entire study area.

The large number of countries that share the marine resources of this province creates conflicts over harvesting and fishing rights of coastal shelf and bank areas. The province has been described as a large marine ecosystem in crisis in terms of declines in catch per unit effort and shift in catch from predator reef fish (snappers and groupers) to herbivorous fish (parrotfish) and other smaller and less valuable species (grunts, porgies, wrasses, etc.). Coastal resources are managed differently throughout the province; the collapse of fisheries and decline in their economic importance is most acute in the eastern Caribbean from Hispaniola to Jamaica and throughout the Lesser Antilles. There are a series of problems associated with managing stocks of fish that occur in a number of national EEZs. In addition to jurisdictional disputes, many fishing methods are destructive to the resource and are thought to be non-sustainable at present levels of effort. These include the use of bleach; collection of live rock, coral, fish, and invertebrates for the aquarium trade; and use of hookahs and fishing spawning aggregations during the spawning season of a species.

There are six ecoregions described in this province. Divisions were based on the faunal distribution of stony corals, octocorals, and fish. They represent ecoregions in which unique species for the province occur or species occur in different communities or abundance.

Guianan Ecoregion

This eastern-most ecoregion consists entirely of the dense mangrove coastline of Guyana, Surinam, and French Guiana. The ecoregion itself is small, with 384,000 km^2 or 7% of the total province, but accounts for 11% of the total mangrove area. The area is characterized by an absence of carbonate geology and a wide coastal shelf consisting primarily of soft mud-bottom communities. It is dominated by the northern flow of the Amazon River plume. There is limited reef development, but important fisheries resources exist in the marine and estuarine systems.

Of all the ecoregions within this province, the Guianan has the least information on coastal resources. The natural communities are relatively unknown It is undoubtedly the most unique of the ecoregions and, located east of the Orinoco River delta, may have the least faunal similarities to other ecoregions in the province.

There are few documented conservation threats to this ecoregion, though there are signs of increasing development pressure, oil drilling, timber concessions, and mangrove removal.

Lesser Antilles Ecoregion

The Lesser Antilles ecoregion includes a relatively small landmass, consisting of small islands from Culebra Island, off Puerto Rico to the Grenadines to Grenada. The oceanography and coastal processes associated with a broad coastal shelf and soft-bottom benthic communities separate Trinidad and Tobago from the Lesser Antilles. The Lesser Antilles ecoregion consists of small volcanic and carbonate islands and banks covering 689,000 km^2, or 12% of the total province. The climate is marine tropical with pronounced wet and dry seasons. This ecoregion has the smallest area of mangrove coastlines, though many of the original fringing mangroves of these islands were likely removed during the more than 400 years of post-Columbian settlements. Therefore, mangrove communities are relatively small and are either a narrow fringe or associated with the mouth of small rivers and streams.

The islands have traditionally been divided into the northern Leeward Islands and the southern Windward Islands, an historical designation relating to the ability of sailing ships to travel between the islands. All islands of the ecoregion are exposed to the northeast trade winds with high wave and wind energy from the western Atlantic. They vary in size from relatively small islands of only a few thousand square kilometers, such as St. Maarten and St. Barthélémy, to the largest island of Guadeloupe with 63,020 km^2. For some island nations, the area of reefs and banks is equal to or greater than the area of land. Reef fish populations have been over-exploited for years. Large populations on small islands have looked to coastal pelagic fisheries such as flying fish, dolphin (mahi mahi), and tuna as relatively new fisheries resources.

The reef resources have been well documented by local marine laboratories. Coastal resources have been described by country for Puerto Rico (Culebra), U.S. Virgin Islands, British Virgin Islands, Anguilla, Barbuda, Nevis and St. Kitts, St. Maarten, Saba, Dominica, St. Vincent, St. Lucia, Barbados, the Grenadines, and Grenada. The large number of countries and territories with jurisdiction over the marine resources of this ecoregion makes it difficult to produce a regional synopsis. Countries vary in their ability to collect and track long-term information on the status of marine resources; there is no regional scientific institution that could provide technical assistance for all the island nations.

The island economies are typically based on small-scale agriculture and tourism with relatively little industrial development. Sugarcane and bananas have been the historically important crops. The cultivation of sugar cane creates associated problems of fertilizer and pesticide usage as well as pollution from mill processing, all of which can present a threat to nearshore marine communities. Runoff and dumping of wastes in the ocean can have long-term impacts to coastal systems. The growth of tourism has spurred a boom in coastal development for resorts and cruise ship ports.

The issues associated with declining catch per unit effort and loss of fisheries revenue have been discussed locally by a number of countries. Attempts have been made to examine the utility of marine fisheries reserves (e.g. St. Lucia), small-scale aquaculture of invertebrates or macroalgae as well as alternative fishing methods to improve the catch and profitability of fishing.

The small size of these islands and the pressures of growing populations that may depend on growing port and transportation infrastructure to support tourism, make for a very vulnerable marine conservation setting. The challenge is to balance the growth needed for economic development with the need to maintain a high level of environmental quality in coastal waters. Coastal systems are, after all, the very commodity tourists are coming to experience.

Bahamian Ecoregion

The Bahamian archipelago includes carbonate banks and islands stretching more than 3,200 km from Little Bahama Banks to the north to Navidad and Silver Banks to the south. Three countries have jurisdiction over this area: the Bahamas and the British territory of the Turks and Caicos occupy most of the 823,000 km^2, while the Dominican Republic claims jurisdiction over the Silver and Navidad banks to the extreme southern end of the archipelago. The archipelago is made up of a relatively young carbonate bank system dominated by the lithogenic and biogenic production of calcium carbonate sediments. There are more than 1,300 small islands and cays, only a handful occupied, with two large population centers—Nassau and Freeport in the Bahamas. Though the total population is less than 350,000 people, more than half that number resides in Nassau.

The climate is subtropical in the northern Bahamas with a noticeably cooler and drier winter season, but becomes distinctly tropical and dry in the southern Bahamas and Turks and Caicos Islands (e.g. less than 750 mm rain per year). The Bahamas represents the most popular tourist destination in the province outside of Cancún, Mexico—the province's mega-resort destination. The proximity to the Miami-Fort Lauderdale area has supported the growth of a billion-dollar tourist industry in the Bahamas which is the envy of the wider Caribbean. American tourists are attracted by the proximity, ease of travel (especially by cruise ship), beaches, yachting, and fishing. A strong commercial and recreational fishing industry exists in both the Bahamas and the Turks and Caicos.

Rocky shores and beaches on windward exposures and mangrove forests to the leeward side of the islands dominate the low-relief coastlines. The mangrove lagoons and bays dominate much of the actual land area, particularly on large islands such as Andros. Mangroves are critical coastal nursery areas for recreational fishing target species such as tarpon, bonefish, and permit. The mangrove trees themselves can be structurally small and sparse in the extremely oligotrophic coastal environment. There are no large riverine systems on these carbonate islands.

Fisheries resources are abundant throughout the archipelago. The area of shallow water bank is large in comparison to the overall land area. Historically, fishermen have exploited sponges, finfish, lobster, turtles, and conch. The total catch of finfish in the Bahamas and Turks and Caicos islands is market-driven. Finfish are only caught in large numbers when the international market for export can support such effort. Most fishermen focus on spiny lobsters, the highest cash value species. Recreational fishing attracts anglers from around the world for coastal pelagics, reef fish, and gamefish that are caught and released.

This ecoregion can be considered the most pristine in the province, but this word should be used with caution. The resources are certainly not "pristine" in terms of intact ecological systems, but rather the ecoregion reports no collapsed fisheries. Grouper and snapper still dominate the finfish catch. The threats are essentially the same throughout the province, but vary greatly with location within the ecoregion. Growing population centers in Nassau, Freeport, Marsh Harbor, Georgetown, and Providenciales are experiencing rapid degradation of coastal water quality and destruction of coastal habitats. Mangroves are almost systematically cleared in an attempt to make way for waterfront access and to control mosquito populations.

In populated areas there are early indications of water quality changes such as small-scale fish kills, reports of seafood poisoning, and loss of seagrass communities near developed shoreline areas. The potential threat of overfishing exists, though there is a growing awareness of the importance of enforcement of existing regulations on gear, closed seasons, and size limits.

South Florida Ecoregion

This ecoregion represents the smallest and perhaps most unique ecoregion within the province. This ecoregion is part of the continental United States and represents a faunal transition area with elements of tropical, subtropical, and temperate faunal assemblages. The area is only 23,600 km^2 and less than 1% of the entire province area, but is an important mosaic of natural communities, ranging from hard-bottom communities off the east coast of Florida to Florida Bay to the atolls of the Dry Tortugas.

Throughout this ecoregion, there is intensive management of shallow-water marine resources in the following protected areas:

- National parks that include Everglades National Park, Biscayne National Park, Dry Tortugas National Park, and Rookery Bay National Estuarine Research Reserve;
- Florida Keys National Marine Sanctuary, which oversees the protection of most of the shallow-water communities, including the Florida reef tract in the Florida Keys;
- Bays and beaches adjacent to the large urban centers of Miami and Fort Lauderdale, which are under aggressive surface water improvement programs; and
- Smaller parks and aquatic reserves in Florida that protect nearshore marine communities.

The South Florida ecoregion includes diverse biotic elements with tropical, subtropical, and temperate affinities. Florida is downstream from the rest of the Tropical Northwestern Atlantic and receives propagules from many of the tropical reefs, seagrass beds, and mangrove bays to the south. Diversity also comes from the northwest in the Gulf of Mexico and from the eastern seaboard of the Atlantic coast of the U.S. Endemism is relatively low in South Florida, but there is an extremely high number of species for many taxa groups. Marine and estuarine species occupy habitats from full-strength seawater to oligohaline or freshwater lenses in the numerous mangrove creeks. For example, there are more than 200 recorded fish species that represent unique continental U.S. populations, but only two endemic species.

The manatee population is the largest of the province and stretches throughout the east and west coasts of the Florida Peninsula. Manatees are under increasing pressure from coastal development which threatens the species with toxic algal blooms and increased boat traffic. There are many important coastal systems within the ecoregion that are critical to the life history of commercially targeted marine species. Florida Bay is a large triangular marine lagoon that includes shallow mud banks and deeper seagrass-carpeted basins. The bay receives a portion of the drainage from the large drainage basin of the south-central Florida Peninsula (Kissimee River-Lake Okeechobee-Taylor Slough). The bay and its associated mangrove creeks are nursery areas for important reef fish such as gray snapper, as well as valuable gamefish like tarpon, permit, and spotted sea trout. These same areas are also the critical remaining habitat of the American crocodile in the U.S. The Dry Tortugas, located at the western edge of the ecoregion, represent an important stopover point for many migratory bird species, including nesting colonies of brown noddies and sooty terns. There are at least four species of sea turtles that use the carbonate beaches of the Dry Tortugas for nesting, an activity that is well protected within the park's boundaries.

The ecoregion can be characterized as both intensively used and intensively managed. Institutionally, there are three separate foci in the management of marine resources and coastal systems: management of fisheries by the appropriate management councils and agencies; management of water quality and wastewater treatment issues by the county and state with federal oversight through the Environmental Protection Agency; and management of coastal development and population growth within the counties by local county and state governments. With this intensive management of specific threats, there appears to be no overall management entity addressing system-wide carrying capacity. Tourism and trade within the ecoregion continue to grow as agencies and conservation organizations race to secure lands into public ownership to prevent future development. For example, the effort to restore hydrological cycles in the Everglades includes buying back land from agricultural use and restoring the area to natural vegetation and community types.

The cost of development in the South Florida ecoregion is certainly higher than in any other part of the province. Environmental and construction regulations make the capital investment high, but investment resources are likely more available, and there is a high demand from both residents and tourists. With all the resources of a "developed country," South Florida may be an interesting case study as a sustainable coastal zone with multi-jurisdictional management. Marine resources are intensively used and intensively managed. Time will tell if management strategies have been successful.

Gulf of Mexico Ecoregion

The Gulf of Mexico is the second largest ecoregion, covering 193,000 km^2 and 21% of the entire province. The ecoregion represents a continuum of soft-bottom coastal lagoons and shorelines stretching from the northeastern tip of the Yucatán Peninsula, around the Gulf of Mexico to the Texas border and including the Texas Flower Garden Banks and Florida Middle Grounds. This ecoregion is bounded to the north by the temperate coastal systems of the Gulf Coast states of the U.S. (Texas, Louisiana, Mississippi, Alabama, and the Florida panhandle).

The ecoregion has very diverse systems including the reefs and hard-bottom communities of the Flower Garden Banks and the Florida Middle Grounds. The Flower Garden Banks are in U.S. waters and are designated as a National Marine Sanctuary. Here, there are deep coral banks with no emerged islands. The Florida Middle Grounds represent the wide coastal shelf area off the West Coast of Florida. These low-relief hard-bottom areas are important to Florida's recreational and tourist fishing industries.

The Mexican components of the Gulf of Mexico ecoregion are quite different. The Gulf's extensive coastlines can be broken into three sections: Tamaulipas, Veracruz to Campeche, and Yucatán to the east. The Tamaulipas section of the Gulf extends into the southern tip of Texas and includes large coastal lagoons and bays. It contains important nesting beaches for the Kemp's Ridley turtle, as well as offshore soft-bottom communities that have supported a trawl fishing industry for shrimp.

The coast from Veracruz to Campeche is likely the most affected within the ecoregion. The area's largest port, numerous oil drilling platforms, and point sources of industrial waste are all situated here. Contamination of groundwater and drinking water supplies has already posed a health problem for both people and livestock, while coral reefs off Veracruz have been described as severely degraded.

The Yucatán Peninsula and Campeche banks represent one of the most productive fishing grounds in the province. The fishery for red grouper is managed between three countries: Cuba, Mexico, and the United States. This area is developed for tourism. There is a faunal break point to the east, just north of Cancún. Cancún and the coast of Quintana Roo fall in the Central Caribbean ecoregion.

Throughout the ecoregion, there are significant land-based sources of pollution stemming from industrial wastes, oil terminals, and oil exploration. The United Nations Environment Programme (UNEP) reports this ecoregion as having the highest load of land-based sources of pollution, from petrochemicals to organic nutrients (phosphorus and nitrogen). There are important commercial fisheries for octopus, red grouper, and other finfish that are managed with size and gear limitations, as well as closed seasons for reproduction.

In all likelihood, fisheries are severely affected by loss and degradation of coastal habitats and nursery areas. There are initiatives to protect large coastal lagoon systems, but regional pollution issues have yet to be addressed.

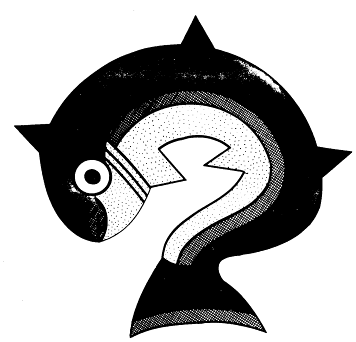
Central Caribbean Ecoregion

The Central Caribbean is the largest and most complex of the ecoregions in the TNWA. The ecoregion includes both continental and insular systems surrounding the Caribbean Sea. The ecoregion occupies 46% of the total area of the entire province with 419,554 km^2 of shallow banks and coastal shelf. Jurisdiction over the area is shared by Venezuela, Aruba, Curaçao, Bonaire, Colombia, Panama, Costa Rica, Nicaragua, Honduras, Guatemala, Belize, Mexico (state of Quintana Roo), Cuba, Haiti, Jamaica, Trinidad and Tobago, Puerto Rico, the Dominican Republic, and the Cayman Islands. As a pattern, the islands have higher coastal population densities than continental areas. There is a wide disparity of wealth throughout the ecoregion, from very poor (such as Haiti) to relatively rich (such as the Cayman Islands and Aruba).

The entire ecoregion can be divided into insular and continental components. A large proportion of marine species are distributed along both the coasts of the greater Antilles and the coasts of Central and South America. Thus, there are biogeographic reasons to group this large area as one ecoregion. However, there are differences in coastal processes, abundance, and distribution of natural communities from islands to continent and from east to west. The coastlines of the ecoregion are diverse, including large river deltas and estuaries, mangrove forests, complex bays and coastal lagoons, offshore cays, upwelling areas, rocky shorelines, and offshore blue holes. There are also a series of coral atolls along the western extent of the ecoregion.

This ecoregion is unique in its coastal morphology. It harbors large land masses with adjacent mountains on both the continent and the larger islands (e.g. Cuba and Hispaniola). There are numerous rivers, both large and small, that naturally transport silt and sediment to deltas, shore, and beaches. Rivers can be both permanent and seasonal. Endemic species have been described for locations in the ecoregion. For example, in the Cayman Islands, three species of mollusks and a species of blenny (*Starksia yuineata*) are endemic. The species inventories and descriptions of many taxa are considered incomplete, and there are likely other species restricted to this ecoregion as well. There are regionally critical populations of seabirds and marine mammals (e.g. West Indian manatee), but unfortunately there are no ecological borders incorporated in the management of marine resources.

This large ecoregion—more than 2 million km^2—has large coastal population densities, a long history of human use of marine resources, and significant land-based sources of pollution associated with oil extraction, port development, and agriculture. The ecoregion has experienced loss of coastal habitats in the removal of mangroves and diversion of rivers for agriculture. There has been a loss of species, including the Caribbean monk seal and the Jamaican petrel. Spawning aggregations of grouper and snapper species have disappeared throughout the ecoregion. Many countries report the collapse and closure of at least one fishery over the past 20 years.



Chapter 2 Assessing and Ranking Ecoregions within Provinces

THE FIRST PHASE of the effort to rank ecoregions within provinces involved the selection of indicators as direct and indirect measures of biological value and conservation status. When quantitative data were not available, ranks were produced after a qualitative assessment based on experts' knowledge. The overall ranking for biological value and for conservation status was obtained by a simple sum of all ranked values.

Indicators of Biological Value

The combination of physical and biological indicators provides a reasonable view of the ecological diversity of an area. Information was compiled on three scales: by province, by ecoregions, and by smaller units (depending on availability, usually national boundaries or coastal systems). Table 2.1 shows a completed biological value table for Belize made by the experts.

The indicators are grouped as follows:

Physical Characteristics

Physical characteristics of the marine environment such as coastline extension, shelf extent, and the measurement of terrestrial runoff are indirect indicators of the biological value of coastal areas. Such characteristics are a reflection of the abiotic environment that shapes the associated biological communities and are directly connected to the diversity and productivity of marine flora and fauna.

For example, the occurrence of biological processes such as reproduction, feeding, and growth are linked to shelf width. This feature, together with the length of the coastline, is related to the spatial complexity necessary to sustain numerous physical environments for the different life history stages of animals and plants.

Nutrient flow (organic and inorganic) in biological communities was also indirectly evaluated. The source of nutrients

Table 2.1 Example of completed biological value table: Belize

Indicators of biological and ecological value of marine bioregions

#	INDICATORS	DATA	SOURCE	SQ
	PHYSICAL CONDITIONS			
1	Coastline extension (km)			
2	Shelf width (min.-max./mean)	13-400 km wide	Wells, 1988.; Rutzler et al., 1982	A
3	Shelf area (km²)			
4	Presence of outstanding communities (mangrove/kelp forests, coral reefs, barrier/atoll reef formations, upwellings, etc.)	fringing mangrove, barrier coral reef, atolls, blue holes, extensive lagoon, seagrass, mangrove cays, longest reef in western hemisphere; faroes	Wells, 1988; Perkins and Carr, 1985	A
5	Coral reef extension (% of the total coastline extension)	257 km (~100%) barrier and fringing reef; three offshore atolls	Wells, 1988.	A
6	Mangrove extension (% of the total coastline extension)	Most of coast, especially near river mouths. Over 200 mangrove cays in the barrier reef lagoon	Wells, 1988. Mumby et al., 1995	A
7	Kelp forest extension (% of the total coastline extension)	0		
8	Position relative to the ocean current (upstream, downstream, midstream)	midstream	Brucks, 1971; Kinder, 1983; Stoddart et al., 1982	A
9	Number of rivers per 100 km of coastline			
	SPECIES COMPOSITION			
10	% estuaries/rias/deltas on overall number of rivers			
	Fishes			
11	# of neritic teleost species	600	Carter, pers com.	C
12	# of neritic Perciformes species			
13	# of species of selected families			
	Invertebrates and Macroalgae			
14	# of spp./genera/families of selected groups of coastal mollusks			
15	# of families of benthic macroalgae	165 taxa; 40 families; 34 genera; 77 spp.; 247 total spp. marine flora	Norris and Bucher, 1982	B
16	# of species of selected macroalgae families	9 Cynaophyta, 73 Chlorophyta, 32 Phaeophyta, 124 Rhodophyta, 4 Angiospermae (seagrasses); 100 spp. marine algae (Stoddart et al., 1982)	Norris and Bucher, 1982; Stoddart et al., 1982	B
17	total # of stony coral species	3 hydrozoan and 42 scleractinian	Cairns, 1982	B
	Marine Mammals			
18	total # of species			

Table 2.1 Example of completed biological value table: Belize *(continued)*

#	INDICATORS	DATA	SOURCE	SQ
	SPECIES COMPOSITION *(CONTINUED)*			
19	# of species of selected groups	1 Manatee (*Trichechus manatus*); 3 dolphin (*Tursiops truncatus, Stenella plagiodon* and *Steno bredanensis*)	Wells, 1988; Bengston and Magor, 1979	C
	Seabirds			
20	# of species/genera of selected groups			
21	# of families of selected groups			
	Sea Reptiles			
22	# of species of sea turtles and sea iguana	3 turtles; 2 crocodile (*C. acutus, C. moreleti*);	Wells, 1988; Perkins and Carr, 1985; Abercrombie et al., 1980	A
	ABUNDANCE			
23	# of individuals of selected species	Largest number of manatees in Caribbean (1977-1989)	O'Shea and Salisbury, 1991	
24	Annual catch for selected species/genera	1995 exports: 800,000 lbs lobster, ~400,000 lbs conch. 1994 exports: 27,000 aquarium fish & inverts; Lobster annual exports 1970-77 (metric tons) 205.9, 219.2, 199.0, 170.8, 206.7, 210.4, 223.9. Shrimp annual exports 1972-76 (mt) 11.3, 6.5, 7.0, 12.7, 28.6. Shrimp began in 1965 (23k lbs exported). Finfish exports 1970-76 (mt) 111.8, 65.3, 52.0, 47.9, 68.9, 65.6, 190.2. Q. conch exports 1970-76 (mt) 364.8, 477.1, 563.0, 506.6, 442.9, 406.6, 359.7 Six shrimp trawlers in 1979	Wells et al., in press; Gibson, 1978 Day, 1979	
	BREEDING			
25	Presence of breeding/nesting sites for selected fish/seabird/sea reptile species/genera	loggerhead, hawksbill, green turtles; magnificent frigatebird, red-footed booby, brown pelican, sooty tern, brown noddy, snapper/grouper. Data available in GIS for birds, turtles, crocs, protected areas, conservation status, fisheries and recreation. Snapper/Grouper aggregation sites: 6	Wells, 1988; Mumby et al., 1995; Trivelpiece and Ferraris, 1987; Moll, 1985 Carter and Perrine, 1994; Carter et al., 1994	B
	ENDEMISM			
26	# endemic species for the Biogeographic Province			
	FISHERIES RESOURCES			
27	# of finfish species that are commercially significant	75% of catch is snappers (Lutjanidae); 11% is groupers (Serranidae); 2% is grunts (Haemulidae). 47 spp. exploited, and also include sharks, Scaridae, Acanthuridae, Holocentridae, Sparidae, Carangidae, Sphyraenidae and others. 65 finfish spp.	Koslow et al., 1994; Polunin and Roberts, 1993; Richards and Bohnsack, 1990	A
28	# of species of mollusks that are commercially significant	Conch fishery based on Queen conch (also horse, milk, helmet) (jewelry and shell trade active); octopus	Gibson, 1978; Creswell and Davis, 1991; Sedberry, pers obs.	

Table 2.1 Example of completed biological value table: Belize *(continued)*

#	INDICATORS	DATA	SOURCE	SQ
	FISHERIES RESOUURCES *(CONTINUED)*			
29	# of species of crustaceans that are commercially significant	99.9% of lobster catch is *Panulirus argus*; Stone crab, *Menippe mercenaria* traditionally local, recent export, 4-5k lbs/yr caught for 1986-87 for N-Central BZ.	Gibson, 1978; Bert and Hochberg, 1992	
30	# of genera of macroalgae that are commercially significant			

Indicators of biological and ecological value of marine bioregions; SQ = (Source Quality): A = Data complete and reliable according to best available sources
B = Data reliable, but geographically incomplete
C = Data uncertain

Explanation of indicators for table 2.1

- 1-3 These data will be automatically estimated by us through GIS.
- 4 Record each type on separate rows.
- 5-7 Estimate the linear extension of each ecosystem type and the % will be estimated by us.
- 9 You may record just the # of rivers and we will estimate the rest.
- 11-12 Species inhabiting the platform (oceanic ones are excluded).
- 13-21 Select the groups according to their biological importance in the region (specious families, population abundance, commercial significance, etc.).
- 22 Sea turtles and the Galápagos sea iguana.
- 23 Select groups according to data availability. Some groups of seabirds are suggested.
- 24 Select groups according to fishery significance in the region. Record separately for each group.
- 25 Record number of sites for each species/group of species. Snapper/Grouper aggregation sites: 6 Breeding aggregations of snapper/groupers, seabird nesting sites in oceanic islands and rookeries, and sea turtle beach sites are suggested.
- 26 Just marine species.
- 27-30 Species under fishery exploitation (do not include introduced exotic species for aquaculture). Other groups can be suggested.

Note: zoological/botanical groups will be selected after consulting with the Project in order to standardize criteria with experts of adjacent regions.

in a system is varied and can include upwellings, water mass convergence, and freshwater drainage which provide the hydrochemical and hydrophysical conditions necessary for phytoplankton blooms in the water column. Terrestrial runoff contributes to coastal productivity by providing inorganic nutrients and organic detritus to the marine environment.

The presence and extension of certain outstanding features or communities, such as coral reefs, mangrove, kelp forests, and fjords, provide indirect information on the occurrence of ecologically valuable marine habitats. In the tropics, coral reefs and mangrove forests provide food and shelter for invertebrates and fish. Kelp forests play a comparable role in cold-water regions.

Presence and Abundance of Species

The species richness of certain groups, such as fish, corals, seabirds, and marine mammals, was used as an indicator of biodiversity.

For a number of reasons, fish are valuable as a standard for comparing biological diversity and productivity. There are known and established quantitative collection methods. Statistics of catches are thus available in most areas and can be used as an indirect measure of abundance. Additionally, fish have been thoroughly studied and reliable taxonomic references exist, thus allowing for useful comparisons between countries or ecoregions. Seabirds and marine mammals are also extremely important in the marine environment since they are at the top of the food web and their populations are relatively vulnerable to human exploitation.

Many species of pinnipeds and seabirds aggregate in specific sites for breeding, nesting, and raising young which makes them easy to observe and count, but also extremely vulnerable to human impact (e.g., taking, habitat deterioration, overfishing of their target food).

Hermatypic corals constitute the most important group of reef builders in tropical waters. Coral reefs provide a topographically complex substrate on which extremely diverse assemblages of fish and invertebrates depend. The presence and abundance of these corals are considered very valuable for marine biodiversity; however, their low tolerance to varying physical conditions (e.g., temperature, salinity, sedimentation) and their slow growth make them extremely vulnerable to anthropogenic impact.

Endemism

Despite the fact that endemism is not common in the marine environment, many species do in fact have a distribution range restricted to a marine province. The presence of endemics was considered as an indicator of biological uniqueness for an ecoregion or province.

Breeding

The presence of breeding sites of certain groups of animals such as seabirds, fish, and both marine mammals and reptiles is of great importance in the evaluation of biological value. Some locations are the sole site for the reproduction of certain seabirds and marine mammals.

Fisheries Resources

The number and abundance of commercially significant species was used as an indicator of the biological value of ecoregions. Conservation and sustainable planning need to take into consideration the harvesting of these biological resources. Numerous species of finfish (e.g., hakes, sardines, anchovies, snappers, groupers, sciaenids, etc.), coastal mollusks (e.g., clams, oysters, abalone, etc.), crustaceans (e.g., lobsters, shrimps), and macro-algae (brown and red) are important resources in marine ecoregions.

Species Lists

It is often difficult to provide species lists for country-scale areas. In many cases, detailed lists of macroalgae, sponges, corals, and fish could be found for only one or a few sampling sites. Although it is difficult to take data from one habitat type and extrapolate it to cover a country or ecoregion's entire range of habitats, scientists concluded that a species list was nonetheless useful as it provided a relative basis for comparison across ecoregions.

Conservation Status

The challenge of marine conservation will be to identify the possible causes and mechanisms of change in marine systems and to segregate potentially degrading anthropogenic events from natural processes. An integral part of this challenge is the ability to characterize and measure change on different scales and levels of detail.

The evaluation and ranking of conservation status relied on 33 potential indicators that are applicable to entire provinces, ecoregions, and coastal systems. In this exercise, conservation status is a measure of the need for conservation rather than a measure of existing conservation efforts.

Indicators are grouped as follows:

Alteration of Habitats

The level of disturbance of the coastline, the reduction of the extension of critical coastal habitats (coral reefs, mangrove and kelp forests, sand dunes, estuaries), and the diminishing of terrestrial runoff through river damming were used as indicators of the conservation status of marine biodiversity and productivity. Depending on the geographical and climatic characteristics of the ecoregion, different critical features and communities can describe the deterioration of coastal conditions. Coastal development for tourism, wood exploitation, shrimp culture, road construction, and other practices have deteriorated continental and insular coastal habitats for many marine organisms. River damming has, in many cases, provoked habitat alteration in the drainage vicinity. The lessening of freshwater input reduces not only the input of organic nutrients, but also alters hydrology and sedimentation dynamics, modifying the bottom vegetation as well as the biological assemblages.

Loss of Species

Extinction of species is possible, but not well documented in the marine environment. Over-harvesting and other anthropogenic impacts, however, may cause the disappearance of species in some locations situated at the limits of the distribution area. Manatees, for example, have disappeared from some parts of their historical distribution, notably the Bahamas, the Lesser Antilles, and south of Bahia state in Brazil, as a result of hunting and incidental mortality. The Caribbean monk seal (*monacus tropicalis*) became extinct in the 1950s in the entire Caribbean.

Loss of Breeding and Nursery Sites

Loss of nesting and breeding sites for seabirds, pinnipeds, fish, and sea turtles are indicators of threats to marine biodiversity and productivity. They not only indicate the decline of the population size, but also the likely deterioration of the habitat conditions necessary for reproduction and feeding, two biological processes that are critical for animal survival.

Changes in Abundance

Scientists record changes in the abundance of fish, invertebrates, seabirds, marine mammals, and other marine groups. For commercial species, overfished stocks are an indicator of changing abundance. The reduction of population size may lead to irreversible variations in that population's genetic features. Changes in abundance that have had both a significant economic and biological impact include: the severe depletion of sea turtles throughout the Caribbean; the intense over-fishing of Clupeiformes (e.g., anchovies, sardines, etc.) stocks in Peru and Chile; the commercial extinction of Nassau grouper (*Epinephelus striatus*) from the U.S. Virgin Islands, Puerto Rico, and much of the Lesser Antilles; and the decline of lobster and conch populations throughout most of the Caribbean.

Potential Threats

Potential threats in the coastal and marine environments are related to the presence of different kinds of human impacts to the coastal zone. There is no information, however, about these threats from any country and the lack of data makes it difficult to assess the relative intensity of each of these threats (pollutant load of each source, etc.). The only way to assess them is through indirect stressors related to human activities in the coast or near the coast, but these may be under-represented if they have a cumulative effect.

There are some indicators of potential threats to marine conservation posed by human activity. These include: the number of exotic species introduced; the number of industries discharging untreated wastes to coastal waters; the existence of major ports, petroleum terminals, refineries, and pipelines; and the concentration of large human populations in coastal areas. All pose a challenge to the environment because of their potential for altering natural habitats. These indicators are of particular interest since most major cities in Latin America are situated on or near the coast.

Tourism can also become a serious threat in areas where there is insufficient infrastructure and planning to support a large number of visitors. Unregulated coastal building, poor sewage treatment, and potentially damaging visitation strategies such as the use of anchors in lieu of mooring buoys, can cause serious damage to delicate habitats. Coral reefs, pinniped colonies, and sea turtle nesting beaches have all suffered as a result.

Table 2.2 illustrates a sample conservation status table for the region of Belize. In this case, locating quantitative country-scale information on conservation status proved to be far more difficult than anticipated. Experts working in well-studied countries (such as Argentina, Colombia, Cuba, Jamaica, Mexico,

Table 2.2 Example of completed conservation status table: Belize

#	INDICATORS	DATA	SOURCE	SQ
	PHYSICAL			
1	Extension of pristine coastline (%)	The data for this section may be available in GIS (ARC/INFO) files—see Mumby et al. 1995 and references therein	Mumby et al., 1995	
2	Extension of moderately altered coastline (%)			
3	Extension of heavily altered coastline (%)			
4	Portion of mangrove coastline altered by construction, wood exploitation, shrimp pond excavations, etc. (% of total coastline extension)			
5	Number of rivers dammed (% of total # of rivers draining in the coast)			
6	Extension of coral reefs altered by natural/ anthropogenic factors (% of total extension)			
	LOSS OF SPECIES			
7	# of extinct species in the last 100 years			
8	# of extinct species in the last 50 years			
9	# of endemic species lost in the last 100 years			
10	# of endemic species lost in the last 50 years			
	LOSS OF BREEDING AND NURSERY AREAS			
	Fish			
11	% of disappeared aggregations (write in species name)	1 Nassau grouper (16.7% of known Nassau grouper aggregations)	Wells et al., in press; Eklund, 1994	
12	% of grouper/snapper/other species aggregations still fished	83.3% (seasonal (winter grouper) spawning closure at Glovers Reef)	Carter and Sedberry, in press	
13	# of nursery grounds (seagrass, coastal lagoons, estuaries) lost due to habitat alteration			
	Seabirds			
14	% nesting sites impacted by egg/adult taking or the introduction of predators			
15	% nesting sites lost			
	Marine Reptiles			
16	% sea turtle nesting sites lost			
17	% sea iguana nesting sites lost			
	CHANGES IN ABUNDANCE			
18	# of fisheries stocks that collapsed in the last 10 years	conch	Richards and Bohnsack, 1990	
19	# overfished finfish populations (attach list of species names)	Nassau and other groupers;	Wells et al., in press; Carter and Sedberry, in press; Shusterich, 1984	
20	Presence of over-exploited black coral populations			
21	Presence of over-exploited mollusk populations	conch overexploited; declines in catches from 1973-1983 indicate overfishing	Wells et al., in press; Creswell and Davis 1991; Shusterich, 1984; Gibson et al., 1983	A
22	Presence of overexploited crustacean populations	lobster at or above MSY; shrimp "depleted in readily accessible waters"	Wells et al., in press	

Table 2.2 Example of completed conservation status table: Belize *(continued)*

#	INDICATORS	DATA	SOURCE	SQ
	CHANGES IN ABUNDANCE *(CONTINUED)*			
23	# species whose early stages are captured for aquaculture (attach species name)	Queen conch egg masses	Creswell and Davis, 1991	A
24	# coastal mollusk populations heavily deteriorated by pollution or habitat loss (attach species name)			
	POTENTIAL THREATS			
25	# introduced coastal/marine exotic species	*Tilapia mozambica*	Carter, pers. comm., Belize Audubon Society	C
26	# industries discharging untreated pollutants into coastal waters			
27	# major ports	1		
28	# cargo/passenger vessels entering ports per year			
29	Presence of oil (or derivatives) terminals/ refineries/ pipes	yes		
30	Coastal (within 60 km from shore) population per km of coastline			
31	# of unprotected threatened species			
32	# of unprotected CITES species			
33	# reef sites visited by tourists	Data may be available in GIS-see Mumby et al., 1995	Mumby et al., 1995	C

Uruguay, and Venezuela) were able to provide detailed data, while others had greater difficulties. On average, researchers provided data for 16-33 indicators with the easiest being fisheries data, usually regarding changes in abundance.

The Ranking Process

After devoting four to six months to examining and completing the Biological Value and Conservation Status data tables, regional experts and project personnel met at a four-day workshop in September 1996 in order to review province, ecoregion, and coastal system delineation and rank ecoregions.

Scientists and staff were divided into groups according to the provinces in which their areas of expertise fell. After first reaching a consensus on province and ecoregion boundaries, the groups discussed the quality and extent of the accumulated data. Based on the presence or absence of data, each group agreed upon which criteria to use for ranking ecoregions within their province. A number of parameters were discarded because they were either inappropriate (e.g., the presence of coral reefs in Cold-temperate South America) or data were simply unavailable (e.g., number of species extinct within the last century for the Tropical Northwestern Atlantic). In some cases, information on one or more indicators was not available for all ecoregions within a province. While published data may not always exist for all areas, the unpublished experience of acknowledged regional experts, some of whom

Table 2.3 Example of completed biological value ranking scorecard: Tropical Northwestern Atlantic Province

#	INDICATORS	Ecoregions: Gulf of Mexico Data	Gulf of Mexico Rank	South Florida Data	South Florida Rank	Bahamian Data	Bahamian Rank	Central Caribbean Data	Central Caribbean Rank	Lesser Antilles Data	Lesser Antilles Rank
	PHYSICAL CONDITIONS										
1	Coastline extension (km)		M		L		M		H		M
2	Shelf width (min.-max./mean)		H		M		M		H		L
3	Shelf area (km^2)		H		L		M		H		L
4	Presence of outstanding communities (mangrove/kelp forests, coral reefs, barrier/atoll reef formations, upwellings, etc.)		L		H		H		H		L
5	Coral reef extension (% of the total coastline extension)		L		H		H		M		L
6	Mangrove extension (% of the total coastline extension)		M		M		M		H		L
7	Kelp forest extension (% of the total coastline extension)										
8	Position relative to the ocean current (upstream, downstream, midstream)		L		L		M		H		H
9	Number of rivers per 100 km of coastline										
10	% estuaries/rias/deltas on overall number of rivers										
	SPECIES COMPOSITION										
	Fishes										
11	# of neritic teleost species	383	M	750	H	488	M	715+	H	433	M
12	# of neritic Perciformes species										
13	# of species of selected families (Serranidae, Lutjanidae, Carangidae, Pomacentridae, Scaridae, Haemulidae, Labridae)										
	Invertebrates and macroalgae										
14	# of spp./genera/families of selected groups of coastal mollusks ** (need more data)	337 bivalves		634 bivalves + gastropods (shallow water only)			–	791 gastropods 427 bivalves			–
15	# of families of benthic macroalgae										
16	# of species of selected macroalgae families ** (need more data)	323		400+		89 (?)		456		–	
17	total # of stony coral species (Hermatypic)	36	M	62	H	61	H	60-70	H	mid 40's	M
	Marine Mammals										
18	total # of species (31 spp. overall)	18	M	18	M	18	M	29	H	11	L
19	# of species of selected groups										
	Seabirds										
20	# of species/genera of selected groups	44		28		34			–	12+	
21	# of families of selected groups										

Table 2.3 Example of a completed biological value ranking scorecard *(continued)*

#	INDICATORS	Gulf of Mexico Data	Gulf of Mexico Rank	South Florida Data	South Florida Rank	Bahamian Data	Bahamian Rank	Central Caribbean Data	Central Caribbean Rank	Lesser Antilles Data	Lesser Antilles Rank
	SPECIES COMPOSITION *(CONTINUED)*										
	Sea Reptiles										
22	# of species of sea turtles and crocodiles	5 turtles 1 crocodiles	H	5 turtles 1 crocodile	H	5 turtles 2 crocodiles	H	5 turtles	H	5 turtles	H
	ABUNDANCE										
23	# of individuals of manatee (H = thousands, L = hundreds or less)		L		H		L		H		L
24	Annual catch for selected groups (tons)										
	Total	40,000	M	17,000	L	10,000	L	>5,000,000	H	no data	L
	Finfish	18,000	M	9,000	M	1,500	L	>300,000	H	no data	L
	Shrimp	16,000	H	2,360	M	not landed	L	>20,000	H	not landed	L
	Lobster		L	3,000	M	8,200	H	10-15,000	H	no data	L
	BREEDING										
25	Presence of breeding/nesting sites for selected fish/seabird/sea reptile species/genera # of species of nesting turtles	3	L	4	M	4	M	5	H	4	M
	ENDEMISM										
26	# endemic species for the Biogeographic Province										
	FISHERIES RESOURCES										
27	# of finfish species that are commercially significant										
28	# of species of mollusks that are commercially significant	4	H	2	L	3	L	14	H	1	L
29	# of species of crustaceans that are commercially significant	19	H	14	M	4	L	23	H	10	M
30	# of genera of macroalgae that are commercially significant										
	Total High Points		18		18		15		54		6
	Total Medium Points		14		16		16		2		10
	Total Low Points		6		5		6		0		12
	Grand Total		**38**		**39**		**37**		**56**		**28**

Note: High = 3 points, Medium = 2 points, Low = 1 point

may have worked in the same region for decades, can be equally valuable.

After an agreement was reached on which criteria to consider, each ecoregion was ranked relative to the other ecoregions in the same province. The group ranked each indicator as low (L), medium (M), and high (H). Ranks were assigned a numerical value (1, 2, and 3 respectively) and totaled for each table of indicators.

The sample scorecard in Tables 2.3 and 2.4 shows the ranking for the Tropical Northwestern Atlantic. These scorecards are typical of the product that was generated for all provinces. Note that each ecoregion was ranked relative to the other ecoregions in the province, therefore a value of "H" for shelf width in Peru cannot be compared with an "H" in the Central Caribbean.

Matrices were then designed for each province by cross-referencing the total L, M, H scores of biological value and conservation status. Table 2.5 shows the ordinal and L, M, H ranks and matrices of the ecoregions within the Tropical Northwestern Atlantic Province. The ordinal matrix may be misleading if ecoregions differ by only a point or two. For example, an ecoregion with a biological value score of 34 would appear to be of greater value than one with a score of 33, yet the actual difference is negligible. To compensate for the inaccuracy, the L, M, H matrix was also prepared such that both regions would be ranked the same. Yet, caution must be used when setting priorities based upon matrices. An ecoregion's position on the matrix is not necessarily "good" or "bad," it merely signifies that different methods should be employed for conservation. An ecoregion with an "H" position may require immediate intervention and assistance, whereas an L or M region may have success with increased education and outreach programs.

For a discussion on sources and quality of information, see Appendix C.

Regional Priorities within Provinces

This section presents the results of the ranking of ecoregions within each province.

The highest-ranking ecoregions for seven provinces are highlighted in Appendix A-4, and include:

Warm-temperate Northeastern Pacific Province: The Cortezian Ecoregion

The three ecoregions occurring in Mexico were ranked, with the Gulf of California's (also referred to as the Sea of Cortez) Cortezian ecoregion ranking the highest in both biological value and conservation status (see Table 2.6). The assessment of the biological value in this province was based upon the following indicators: presence and extension of unique coastal communities; number of rivers and number of estuaries (all indicators of terrestrial sources of coastal productivity); species richness of fish and use of the area by marine mammals and seabirds; and the number of endemic species in the ecoregion.

The conservation status of the ecoregions was assessed using the following indicators: coastal disturbance and rivers dammed; number of species lost or declining in abundance in the past century; and number of over-exploited populations of finfish or invertebrates.

The resulting ranks for both biological value and conservation status ranged from 15 to 55 points, with the Cortezian ecoregion having consistently higher scores than the other two ecoregions. The ranking indicates the unusual setting of the Gulf of California and its vulnerability as an enclosed sea to over-exploitation and land-based sources of pollution.

Tropical Eastern Pacific Province: The Panama Bight Ecoregion

Seven ecoregions in the Tropical Eastern Pacific were ranked (see Table 2.7), but the highest ranking ecoregion, the Panama Bight, was tied with the Nicoya ecoregion in biological value. The two ecoregions could be segregated on the basis of conservation status; on this basis, the Panama Bight was evaluated as the more threatened of the two.

The assessment of the biological value of the ecoregions in this province was based upon the following indicators: presence and extension of unique coastal communities such as mangroves and coral reefs; number of rivers and number of estuaries (all indicators of terrestrial sources of coastal productivity); species richness of stony corals; breeding sites for marine mammals; and number of commercially important fish and crustaceans.

The conservation status of the ecoregions was assessed through the following

Table 2.4 Example of completed conservation status ranking scorecard: Tropical Northwestern Atlantic Province
Higher rank means a higher degree of threats.

#	INDICATORS	Ecoregions: Gulf of Mexico Data	Gulf of Mexico Rank	South Florida Data	South Florida Rank	Bahamian Data	Bahamian Rank	Central Caribbean Data	Central Caribbean Rank	Lesser Antilles Data	Lesser Antilles Rank
	PHYSICAL CONDITIONS										
1	Extension of pristine coastline (%) (vegetation intact)		M		M		L	Colombia-45% Costa Rica-80% Venezuela-25%	M		H
2	Extension of moderately altered coastline (%)										
3	Extension of heavily altered coastline (%)										
4	Portion of mangrove coastline altered by construction, wood exploitation, shrimp pond excavations, etc. (% of total coastline extension)		M		M		L		M		H
5	Number of rivers dammed (% of total # of rivers draining in the coast)										
6	Extension of coral reefs altered by natural/ anthropogenic factors (% of total extension)		H		H		L		M		H
	LOSS OF SPECIES										
7	# of extinct species in the last 100 years										
8	# of extinct species in the last 50 years										
9	# of endemic species lost in the last 100 years										
10	# of endemic species lost in the last 50 years										
	LOSS OF BREEDING/NURSERY AREAS										
	Fish										
11	% of disappeared aggregations (write in species name)		L		L		L		H		H
12	% of grouper/snapper/other species aggregations still fished										
13	# of nursery grounds (seagrass, coastal lagoons, estuaries) lost due to habitat alteration										
	Seabirds										
14	% nesting sites impacted by egg/adult taking or the introduction of predators (Need more data)										
15	% nesting sites lost (Need more data)										
	Marine Reptiles										
16	Quality of sea turtle nesting sites (H= high risk)		H		L		L		H		H
17	% sea iguana nesting sites lost										
	CHANGES IN ABUNDANCE										
18	# of fisheries stocks collapsed (past 10 years)	2	M	3	M	0	L	2-Colombia 2-Jamaica 12-Cuba	H	~10	~M
19	# overfished finfish populations (attach list of species names)										
20	Presence of over-exploited black coral populations		L		L		L		H		H
21	Presence of over-exploited mollusk populations	3-Strombids	H	0	L	0	L		H		H
22	Presence of overexploited crustacean populations	4	M	3	M	0	L	9	H	YES	M
23	# species whose early stages are captured for aquaculture (attach species name)										
24	# coastal mollusk populations heavily deteriorated by pollution or habitat loss (attach species name)	2	M	3-4	M	0	L	7	H	1	M

Table 2.4 Example of completed conservation status ranking scorecard *(continued)*

#	Indicators of conservation status — INDICATORS — POTENTIAL THREATS	Gulf of Mexico Data	Gulf of Mexico Rank	South Florida Data	South Florida Rank	Bahamian Data	Bahamian Rank	Central Caribbean Data	Central Caribbean Rank	Lesser Antilles Data	Lesser Antilles Rank
25	# introduced coastal/marine exotic species (established— ie. breeding)	1	M	>4	H	0	L	4	H	1	M
26	# industries discharging untreated pollutants into coastal waters		H		L		L		M		M
27	# major ports	19	M	3	L	2	L	>65	H	~10	M
28	# cargo/passenger vessels entering ports per year		H		H		M		H		M
29	Presence of oil (or derivatives) terminals/ refineries/ pipes	4/12/7/3 petroleum buoys	H		M	2/1/00	L		M		L
30	Coastal (within 60km from shore) population per km of coastline	820	H	~500	M	40	L	Colombia-40, Cayman-126, DR-4584	M		H
31	# of unprotected threatened species										
32	# of unprotected CITES species										
33	# reef sites visited by tourists		L		H		L		M		M
	Total High Points		21		12		0		30		24
	Total Medium Points		14		14		2		14		16
	Total Low Points		3		6		16		0		1
	Grand Total		**38**		**32**		**18**		**44**		**41**

Note: High = 3 points, Medium = 2 points, Low = 1 point

indicators: coastal disturbance and rivers dammed; number of species lost or declining in abundance in the past century; and number of over-fished or over-exploited populations of finfish or invertebrates.

Warm-temperate Southeastern Pacific Province: The Humboldtian Ecoregion

Information was abundantly available for this province. The assessment of the biological value of the ecoregions was based upon the following indicators: presence and extension of kelp forests and upwellings (indicators of benthic and pelagic productivity); number of rivers and estuaries (indicators of terrestrial sources of coastal productivity); species richness of fish, macroalgae, marine mammals, seabirds, and marine reptiles; abundance of penguins, sea lions, fur seals, sea otter (an endemic species), and commercial species.

The conservation status of the ecoregions was based on the following indicators: coastal disturbance and rivers dammed; seabird colony sites impacted or lost; number of over-fished populations; incidence of sources of pollution; and number of unprotected threatened species and sites.

Due to the presence of abundant populations of fish, seabirds, and marine mammals in the Humboldtian ecoregion, this ecoregion scored the highest in biological value (72 points) for the province, well ahead of the other three ecoregions (58-62 points) (see Table 2.8). Twenty-nine species of marine mammals are reported to occur in this area, and 76 species of seabirds are reported as common on Peruvian coasts. This ecoregion has the highest abundance of penguin, sea lion, guano bird, and fur seal colonies.

Table 2.5 Example of ranking matrices: Tropical Northwestern Atlantic Province. Higher rank of conservation status means a higher degree of threats.

Biological and Ecological Value	Gulf of Mexico	South Florida	Bahamian	Central Caribbean	Lesser Antilles
Score	38	38	37	56	27
Ordinal Rank	2	2	3	1	4
H,M,L Rank	M	M	M	H	L

Conservation Status	Gulf of Mexico	South Florida	Bahamian	Central Caribbean	Lesser Antilles
Score	38	32	18	44	41
Ordinal Rank	3	4	5	1	2
H,M,L Rank	M	M	L	H	H

Matrix based on ordinal 1-5 rank:

Biological Value \ Conservation Status	1	2	3	4	5
1	Central Caribbean				
2			Gulf of Mexico	South Florida	
3					Bahamian
4		Lesser Antilles			
5					

1= High Value/Priority, 5= Low Value/Priority

Alternate matrix based on High, Medium, Low rank:

Biological Value \ Conservation Status	H	M	L
H	Central Caribbean		
M		Gulf of Mexico, South Florida	Bahamian
L	Lesser Antilles		

The Paracas National Reserve, the most important marine protected area in Peru (declared a RAMSAR site in 1992), includes islands, peninsulas, and high coastal productivity. The black storm petrel (*Oceanodroma markami*) has its only nesting sites in this area. The diving petrel (*Pelecanus garnotti*) and the Peruvian penguin (*Spheniscus humboldti*) are endemic to the province. Flamingos (*Phoenicopterus chilensis*), pelicans (*Pelecanus thagus*), the guano cormorant (*Phalocrocorax bougainvilli*), and boobies (*Sula variegata*) are all abundant. The Paracas Peninsula is also the northern breeding limit of the southern sea lion (*Otaria byronia*) and the Peruvian penguin (*Spheniscus humboldti*), which has its only breeding site in this area. Young sea turtles (*Chelonia mydas*) also find refuge in the park.

The Humboldtian ecoregion has the highest level of conservation problems, including coastal pollution, over-fishing, and human impacts on seabirds and pinnipeds. Guano harvesting in some nesting areas is a potential threat for seabird colonies while sea lions and fur seals are sometimes killed by fisheries operations. Marine pollution from fish processing plants, which discharge their wastes into the sea, is a real threat to this area, both in the Peruvian and Chilean portion of the ecoregion.

Endemic species of the Humboldt Current have their northern distribution boundary in Central Peru. The brown pelican (*Pelecanus occidentalis*), the blue-footed booby (*Sula nebouxii*), the Inca tern (*Larosterna inca*), and possibly the diving petrel (*Pelecanus garnotti*) are found in this area. Penguins are abundant in the Central Chile Ecoregion, as well as hake (*Merluccius*) and commercial mollusks (particularly, *Concholepas concholepas*).

In Punta San Juan, millions of guano birds make their homes in the area's high cliffs and beaches, feeding upon the abundant fish populations. This is also the most important breeding site for the Peruvian penguin and the illegal killing of fur seal pups has been reported here.

The Humboldtian ecoregion was followed in the priority matrix by the two nearby ecoregions, Central Peru and Central Chile, both of which had similar scores of biological value and conservation status. The cross matrices allowed the experts to assign the first three priorities for conservation investments to the Humboldtian, Central Peru, and Central Chile ecoregions. These three areas have the highest current and potential biological value and conservation concerns of the entire province. Conservation actions must focus on waste treatment, fisheries regulations, and guano exploitation.

Cold-temperate South America Province: The North Patagonian Gulfs Ecoregion

This was one of the most documented provinces of the entire study area. The biological value of each ecoregion was assessed through the following indicators: coastline and platform extension (since the most valuable resources are associated with the shelf and the highly indented coastline); the presence and extension of outstanding features such as upwellings, channels, fjords, rivers, and estuaries; species richness of fish, macroalgae, and seabirds; abundance of

Table 2.6 Cross matrices of biological value and conservation status for setting geographic priorities within the Warm-temperate Northeastern Pacific Province. Higher rank of conservation status means a higher degree of threats.

	Biological and Ecological Value		
	Mexican Temperate Pacific	Magdalena Transition	Cortezian
Score	30	34	55
Ordinal Rank	3	2	1
H,M,L Rank	L	M	H

	Conservation Status		
	Mexican Temperate Pacific	Magdalena Transition	Cortezian
Score	25	34	37
Ordinal Rank	2	3	1
H,M,L Rank	M	L	H

Matrix based on ordinal 1-3 rank:

Biological Value	Conservation Status 1	Conservation Status 2	Conservation Status 3
1	Cortezian		
2			Magdalena Transition
3		Mexican Temperate Pacific	

1= High Value/Priority, 3= Low Value/Priority

Alternate matrix based on High, Medium, Low rank:

Biological Value	Conservation Status H	Conservation Status M	Conservation Status L
H	Cortezian		
M			Magdalena Transition
L		Mexican Temperate Pacific	

Table 2.7 Cross matrices of biological value and conservation status for setting geographic priorities within the Tropical Eastern Pacific Province. Higher rank of conservation status means a higher degree of threats.

	Biological and Ecological Value						
	Mexican Tropical Pacific	Chiapas/ Nicaragua	Nicoya	Panama Bight	Cocos Is.	Guayaquil	Clipperton and Revillagigedo Is.
Score	32	41	42	45	33	40	23
Ordinal Rank	6	3	2	1	5	4	7
H,M,L Rank	L	M	H	H	L	M	L

	Conservation Status						
	Mexican Tropical Pacific	Chiapas/ Nicaragua	Nicoya	Panama Bight	Cocos Is.	Guayaquil	Clipperton and Revillagigedo Is.
Score	43	48	39	47	25	45	21
Ordinal Rank	6	3	2	1	5	4	7
H,M,L Rank	M	H	M	H	L	M	L

Matrix based on ordinal 1-5 rank:

Biological Value	Conservation Status 1	2	3	4	5	6	7
1		Panama Bight					
2					Nicoya		
3	Chiapas/ Nicaragua						
4			Guayaquil				
5							
6				Mexican Tropical Pacific			
7							Clipperton and Revillagigedo Is.

1= High Value/Priority, 7= Low Value/Priority

Alternate matrix based on High, Medium, Low rank:

Biological Value	Conservation Status H	M	L
H	Panama Bight	Nicoya	
M	Chiapas/ Nicaragua	Guayaquil	
L		Mexican Tropical Pacific	Cocos Is. Clipperton and Revillagigedo Is.

various groups of marine mammals (sea otters, dolphins, whales, pinnipeds); breeding sites of marine mammals and seabirds; abundance of commercially significant populations; and presence of endemics (seabirds, invertebrates).

Conservation status was assessed through the following indicators: degree of disturbance of coastline; impacted or lost breeding sites for fish and seabirds; number of over-fished populations; presence of red tides (toxic algal blooms); introduced species; presence of polluting industries and ports; number of unprotected threatened species; and intensity of tourist visitation in critical areas.

The North Patagonian Gulfs ecoregion received the highest rank for biological value and conservation concerns (see Table 2.9). The numerous seabird and pinniped colonies on rocks, promontories, and islands along the gulfs, as well as abundant fishery resources in the wide and productive adjacent shelf, gave the ecoregion a high value for bioproductivity. The Valdés Peninsula and surrounding gulfs constitute a critical area for conservation due to the abundance of marine mammals, seabirds, and the high rate of tourism.

Fifty-nine species of seabirds inhabit the ecoregion. Of these, 17 breed in the area while 42 use it as foraging and migratory grounds. In addition, 23 shorebirds and three marine ducks are also found here.

The high conservation status score (43) principally results from the over-harvesting of invertebrate (mollusk and crustacean) populations; high potential threats generated by the existence of numerous ports and oil facilities; and

Table 2.8 Cross matrices of biological value and conservation status for setting geographic priorities within the Warm-temperate Southeastern Pacific Province. Higher rank of conservation status means a higher degree of threats.

	Biological and Ecological Value			
	Central Peru	Humboltian	Central Chile	Araucanian
Score	62	72	59	58
Ordinal Rank	2	1	3	4
H,M,L Rank	M	H	L	L

	Conservation Status			
	Central Peru	Humboltian	Central Chile	Araucanian
Score	25	34	27	19
Ordinal Rank	3	1	2	4
H,M,L Rank	M	H	M	L

Matrix based on ordinal 1-5 rank:

Biological Value	Conservation Status 1	2	3	4
1	Humboltian			
2			Central Peru	
3		Central Chile		
4				Araucanian

1= High Value/Priority, 4= Low Value/Priority

Alternate matrix based on High, Medium, Low rank:

Biological Value	Conservation Status H	M	L
H	Humboltian		
M		Central Peru	
L		Central Chile	Araucanian

Table 2.9 Cross matrices of biological value and conservation status for setting geographic priorities within the Cold-temperate South America Province. Higher rank of conservation status means a higher degree of threats.

Biological and Ecological Value	Chiloense	Channels and Fjords of Southern Chile	Malvinas/ Falklands	Patagonian Shelf	North Patagonian Gulfs
Score	59	60	62	60	64
Ordinal Rank	4	3	2	3	1
H,M,L, Rank	M	M	H	M	H

Conservation Status	Chiloense	Channels and Fjords of Southern Chile	Malvinas/ Falklands	Patagonian Shelf	North Patagonian Gulfs
Score	34	30	27	29	43
Ordinal Rank	2	3	5	4	1
H,M,L, Rank	M	M	L	M	H

Matrix based on ordinal 1-5 rank:

Biological Value \ Conservation Status	1	2	3	4	5
1	North Patagonian Gulfs				
2					Malvinas/ Falklands
3			Channels and Fjords of Southern Chile	Patagonian Shelf	
4		Chiloense			
5					

1= High Value/Priority; 4= Low Value/Priority

Alternate matrix based on High, Medium, Low rank:

Biological Value \ Conservation Status	H	M	L
H	North Patagonian Gulfs		Malvinas/ Falklands
M		Chiloense, Channels and Fjords of Southern Chile, Patagonian Shelf	
L			

abundant tourist visitation to important pinniped and seabird aggregation sites as well as depletion of coastal fisheries resources. Both scores gave this ecoregion the highest priority for conservation investments.

Sixty-seven seabird colonies, inhabiting 32 sites along the coastline of San Matías, San José, Nuevo, and San Jorge Gulfs, are threatened by oil pollution and guano collection. At San Jorge Gulf, oil extraction and transportation have resulted in dumping of oily ballast water and the die-off of seabirds. Some breeding sites are recorded as having been lost in the last few years due to guano gathering.

San Antonio Bay is the most important coastal ecotourism site in Chubut Province, with more than 100,000 visitors per year. Six sea bird and shore bird species nest in the area and 17 species of migratory birds (with more than 100,000 individuals) winter in the area. The sea lion (*O. flavescens*) and the endemic Franciscana dolphin (*P. blainvillei*) are also found here. Discharge of untreated wastes into San Antonio Bay (in the San Matías Gulf) has resulted in localized eutrophication. A mineral processing plant (Geotectónica), currently closed, polluted the coastal zone with heavy metals (zinc, lead, copper) that are now leaking into the bays. There are projected plans to clean the area.

In Madryn Port, fishing plants are equipped for effluent treatment, but compliance with regulations is irregular. Biological treatment is inefficient in two of the facilities (Harengus and

Conarpesa). The secondary treatment plant (Servicorp) is ineffective. Effluents of an aluminum plant (Aluar) are used for irrigation and coastal eutrophication has steadily increased along coastal waters over recent years.

In Comodoro Rivadavia, cement plants (Cemento Patagónico), petroleum dehydration, and fish processing either do not treat effluents or have deficient treatment methods. Sewage treatment is non-existent; pipes discharge directly into the ocean and coastal eutrophication is significant.

At Caleta Olivia, there is ineffective secondary treatment of sewage effluents, yet a fishing harbor will soon be opened. It remains unclear whether the regulations will comply with the recommendations of the Environmental Impact Statement.

The barnacle *Balanus glandula* (introduced in the early 70s) has developed a belt along rocky shores whereas prior to this date, the species did not exist in this area. Exotic species make up most of the components of harbor fouling communities, as in Bahía Blanca.

The two second-ranked ecoregions for both biological value and conservation concerns (Chiloense Channels and Fjords of Southern Chile), also have important breeding colonies of penguins, cormorants, sea lions, and fur seals. The increasing salmon culture activity represents a potential threat to the Chiloense ecoregion. Aquaculture operations may generate water eutrophication, an increase in pinniped mortality, and an unknown impact from the introduction of exotic salmon species to coastal ecosystems.

Warm-temperate Southwestern Atlantic Province: The Buenos Aires-Uruguay Shelf Ecoregion

Information was fairly abundant for this province. Experts assessed the biological value of the ecoregions using 28 indicators which can be grouped in the following categories: coastline and shelf extension; presence and extension of outstanding features/communities such as upwellings, kelp and mangrove forests, coral reefs; terrestrial runoff; species richness of fish, macroalgae, corals, toothed and beaked whales, pinnipeds, seabirds, and marine turtles; abundance of marine mammals, seabirds, and fish; presence of breeding/nesting sites for marine mammals, seabirds, and fish; presence of endemic species for the province; and number and abundance of commercially significant species.

Conservation concerns were assessed through 17 indicators in the following categories: alteration of coastline; impacted or lost seabird nesting sites; fish nursery grounds and spawning aggregations lost due to anthropogenic impact; overharvested fisheries resources; introduced species; unprotected threatened species; intensity of land-based sources of pollution (industries, oil facilities); and tourism and military maneuvers.

The Uruguay-Buenos Aires Shelf ecoregion received the highest score on biological importance and on conservation concerns (see Table 2.10). The Uruguay-Buenos Aires Shelf constitutes a wide platform with high biological productivity, abundant populations of finfish, and numerous colonies of marine mammals and seabirds that feed upon those fish. The confluence of the Malvinas and Brazil Currents, together with the abundant terrestrial runoff of Río de la Plata, and the relatively shallow waters of the area, combine to produce a unique environment. However, pollution generated from industries and oil facilities, together with the exploitation of coastal mollusks, coastal development, and intensive tourism, have all combined to assign this ecoregion the highest rank on conservation concerns.

Table 2.10 Cross matrices of biological value and conservation status for setting geographic priorities within the Warm-temperate Southwestern Atlantic Province. Higher rank of conservation status means a higher degree of threats.

Biological and Ecological Value	Uruguay-Buenos Aires Shelf	Río de la Plata	Rio Grande	South-eastern Brazil
Score	69	36	53	60
Ordinal Rank	1	4	3	2
H,M,L Rank	H	L	M	M

Conservation Status	Uruguay-Buenos Aires Shelf	Río de la Plata	Rio Grande	South-eastern Brazil
Score	39	29	29	37
Ordinal Rank	1	3	3	2
H,M,L Rank	H	L	L	H

Matrix based on ordinal 1-5 rank:

Biological Value \ Conservation Status	1	2	3	4
1	Uruguay-Buenos Aires Shelf			
2		South-eastern Brazil		
3			Rio Grande	
4			Río de la Plata	

1= High Value/Priority; 4= Low Value/Priority

Alternate matrix based on High, Medium, Low rank:

Biological Value \ Conservation Status	H	M	L
H	Uruguay-Buenos Aires Shelf		
M	South-eastern Brazil		Rio Grande
L			Río de la Plata

Sixty-five seabirds (e.g. penguins, albatrosses, petrels, shearwaters, gulls, etc.) and 41 estuarine birds can be found in nearby cliffs, promontories, estuaries, coastal wetlands, and sand dunes. Thousands of migratory birds visit this ecoregion. The tern (*Larus atlanticus*) is endemic to the province while 20 species of tooth whales (Phocoenids, Delphinids, Ziphiids, and Physeterids), the right whale and five pinnipeds are reported to inhabit the ecoregion. Endemic to the South Atlantic, the franciscana dolphin (*P. blainvillei*), the southern fur seal (*A. australis*), the sea lion (*Otaria flavescens*), and the southern right whale (*Eubalaena australis*) have breeding grounds in the area. Marine turtles (*Chelonia mydas, Dermochelys coriacea, Caretta caretta*) reach this latitude as well.

About 22 species of fish, 9 mollusks, and 5 crustaceans are commercially significant, and together account for the production of hundreds of thousands of metric tons. The population of hake (*Merluccius hubbsi*) alone has an estimated potential fishable stock of 350,000 metric tons.

The two ecoregions ranked second for biological value and conservation concerns after the Uruguay-Buenos Aires Shelf, were Southeastern Brazil and Rio Grande (Brazil). Adjacent to one another, Southeastern Brazil has higher levels of conservation concerns than Rio Grande, though the two ecoregions have a similar shelf coverage within the EEZ contour (about 30%). Rio Grande is characterized by numerous coastal lagoons, including the Patos (the largest in South America) and Mirim lagoons. These lagoons have an important freshwater discharge that create a productive environment for fish, invertebrates, and migratory birds, as well as resident shorebirds and seabirds.

The conservation status of Southeastern Brazil's mangroves was assessed by WWF as endangered, considering its medium level of threat. A combination of sustainable use and restoration was recommended.

Impacts from human activities in great metropolitan areas such as Rio de Janeiro and São Paulo are the main threat to marine conservation in the ecoregion.

Tropical Southwestern Atlantic Province: The Northeastern Brazil Ecoregion

Limited data was available for this province. Experts assessed this ecoregion using 21 indicators, including: presence and extension of outstanding features/communities (coral reefs, mangrove forests, macroalgae beds, and terrestrial runoff); species richness for fish, mollusks, macroalgae, corals, marine mammals, seabirds, and sea turtles; and abundance of fishery resources.

Conservation concerns were evaluated through the following indicators: level of coastal, mangrove, and reef disturbance; number of extinct species; impact and loss of fish nursery grounds, seabird, and marine turtles nesting sites; changes in abundance of fishery resources; sources of pollution; and reef visitation.

The Northeastern and Eastern Brazil ecoregions received the highest biological importance rank followed by Amazonian (see Table 2.11). In Northeastern Brazil,

Table 2.11 Cross matrices of biological value and conservation status for setting geographic priorities within the Tropical Southwestern Atlantic Province. Higher rank of conservation status means a higher degree of threats.

	Biological and Ecological Value				
	Amazonian	North-eastern Brazil	São Pedro and São Paulo Is.	Eastern Brazil	Trindade and Martin Vaz Is.
Score	39	52	23	50	22
Ordinal Rank	3	1	4	2	5
H,M,L Rank	M	H	L	H	L

	Conservation Status				
	Amazonian	North-eastern Brazil	São Pedro and São Paulo Is.	Eastern Brazil	Trindade and Martin Vaz Is.
Score	24	44	19	41	20
Ordinal Rank	3	1	5	2	4
H,M,L Rank	L	H	L	H	L

Matrix based on ordinal 1-5 rank:

Biological Value	Conservation Status: 1	2	3	4	5
1	Northeastern Brazil				
2		Eastern Brazil			
3			Amazonian		
4					São Pedro and São Paulo Is.
5				Trindade and Martin Vaz Is.	

1= High Value/Priority; 5= Low Value/Priority

Alternate matrix based on High, Medium, Low rank:

Biological Value	Conservation Status: H	M	L
H	Northeastern Brazil,Eastern Brazil		
M			Amazonian
L			São Pedro and São Paulo Is., Trindade and Martin Vaz Is.

as in Eastern Brazil, fish, seabird, and turtle richness and the presence of coral reefs combine to produce these results. Large numbers of nesting sites and nursery grounds for sea turtles are also found. In Northeastern Brazil, coral reefs at Atol das Rocas and the Fernando de Noronha archipelago give the ecoregion a high conservation value. In Eastern Brazil, the Abrolhos Bank is the southernmost extent of the Caribbean coral species. The bank contains high coral-based biodiversity and is a major habitat for the breeding and calving of humpback whales.

The Amazonian ecoregion is occupied mostly by the delta—a good habitat for abundant populations of shorebirds. The waters covering the platform area (20% of the ecoregion), particularly its northern portion, contain high densities of suspended sediments that prevent the existence of certain diverse tropical communities such as coral reefs. The conservation status of mangroves of both the Northeastern Brazil and Eastern Brazil ecoregions were assessed respectively as Vulnerable to Endangered (both with medium level of threats) by WWF (Olson et al., 1996). In contrast, the mangroves of the Amazonian ecoregion were evaluated as one of the two best conserved (in Relatively Stable status) in South America (together with the mangrove units of the Panama Bight ecoregion, in the Tropical Eastern Pacific), with a medium level of threat. For the Amazonian ecoregion, sustainable use (at the delta and to the east) and restricted access, combined with sustainable use (from this area to the eastern boundary of the ecoregion), were recommended. Restoration was advised for the Northeastern Brazil ecoregion.

The biological value and conservation status scores for the Northeastern Brazil and Eastern Brazil ecoregions were similar. Only a slight difference made the former outrank the latter. Conservation investors should consider this slight difference when making investment decisions.

Tropical Northwestern Atlantic Province: The Central Caribbean Ecoregion

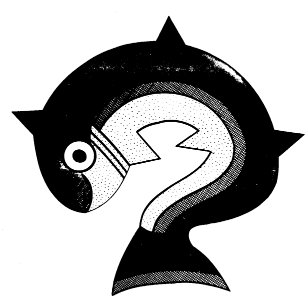
The Central Caribbean ecoregion is the subject of a case study in the next chapter.

Conclusion

As opposed to the ad hoc processes generally used in the past to delineate high-priority sites for marine conservation, the framework first developed in the study of terrestrial ecoregions and applied here with some modifications, provides an empirical basis for identifying marine ecoregions that are a high priority for biodiversity conservation.

The high-priority ecoregions identified here are still generally much too large to be considered as sites for actively managed biodiversity conservation.

In the next chapter, a framework for identifying high-priority coastal systems in the Central Caribbean ecoregion of the Tropical Northwestern Atlantic province is proposed. These smaller systems are examples of the types of systems that donors, governments, NGOs, and conservation organizations could target for active conservation management.



Delineating, Classifying, and Ranking Coastal Systems — Part 2

Chapter 3 Identifying and Ranking Coastal Systems in the Central Caribbean Ecoregion

THE DELINEATION OF PROVINCES and ecoregions as well as the ranking of ecoregions within each province provides valuable information for governments, donors, and others interested in marine conservation. In order to identify specific sites for marine conservation action and coastal stewardship programs, however, it is necessary to go one step further and identify and rank smaller "Coastal Systems" within an ecoregion. As a case study, the Central Caribbean ecoregion in the Tropical Northwestern Atlantic has been selected.

This chapter includes a brief description of the Tropical Northwestern Atlantic province, followed by a description of the approach used to rank the ecoregions within the province and background on the Central Caribbean ecoregion. This effort to rank coastal systems within the ecoregion represents a preliminary attempt to develop conservation priorities for geographic units. With more accurate information, the process could be substantially improved.

The Tropical Northwestern Atlantic Province

The Tropical Northwestern Atlantic is the largest coastal marine province in the Western Hemisphere and extends from the tropical waters of the Gulf of Mexico and South Florida to the French Guiana-Brazil border (see Appendix A-11). The province is popularly referred to as the "wider Caribbean" and is principally known for the extensive coral reef development along coastlines and at shallow platform margins (barrier reef systems). The description of this province and its ecoregions is provided in Chapter 1.

Three threats can be described as impacting marine diversity province-wide:

- *Changes in water quality leading to dynamic habitat degradation*

Nutrification occurs when naturally

oligotrophic systems, such as coral reefs, receive elevated levels of inorganic nutrients, especially phosphorus and nitrogen. The primary source of these nutrients is untreated sewage or agricultural runoff entering the marine environment from outfalls and streams, with lesser amounts discharged by vessels into large marinas and harbors. Pollution abatement is relatively rare; less than 10% of all sewage generated in the province's coastal areas receives secondary treatment. Livestock operations and forestry can also contribute to elevated nutrient levels in nearshore marine environments by releasing large amounts of nitrogen and phosphorus into coastal rivers.

Agriculture contributes nutrients during cropland conversion and through the application of fertilizers. Silt and sediment come from land conversion and dredging. Upland management, including livestock ranching, timber practices, road building, and agriculture alter the amount and rate of sediment deposition in waterways and runoff destined for the nearshore marine environment. Coastal development produces beach alteration and frequently destroys mangrove systems and coastal lagoons; coastal wetlands that are critical for filtering land-borne particles. Silt and sediment smother coral reefs, decreasing growth and reproductive rates in corals and possibly increasing the incidence of coral diseases. Sediments and nutrification can also negatively affect sponges. Large shallow-water sponges are important for water filtering and for fauna habitat on both reefs and in seagrass beds.

- *Coastal development leading to physical habitat degradation and loss*

Mangrove complexes and coastal lagoons are vitally important habitats for many fish and invertebrate species, especially during the early stages in their life cycles. Development poses a constant threat to such systems. Mangroves are cleared for wood and charcoal and to make way for shoreline development. Coastal lagoons are dredged for harbors, converted to shrimp farms, and lost to resort development. The decline in coastal vegetation communities, nearshore marine habitats, and mangrove wetlands can contribute to the decline of commercially important species such as lobster, snapper, and grunt which rely on coastal areas as juveniles.

- *Over-harvesting or extraction threats to populations and natural communities*

Over-fishing occurs chronically throughout the province. Destructive fishing practices, poor enforcement of existing regulations, and insufficient fisheries management coupled with severe economic constraints make over-fishing a difficult problem to tackle. Over-fishing is a particularly insidious threat. Depletion of target species not only impacts the specific population, but also results in second-order effects for the entire biological community. Removal of spiny lobsters, for example, not only changes the population dynamics of the lobster, but also alters the reef environments where lobsters play a key ecological role as detritivores in recycling nutrients. Over-exploitation of some snapper and grouper species has resulted in the alteration of the fish community structure of seagrass-reef complexes in many areas.

Ranking the Ecoregions

The Tropical Northwestern Atlantic province includes six ecoregions: the Guianan, the Lesser Antilles, the Bahamian, the Central Caribbean, the South Florida, and the Gulf of Mexico (see Chapter 1 for their description and Tables 2.3-5 for ranking). These divisions were based on faunal distribution of organisms such as stony corals, octocorals, and fishes. Bermuda may also be included as the seventh ecoregion in this province, but was excluded from this exercise. Geographic indicators of the ecoregions within the province are given in Table 1.1.

The ranking of ecoregions within the Tropical Northwestern Atlantic followed the same approach outlined earlier. Indicators of biological and ecological value were compiled for five of the six ecoregions. Due to insufficient information, the Guianan ecoregion was not ranked.

The indicators of biological and ecological value included physical conditions, species composition, abundance of species, breeding areas, and fishery resources. With a score of 56, the Central Caribbean was clearly the highest scoring ecoregion while the Gulf of Mexico, South Florida and the Bahamian ecoregions had scores of 38, 39, and 37, respectively. The Lesser Antilles ranked the lowest with a score of 28 (see Table 2.3).

The conservation status score was based on changes in physical conditions, loss or changes in abundance of species, loss of breeding areas or nesting sites, and changes in fisheries. All ecoregions except the Bahamian were assessed as having serious conservation threats to coastal marine biological diversity. The Central Caribbean and the Lesser Antilles ranked the highest in conservation status (most threatened) with scores of 44 and 41 (see Table 2.4).

Case Study: The Central Caribbean Ecoregion

The Central Caribbean is the largest and most complex of the ecoregions in the Tropical Northwestern Atlantic province. Including both continental and insular systems and some 2,648,000 km^2 of shallow banks and coastal shelf, the ecoregion occupies 46% of the entire province. Politically, the ecoregion includes the entire coastal areas of Venezuela, Aruba, Curaçao, Bonaire, Belize, Cuba, Haiti, Jamaica, Trinidad and Tobago, Puerto Rico, the Dominican Republic, and the Cayman Islands. It includes parts of Colombia, Panama, Costa Rica, Nicaragua, Honduras, Guatemala, and Mexico (see Appendix A-12).

The islands typically have higher coastal population densities than continental areas. There is a wide disparity of wealth throughout the ecoregion, from very poor (such as Haiti) to relatively rich (such as the Cayman Islands and Aruba).

The entire ecoregion can be divided into insular and continental components. A large proportion of marine species are distributed along both the coasts of the greater Antilles and the coasts of Central and South America. Thus, there are biogeographic reasons to group this large area as one ecoregion. However, there are differences in coastal processes, abundance, and distribution of natural communities from islands to continent and from east to west. The coastlines of the ecoregion are diverse, including large river deltas and estuaries, mangrove forests, sandy beaches, complex bays and coastal lagoons, offshore cays, upwelling areas, rocky shorelines, and offshore blue holes. There are also a series of coral atolls along the western extent of the ecoregion and a few oceanic banks.

This ecoregion is unique in its coastal morphology. It harbors large land masses with adjacent mountains on both the continent and the larger islands (e.g. Cuba and Hispaniola). There are numerous rivers, both large and small, that naturally transport silt and sediment to deltas, shore, and beaches. Rivers can be both permanent and seasonal. Endemic species have been described for locations in the ecoregion. For example, in the Cayman Islands, three species of mollusks and a species of fish of the blenny family (*Starksia y-lineata*) are endemic. The species inventories and descriptions of many taxa are considered incomplete, and there are likely other species restricted to this ecoregion as well. There are regionally critical populations of seabirds and marine mammals (e.g. West Indian manatee), but unfortunately there are no ecological borders incorporated in the management of marine resources.

This vast ecoregion has large coastal population densities, a long history of human use of marine resources, and significant land-based sources of pollution associated with oil extraction, port development, and agriculture. The ecoregion has experienced loss of coastal habitats in the removal of mangroves and diversion of rivers for agriculture. Species have been lost, including the Caribbean monk seal and the Jamaican petrel. Spawning aggregations of grouper and snapper species have disappeared throughout the ecoregion. Many countries report the collapse and closure of at least one fishery in the past 20 years.

The Ecoregion's Biological Value

The Central Caribbean provides a multitude of challenges for the conservation of marine resources, most notably large diverse coastal areas under multinational jurisdictions (see Appendix A-12). Table 2.3 shows a scorecard for the ecoregion's biological value.

Physical conditions

The Central Caribbean extends across more than 20 degrees of longitude and more than 10 degrees of latitude, poised just north of the equator. Physical characteristics such as coastline shape, continental shelf width, and abundance of rivers and estuaries all contribute to a very complex matrix of oceanographic and geomorphological features which support a wide variety of marine communities and systems. From the south, the ecoregion begins at the Orinoco River delta, the third largest river in the hemisphere, and extends to the eastern shore of the Yucatán Peninsula. The ecoregion is made up geographically of three components: the continental coastline of Central and South America, the insular coasts of the Greater Antilles (Cuba, Jamaica, Hispaniola, and Puerto Rico), and a number of small islands and banks. No other ecoregion contains such diversity of geography.

Species composition

The Caribbean coasts of Colombia and Venezuela alone can account for a province-wide maximum of fish, macroalgae, seabird, and marine mammal species. The number of seabird and marine mammal species tends to be slightly higher for the coasts of Colombia and Venezuela than for other locations in the ecoregion. The number of fish and mollusk species is especially high, including both marine and estuarine species. Only South Florida, an important faunal transition area, has comparable numbers of teleost and mollusk species. Some 791 species of gastropods and 427 species of bivalves are reported for the Caribbean coast of South America. Of the 31 species of marine mammals that are recorded province wide, 29 are reported for the Central Caribbean Ecoregion.

Abundance of marine life and fisheries resources

The coast of Venezuela boasts the highest tonnage of fish landed in both the province and the ecoregion. The total tonnage of fisheries landings for invertebrates and finfish exceed half a million tons annually. The second highest fisheries landings are in the Gulf of Mexico. The central Caribbean is ranked highest in fisheries resources in terms of total tonnage landed and number of species harvested commercially, yet it is difficult to compare catches over broad areas and between countries due to lack of fisheries statistics in many countries.

Breeding and nesting sites for marine life

This ecoregion has important nesting sites for turtles as well as for seabirds. Almost all the province's nesting sites for boobies and gannets (family Sulidae) are found within this ecoregion.

The Ecoregion's Conservation Status

Conservation status indicators were compiled for all five ecoregions within the Tropical Northwestern Atlantic for which we have data (see Table 2.4).

The ranking of conservation status was based on four main groups of indicators: changes in the ecoregion's physical coastline; loss of species; changes in abundance of species; and evaluation of potential threats.

Physical changes in the coastline can often be evaluated by remote sensing. Measures such as the extent of altered coastlines, number of rivers dammed, and the number of major ports or oil terminals, are indicators of both local changes in water quality and land-based sources of pollution. Losses of species (both in recorded extinction and in local loss of species) were recorded for fish, invertebrates, seabirds, and marine mammals. Historical documentation of the decrease in abundance of organisms has been compiled primarily for fishery target species, but some records are also available for seabirds. A summary of the ranking between ecoregions in the province is given in Table 2.4.

There appears to be a high correlation between the number of people living on coastal plains and the quality of the marine environment. More people typically mean more land-based sources of pollution, more port development, more fishing activity, and greater loss of coastal wetlands and nearshore habitats. There are a number of marine species that are listed as threatened or endangered for the ecoregion. Corals, mollusks, crustaceans, fish, seabirds, and marine mammals that are of regional concern are listed in both the IUCN "redbook" or identified as CITES species needing protection. Unfortunately, there is no comprehensive dataset on the status of these species throughout the ecoregion or the province. The lack of information does not make the problem of species loss and decline any less real. These threats are likely to persist, since there is no reason to believe that trends in coastal development, over-harvesting, or pollution of coastal waters are abating.

Reports on the conservation status of the ecoregion from an objective set of criteria do not provide information on the specific threats in a given area. Threats to marine biodiversity occur on a regional scale, such as increased land-based sources of pollution throughout the Caribbean Sea, or on a very localized scale, such as an oil spill. Site-based action depends on an analysis of threats to determine their scale or extent, scope and duration, severity, reversibility, and sometimes, probability or likelihood of occurrence.

Clearly, there are close ties between land-based activities in coastal areas and consequent impacts on marine resources. Coastal marine conservation must be, by necessity, closely linked to terrestrial conservation.

There appear to be two main types of threats to coastal marine biological diversity: threats to coastal water quality and coastal habitats such as mangrove forests and direct threats to targeted species. Threats that may be significant in a given location, but are less prevalent regionally include: oil pollution; salinity changes due to alteration of river flows; waterborne or airborne pesticides and other chemical contaminants; mechanical damage from vessel grounding and inadequate anchoring; propeller impacts to substrate materials; disturbance by divers; introduction of exotic or alien species; marine debris; and beach erosion.

Threats that affect directly species targets include: manatee hunting; turtle and turtle-egg gathering; seabird-egg gathering; fishing for spawning aggregations; and intensive fishing of fish stocks at critical life stages, such as juveniles and spawning stocks.

Delineating Coastal Systems in the Central Caribbean

In previous sections, oceanography, coastal morphology, climate changes, and specific faunal complexes defined the delineation of ecoregions. Ranking ecoregions within provinces required completing "scorecards" on biological value and conservation status of individual ecoregions.

For effective conservation action, an additional level of resolution needs to be added to look at smaller ecological units of the coastline. This classification needs to balance both the need to initiate conservation action against the cost or difficulty of compiling information at a smaller scale.

Experts from around the region proposed creating smaller ecologically sensitive units with a realistic scale to both track information and plan management actions. These smaller units were designated as **coastal biogeographic systems** or more simply **coastal systems**.

A coastal system can be described as an area of coastline and shelf waters with similar geology, shelf morphology, runoff, and coastal oceanography. Coastal systems are influenced both by land from drainage areas and by sea from coastal oceanography, including currents, tides, and upwellings. Ideally, there would be sufficient information on the physiography and ecology of coastal areas to define units that contain a discrete assemblage of natural communities and, perhaps, discrete populations of some marine organisms.

Coastal systems are larger than any marine park or protected area, as parks and protected areas are designed to be only one component of coastal zone management. Rather, the Coastal System should be considered a minimum size for considering ecological and physical processes that are essential to maintaining coastal biological diversity. Sections of the coastal shelf were delineated by boundaries generated by expert opinion.

The Central Caribbean ecoregion was broken up into 51 coastal systems that extended from coastal wetlands (mangroves) to the 1,000-m depth contour or isobath (see Appendix A-13). Coastal systems varied in size from a few thousand square kilometers to more than 28,000 km^2 in the Orinoco River Delta. These coastal systems were classified both by physical features and by dominant natural community types, including:

- Mangrove-dominated coastal systems with both continental forest and island forest systems;
- Reef-dominated coastal systems with island reef systems, banks, atolls, high-energy rocky shore/fringing reef systems, and mixed-shore fringing reef systems;
- Mixed coastal systems that include large shallow bays, numerous offshore islands, coral reefs, seagrass beds, and mangrove forests;
- Seagrass-dominated coastal systems;
- Beach-dominated coastal systems;
- Upwelling systems; and
- Rocky platform systems.

Selecting Priority Sites for Conservation Action

As a next step, a priority-setting exercise developed methods for identifying locations within the Central Caribbean ecoregion for site-based conservation. There were two questions to be addressed:

Table 3.1 Sources of threats and their associated stresses to different coastal system types in the Central Caribbean.

Coastal System type (according to dominant habitat)	Sources of threats	Stress
Seagrass	• overfishing (with no quota, closed seasons, size limits, fishing gear restrictions, or no-take zones) and illegal hunting	• decline of populations of fish, invertebrates, sea turtles, manatees, and alteration of biological communities and habitats
	• sewage, agricultural run-off	• nutrification
	• mangrove deforestation	• near-shore sedimentation
	• irresponsible boating	• mechanical damage to seafloor, and habitat degradation
Mangrove (island and continental)	• hydrologic alteration for irrigation, urban development, flood control	• water quality changes (freshwater diversion)
	• logging	• loss of mangrove habitats
	• development of coastal wetlands (dredge and fill activities); coastal aquaculture	• loss of coastal fish habitat; coastal erosion
Coral reef (atolls, banks, fringing reef)	• overfishing (with no quota, closed seasons, size limits, fishing gear restrictions, or no-take zones)	• decline of reef fish and invertebrate populations, and alteration of biological communities and habitats
	• sewage, shoreline development	• nutrification; increase of algae coverage and coral deterioration
	• upland deforestation, agricultural run-off	• sedimentation; coral deterioration
	• irresponsible diving and boating, destructive fishing practices	• mechanical damage to coral reefs
Mixed (large areas with offshore islands, mangroves, coral reefs, and seagrass beds)	• overfishing (with no closed seasons, size or quota limits, fishing gear restrictions, or no-take zones)	• decline of populations and alteration of biological communities and habitats
	• sewage, shoreline development	• nutrification
	• upland deforestation, agricultural run-off	• sedimentation
	• development of coastal wetlands (dredge and fill activities)	• deforestation of mangrove keys
	• irresponsible diving and boating, destructive fishing practices	• mechanical damage to seafloor (seagrass beds, coral reefs)
Upwelling	• overfishing (with no closed seasons, size or quota limits, fishing gear restrictions, or no-take zones)	• population decline of dolphins and pelagic fish
Beach	• unregulated or irresponsible construction	• beach erosion; habitat degradation for sea turtles nesting
Rocky platform	• littering, shoreline development	• habitat degradation

What are the smaller units of ecological significance, and which of these smaller units should be targeted for initial action?

Conservation targets such as species or natural communities can represent one method of mapping and identifying priority sites. However, complete information on the status of species and communities does not exist on a coastal-system scale. In the selection of coastal sites, three approaches were employed:

- *Selecting the best representatives of each type of coastal setting or environment:* In the Central Caribbean, each type is represented by the seven kinds of coastal systems listed above.

- *Selecting the widest geographic distribution of coastal systems:* The circulation pattern in the Central Caribbean is from east to west through the Caribbean basin, then north through the straits of Yucatán to the Gulf of Mexico. Colombia and Venezuela represent upstream systems, while Belize, Mexico (coast of the state of Quintana Roo), and Cuba are downstream systems.

- *Selecting sites based on feasibility and the urgency of their conservation status:* A discussion of the current status of resources, amount of coastal development and habitat loss, as well as feasibility for working in these areas served to finalize the selection of priority coastal systems.

Delineation of Coastal Systems

The delineation of coastal systems represents a viable starting point for recognizing that there are large sections of coastline that should be included in a conservation portfolio. These include unique features such as extensive mangrove forests, wide coastal shelves and seagrass beds, and well-developed coral reefs. These criteria comprise one method of assigning a biological value to different geographic areas. Each type of coastal system needs to be represented in a priority portfolio.

In addition, the *threats and human impacts* to these units were assessed in order to identify the most intact sites. Three central threats—over-harvesting, loss of coastal habitats, and changes in water quality—can occur on both regional and local scales. Specific threats can jeopardize the ecological processes of coastal systems (see Table 3.1). Many times, in a priority-setting exercise there may be quantitative information on the status of each geographic unit, but specific information on, for example, the status of fisheries target species or the amount of oil pollution does not exist at the level of coastal systems in the Central Caribbean ecoregion. The threats assessment needs to be evaluated on a more generic level by regional experts who can give an opinion based on personal experience and observations of changes to an area over time. This method assigns a conservation status to smaller coastal areas, but because of the smaller scale, the emphasis must be placed on areas with the lowest level of disturbance and change from human activities.

Finally, a *feasibility assessment* can help identify those sites with the best chance for coastal marine conservation programs. Environmental degradation and loss of biological diversity are often the consequences of other social, economic, or political problems. Ideally, an area's population would already possess a high level of problem awareness; have organizations willing to take a leadership role in improving marine park management or in changing fishing practices; and the government would be willing to support academic institutions working in the area as well as government agencies with jurisdictional responsibility. This feasibility assessment can also be based on an area's accessibility, since work in remote regions is inherently more difficult.

There is one additional factor in the ranking of coastal systems: *geographic position*. We recognize that the larvae and propagules of many species rely on ocean currents and coastal circulation for dispersal. Ocean currents are well described and move primarily from the southeastern area of the ecoregion to the northwestern areas. This general pattern of water circulation places coastal systems as “upstream,” “midstream,” and “downstream.” However, this positioning is based only on a macro-scale model. Coastal currents can vary both seasonally and yearly, and the actual transport process of larvae and propagules can be highly stochastic. Smaller-scale gyres, eddies, and upwelling events can impact larval dispersal and recruitment and, thus, species population dynamics and distribution within and between coastal systems. The seasonal and inter-annual variability of coastal circulation and the impact of freshwater runoff are key areas for research and monitoring of coastal systems and help to form a better understanding of how larvae travel from one coastal system to the other. Geographic position can serve as an initial approximation of a system’s importance as a source of propagules from one system to another coastal system. This study attempted to capture both upstream and downstream components of each type of coastal system.

These criteria for the selection of priority coastal systems within the Central Caribbean ecoregion were developed and applied by a number of conservation scientists and planners of The Nature Conservancy’s Latin America and Caribbean Region. The result of this exercise was reviewed by the project contributors who delineated and classified the coastal systems. Additional information about ecological integrity and threats to coastal systems, as well as the local social and political context, might refine this process or lead to a different result. The authors view this as a first attempt to develop priorities for marine conservation units in the Caribbean. Further efforts to improve this process and to adapt it to the specific conditions of other ecoregions are welcomed.

Conservation Status Assessment

The assessment of threats or conservation status of a coastal system is outlined in Table 3.2, where coastal systems are arranged by type. For example, there is only one atoll reef coastal system (Belize and Mexican Atolls) and one bank reef system (Pedro Bank) within the Central Caribbean ecoregion. Both of these systems are a long distance from the mainland or population centers and are threatened primarily by over-harvesting. They are given a high urgency classification for conservation action based on the present low level of human disturbance, but the high probability for increased impacts in the near future.

The assessment of feasibility for conservation action was based upon the existence of parks and protected areas as well as the institutional capacity for the protection of coastal resources (see Table 3.3). The latter includes the presence of conservation nongovernmental organizations, research centers, and government agencies actively involved in local resource stewardship.

Existing parks or protected areas that include coastal environments were considered an important starting point for site-based conservation programs. Often, the design and authorization of a park or protected area can take years. Thus, the existence of a park, even without a management structure, is an advantage. Coastal systems that include more than one country can provide additional challenges and difficulties in site-based conservation, unless there is already a history of collaborative programs and cooperation in managing coastal resources such as fisheries. High feasibility areas are likely to involve only a single country

Table 3.2 Analysis of threats and urgency for conservation by coastal system for the Central Caribbean marine ecoregion. Coastal systems types are grouped by main category. Loss or decline of species abundance include targeted fisheries species (finfish and invertebrates). Urgency for conservation action reflects the needs to abate current or potential threats from habitat degradation and resource extraction activities and is based on regional expert opinion.

Coastal System	Area (km²)	Coastal System Type*	Sources of threats	Stress F= loss or decline in species abundance, WQ = water quality changes, H = coastal habitat loss	Urgency for conservation action (high, medium, low)
Belize and Mexican Atolls	9,438	A	overfishing	F	H
Pedro Bank	20,133	B	overfishing	F, H	H
Barlovento	14,506	M	deforestation	WQ, F, H	M
Central Honduran Coast	11,247	M	agriculture, fishing	WQ, F	H
Falcón	14,648	M	urbanization, oil	WQ, H	H
Gulf of Venezuela-Lago de Maracaibo	27,937	M	oil, fishing	WQ, F, H	H
Orinoco Delta	28,694	M	oil	WQ	M-H
Gulf of Honduras	6,154	M	overfishing, logging	WQ, F	H
Southwestern Colombia	9,708	M	-	-	L
North Central Cuba	16,886	MI	development	WQ, F	H
Samaná	2,094	MI	agriculture, fishing	WQ, F, H	M-H
Southern Jamaica	7,496	MI	development, fishing	WQ, F, H	H
Bocas del Toro	4,780	MX	oil, fishing	WQ, F, H	H
Coastal Belize	4,855	MX	farming, development	WQ, F, H	H
East Panama Canal	2,473	MX	tourism	WQ, H	L-M
Eastern Yucatán Bays	7,667	MX	overfishing, development	WQ, F, H	M
Gulf of Batabanó	27,673	MX	overfishing, coastal development, pollution, tourism	WQ, F, H	M
Offshore Venezuela Is.	13,475	MX	overfishing, tourism	F	M
San Blas	6,795	MX	overfishing	F	H
West Central Colombia	12,534	MX	highway construction	WQ, H	H
Northwestern Cuba	6,044	MX	fishing, development, mining	WQ, F, H	M-H
Southeastern Cuba	24,422	MX	river damming, industrial wastes, fishing	WQ, F, H	M-H
Central Venezuela	12,734	O	industry	WQ	H
East Central Colombia	2,330	O	development, overfishing, tourism	WQ, F	H
Eastern Colombia	24,345	O	overfishing	F	L
San Juan River	13,065	O	tourism, fishing	WQ, F	H
South Central Cuba	2,849	O	industrial waste	WQ, F	H
West Panama Canal	8,486	O	-	-	L
Central Hispaniola	8,942	RF	overfishing, development	WQ, F, H	L
Eastern Cuba	13,407	RF	mining, development, overfishing	WQ, H	H
Southern Puerto Rico	9,082	RF	fishing, development	WQ, F	M-H
Eastern Hispaniola	11,314	RF	overfishing, development, tourism	WQ, F, H	M-H
Southeastern Jamaica	5,563	RF	urbanization	WQ, F, H	H
Southwestern Hispaniola	11,757	RF	deforestation, overfishing	WQ, F, H	M-H

Table 3.2 Analysis of threats and urgency for conservation by coastal system for the Central Caribbean marine ecoregion *(continued)*

Coastal System	Area (km^2)	Coastal System Type*	Sources of threats	Stress F= loss or decline in species abundance, WQ = water quality changes, H = coastal habitat loss	Urgency for conservation action (high, medium, low)
Western Cuba	1,899	RF	isolated area	WQ, F	L
Western Hispaniola	8,372	RF	all	WQ, F, H	M
Aruba-Curaçao-Bonaire	4,505	RI	oil, development, overfishing	WQ, F, H	M-H
Bay Islands	6,284	RI	fishing, tourism	WQ, F, H	H
Cayman Islands	3,380	RI	fishing, tourism	WQ, F	M
Offshore Colombian Islands	11,446	RI	fishing, tourism	WQ, F	H
Swan Islands	5,453	RI	overfishing	F	M
Costa Rican Reefs	1,719	RMS	deforestation, development	WQ, F	H
Havana-Matanzas	2,109	RMS	pollution, development (large city, tourist beaches)	WQ, H	L
Northern Jamaica	3,382	RMS	coastal development	WQ, F, H	H
Quintana Roo	12,131	RMS	tourism development, overfishing	WQ, F	H
Northern Hispaniola	8,599	RMS/MI	deforestation, agriculture, fishing	WQ, F, H	M
Northern Puerto Rico	4,223	RMS/MI	fishing, development	WQ, F, H	M
Eastern Venezuela	50,457	S	overfishing, development, natural gas	WQ, F	M-H
Northern Miskitos	85,504	S	deforestation, overfishing	WQ, F	M-H[a]
Southern Miskitos	73,238	S	overfishing	F	M
Trinidad and Tobago	36,604	S	development, overfishing	WQ, F, H	L-M
total area	**722,817**				

Coastal system types (according to dominant habitat present): A- atoll; B- bank; M- mangrove continental forest; MI- mangrove island forest; MX- mixed mangrove-reef-seagrass; RF- high-energy rocky shore/fringing reef; RI- island reefs; RMS- mixed shore/fringing reef; S- seagrass; O- other such as upwelling areas, beaches and rocky platforms; a- higher in the coastal wetlands and flooded plains, M-H- when considered the whole system.

where protected areas and organizations active in coastal management and conservation issues are already in place. Also, the presence of marine laboratories or national universities that have worked in the area is a tremendous advantage.

Unfortunately, there are areas of spectacular natural beauty and biological importance that are already impacted by oil extraction, port development, or large coastal populations. These sites may be the focus of specific restoration projects which require different skills and funding sources than conservation projects. The feasibility assessment includes as "high" feasibility areas the Belize and Mexican Atolls. Although this coastal system is a long distance from shore and there are accessibility issues, both Belize and Mexico are active in protecting their reefs and recognize the contributions of these reefs to tourism and fisheries. There are already nongovernmental conservation organizations working in both countries for the protection of this area and several research institutions are carrying out ecological and fisheries research at these sites. In Cuba, particularly in the Gulf of Batabanó and the Southeastern Cuba and North Central Cuba coastal systems, extensive ecological and fisheries resource assessments have been conducted during the last 20

Table 3.3 Analysis of feasibility for conservation investment by coastal system (grouped by type) for the Central Caribbean Ecoregion. Feasibility evaluation includes the presence of protected areas and parks, as well as the current national capacity for marine resource research and protection, and the political will to conserve resources in the area (analysis based on regional expert opinion).

Coastal System	Area (km^2)	Coastline Length (km)	Coastline Mangrove Length (km)	Coastal System Type*	Feasibility (H=high, M=medium, L=low)	Feasibility comments
Belize and Mexican Atolls	9,438	366	366	A	H	Belize and Mexico both have high interest in coral reef conservation
Pedro Bank	20,133	0	0	B	L	Bank belongs to Jamaica, but is offshore and inaccessible
Barlovento	14,506	412	258	M	L	One protected area along this section of the Venezuelan coast
Central Honduran Coast	11,247	404	260	M	M	Some protected areas exist; extensive agricultural development occurring
Falcón	14,648	499	140	M	M-H	Three national parks and one wildlife refuge exist
Gulf of Venezuela-Lago de Maracaibo	27,937	1,435	659	M	L	Coast is heavily impacted by oil exploration
Orinoco Delta	28,694	1,923	1,839	M	M-H	Largely intact estuary with many upstream alterations to drainage basin
Gulf of Honduras	6,154	404	314	M	H	Tri-national area with ongoing initiative for marine resource management
Southwestern Colombia	9,708	486	293	M	L	Extensive coastal development exists
North Central Cuba	16,886	3,573	3,013	MI	H	Zoning with protected areas proposed after comprehensive ecological assessment
Samana	2,094	204	77	MI	L	Already a large national park, with part of bay as a humpback whale sanctuary
Southern Jamaica	7,496	302	144	MI	M-H	Proposed park in the area with strong conservation NGO community
Bocas del Toro	4,780	633	191	MX	H	Straddles two countries where two parks already exist; park zoning proposed; on-going initiatives in cooperative management
Coastal Belize	4,855	360	338	MX	M	Lack of resources for protection and a small marine reserve is present. On-going process for the designation of another marine reserve
East Panama Canal	2,473	166	49	MX	M	One park already exists
Eastern Yucatán Bays	7,667	901	850	MX	H	One half of area is a bioreserve; much activity under way in reef conservation
Gulf of Batabanó	27,673	1,831	1,688	MX	H	Marine resources well studied and one protected area exists
Offshore Venezuela Islands	13,475	232	222	MX	H	Public land with two national parks and one wildlife refuge in existence
San Blas	6,795	356	50	MX	M	Coast is largely the Kuna Indian Reservation
West Central Colombia	12,534	516	244	MX	M	One national park exists
Northwestern Cuba	6,044	375	355	MX	M	No MPAs exist
Southeastern Cuba	24,422	1,434	1,351	MX	H	Small reef reserve present

Table 3.3 Analysis of feasibility for conservation investment by coastal system *(continued)*

Coastal System	Area (km^2)	Coastline Length (km)	Coastline Mangrove Length (km)	Coastal System Type*	Feasibility (H=high, M=medium, L=low)	Feasibility comments
Central Venezuela	12,734	209	25	O	M-H	Two national parks exist; some part composed of military lands
East Central Colombia	2,330	119	31	O	L-M	An important national fisheries area
Eastern Colombia	24,345	445	42	O	L-M	
San Juan River	13,065	292	104	O	M	Two parks straddling borders of two countries
South Central Cuba	2,849	196	38	O	L	Nuclear power station under construction
West Panama Canal	8,486	188	0	O	L	
Central Hispaniola	8,942	325	46	RF	L	No parks exist
Eastern Cuba	13,407	939	92	RF	M	National park exists with coastal jurisdiction
Southern Puerto Rico	9,082	348	117	RF	M-H	Marine fisheries reserves under discussion; university marine lab present
Eastern Hispaniola	11,314	325	60	RF	H	One national park present with comprehensive environmental assessment
Southeastern Jamaica	5,563	132	37	RF	M	Three parks and one proposed park present
Southwestern Hispaniola	11,757	676	142	RF	L	Area includes two countries with one national park; NGOs exist.
Western Cuba	1,899	302	169	RF	M	One coastal PA exists; isolated and well conserved beaches and reefs
Western Hispaniola	8,372	755	131	RF	L	
Aruba-Curaçao-Bonaire	4,505	319	23	RI	M-H	Three separate islands with three existing parks
Bay Islands	6,284	193	193	RI	H	Biological station and NGO present; ongoing research
Cayman Islands	3,380	187	48	RI	L-M	Four protected areas
Offshore Colombian Islands	11,446	51	0	RI	M	No MPAs exist; NGO present
Swan Islands	5,453	6	0	RI	L	Military
Costa Rican Reefs	1,719	92	19	RMS	M-H	Two parks exist
Havana-Matanzas	2,109	280	31	RMS	L	No MPAs present; large cities and tourism development included
Northern Jamaica	3,382	293	80	RMS	M-H	One existing park
Quintana Roo	12,131	393	236	RMS	H	Four protected areas present
Northern Hispaniola	8,599	787	156	RMS/MI	H	One national park at the border of two countries
Northern Puerto Rico	4,223	249	68	RMS/MI	M	Two protected areas exist
Eastern Venezuela	50,457	949	65	S	M	Four national parks present
Northern Miskitos	85,504	216	64	S	M	Coastal parks exist
Southern Miskitos	73,238	481	332	S	H	One MPA exists
Trinidad and Tobago	36,583	552	72	S	M-H	One MPA exists
Totals	**722,817**	**27,109**	**15,129**			

* Coastal system types (according to dominant habitat present): A- atoll; B- bank; M- mangrove continental forest; MI- mangrove island forest; MX- mixed mangrove-reef-seagrass; RF- high-energy rocky shore/fringing reef; RI- island reefs; RMS- mixed shore/fringing reef; S- seagrass; O- other such as upwelling areas, beaches and rocky platforms.

years. Government agencies are active in fisheries regulations and coastal planning. Implementation of proposed zoning for the North Central Coastal System is currently under review, as is a marine park for the Canarreos Archipelago, a lengthy array of keys and reefs that border the Gulf of Batabanó.

Priority Coastal Systems for the Central Caribbean Ecoregion

Based on criteria of geographic position, conservation urgency, and a very coarse inspection of feasibility, priority coastal systems can be reduced to a subset of 25 sites from the total of 51 coastal systems (see Table 3.4 and appendix A-14). The following list of 25 coastal sites includes all types of coastal systems and captures areas with minimal human impact and the greatest probability for success while still including 57% of the ecoregion's total coastal shelf. The portfolio would include:

- Nine reef-dominated coastal systems, including one downstream atoll system, one midstream bank system, two up-stream island reef systems, two high-energy rocky shore or fringing reef systems (one upstream, one midstream), and three mixed shore/ fringing reef systems (two midstream and one downstream);

- Five mixed reef-mangrove-seagrass coastal systems (upstream, midstream, and downstream);

- Five mangrove-dominated coastal systems, including three continental mangrove forest systems (one upstream, one midstream, and one downstream) and two island mangrove forest systems (one midstream and one upstream);

- Three seagrass-dominated coastal systems (two upstream and one midstream);

- One upstream rocky platform-dominated coastal system;

- One midstream upwelling-dominated system; and,

- One midstream beach-dominated system.

In the case of seagrass-dominated coastal systems of Central America (Northern Miskitos and Southern Miskitos) the experts recognize the importance of mangrove forests, coastal lagoons and flooded plains with pine trees of the Northern Miskitos within the Central America region. However, the needs of prioritizing, and the fact that Southern Miskitos has a greater habitat diversity and higher rank in feasibility for conservation made the latter and not the former be selected within this category of coastal system type.

In each of these 25 coastal systems, conservation of the ecoregion's coastal biological diversity is a high priority. Some part of the coastal system needs to be in a marine protected area or marine reserve; the hydrological processes linking land and sea need to be intact; and coastal habitats and shorelines need to be protected. Unfortunately, there are many coastal systems of spectacular natural beauty and biological diversity that are already severely impacted by land-based sources of pollution, loss of coastal habitats, and over-harvesting. These are not good candidate sites for conserving biological diversity.

This process of delineating coastal systems, assessing threats and conservation urgency, and then evaluating feasibility for site-based conservation programs can be refined using new criteria, additional information, or more regional experts. The purpose was to move from a selection of more than 50 coastal systems to a smaller subset. It is not clear what minimum number of coastal systems needs to be protected to achieve the overall goal of maintaining the regional coastal biological diversity. Clearly, the systems that are "conserved" need to meet fairly rigorous standards based on what we now know about marine systems:

- At least 20% of the coastal shelf area would need to be in a "no-take" or fisheries reserve zone to protect the size distribution and spawning stock of commercially important species.

- Land-based sources of pollution and contaminants would need to be addressed through improved runoff control, sewage treatment, and/or environmental regulations.

- Coastal development would need to be regulated in such a manner as to protect coastal wetlands, mangrove forests, sandy beaches, and other nearshore habitats that support components of the overall system's biodiversity and the protection of the coastline.

- Lastly, targeted species such as sea turtles, sea birds, marine mammals, or seasonal fish spawning aggregations and nursery areas would need special protective measures.

These recommendations may be rather restrictive and might dramatically change how people are accustomed to using coastal resources. Yet, if all of these measures could be effectively implemented and managed within one coastal system, it could serve as a global model for the long-term protection and use of oceans.

Conclusion and Recommendations

The design and implementation of conservation programs at a specific site must consider the larger goal of preserving regional biological resources. Each site has to be viewed as contributing some component of protection to the larger system and, as a result, its success is dependent upon the success of other site-based programs. The feasibility analysis included a review of existing and proposed marine parks and coastal protected areas in different coastal systems. Relatively few are managed for biodiversity conservation; existing marine protected areas function as zones for tourism and recreation. In some cases, parks may provide protection to seabird nesting areas. Management plans for these marine parks are often made without reference to the adjacent land areas that may be the source of stresses on the reserve. The value of these marine protected areas may be their promotion of environmental awareness, a benefit that can become the foundation on which to build more effective conservation projects.

One of the requirements for implementation is the identification of the full range of actions needed to conserve the portfolio of priority sites within the ecoregion. In the Central Caribbean ecoregion, the relative homogeneity of species targets and the commonality of threats enable similar strategies and programs to be initiated throughout the coastal systems targeted. In addition to the inherent difficulties in abating or mitigating threats to natural resources, there are also issues of national sovereignty, common property resources, traditional use rights, and conflicting, ineffective policies and regulations. Analysis of the situation in the Central Caribbean ecoregion has found that, to date, there has been very little effective action to deal with these stresses in any country. Furthermore, there are too many countries sharing jurisdiction over what is a common resource to effectively manage an area on a regional scale. The major strategies for marine biodiversity conservation should aim to prevent nutrients and sediment from reaching coastal water; preserve coastal habitats; and maintain critical population levels of exploited species such as queen conch, reef fishes, and spiny lobster. Overall goals for threat abatement should include:

Table 3.4 Conservation priorities for the Central Caribbean Ecoregion. Priority ranking was based on urgency for conservation, feasibility for conservation investments and the position relative to principal ocean currents. The results may change with additional ecological data and a different social context. (Coastal systems are grouped by category and the information on the 25 highly ranked systems is highlighted.)

Coastal System	Area (km^2)	Coastal System Type*	Urgency for conservation action (high, medium, low)	Feasibility for conservation investment (high, medium, low)	Position in region (up-, mid- or downstream)	Conservation priority (high, medium, low)
Belize and Mexican Atolls	**9,438**	**A**	**H**	**H**	**M**	**HIGH**
Pedro Bank	**20,133**	**B**	**H**	**L**	**M**	**HIGH**
Barlovento	14,506	M	M	L	M	L
Central Honduran Coast	11,247	M	H	M	M	M
Falcón	**14,648**	**M**	**H**	**M-H**	**U**	**HIGH**
Gulf of Venezuela-Lago de Maracaibo	27,937	M	H	L	M	L
Orinoco Delta	**28,694**	**M**	**M-H**	**M-H**	**U**	**HIGH**
Gulf of Honduras	**6,154**	**M**	**H**	**H**	**M**	**HIGH**
Southwestern Colombia	9,708	M	L	L	M	L
North Central Cuba	**16,886**	**MI**	**H**	**H**	**D**	**HIGH**
Samana	2,094	MI	M-H	L	U	M
South Jamaica	**7,496**	**MI**	**H**	**M-H**	**M**	**HIGH**
Bocas del Toro	**4,780**	**MX**	**H**	**H**	**M**	**HIGH**
Coastal Belize	**4,855**	**MX**	**H**	**M**	**D**	**HIGH**
East Panama Canal	2,473	MX	L-M	M	M	M
Eastern Yucatán Bays	7,667	MX	M	H	D	M
Gulf of Batabanó	**27,673**	**MX**	**M**	**H**	**D**	**HIGH**
Offshore Venezuela Islands	**13,475**	**MX**	**M**	**H**	**U**	**HIGH**
San Blas	6,795	MX	H	M	M	M
West Central Colombia	12,534	MX	H	M	U	M
Northwestern Cuba	6,044	MX	M-H	M	U	M
Southeastern Cuba	**24,422**	**MX**	**M-H**	**H**	**M**	**HIGH**
Central Venezuela	**12,734**	**O**	**H**	**M-H**	**U**	**HIGH**
East Central Colombia	**2,330**	**O**	**H**	**M**	**M**	**HIGH**
Eastern Colombia	24,345	O	L	L	M	M
San Juan River	**13,065**	**O**	**H**	**M**	**M**	**HIGH**

Table 3.4 Conservation priorities for the Central Caribbean Ecoregion *(continued)*

Coastal System	Area (km²)	Coastal System Type*	Urgency for conservation action (high, medium, low)	Feasibility for conservation investment (high, medium, low)	Position in region (up-, mid- or downstream)	Conservation priority (high, medium, low)
South Central Cuba	2,849	O	H	L	M	L
West Panama Canal	8,486	O	L	L	M	L
Central Hispaniola	8,942	RF	L	L	M	L
Eastern Cuba	13,407	RF	H	M	M	L
Southern Puerto Rico	**9,082**	**RF**	**M-H**	**M-H**	**U**	**HIGH**
Eastern Hispaniola	**11,314**	**RF**	**M-H**	**H**	**M-U**	**HIGH**
Southeastern Jamaica	5,563	RF	H	M	M	M
Southwestern Hispaniola	11,757	RF	M-H	L	M	L
Western Cuba	1,899	RF	L	M	D	M
Western Hispaniola	8,372	RF	?	L	M	L
Aruba-Curaçao-Bonaire	**4,505**	**RI**	**M-H**	**M-H**	**U**	**HIGH**
Bay Islands	**6,284**	**RI**	**H**	**H**	**M**	**HIGH**
Cayman Islands	3,380	RI	M	L-M	M	L
Offshore Colombian Islands	11,446	RI	H	M	M	M
Swan Islands	5,453	RI	M	L	M	L
Costa Rican Reefs	1,719	RMS	H	M-H	M	M
Havana-Matanzas	2,109	RMS	L	L	D	L
Northern Jamaica	**3,382**	**RMS**	**H**	**M-H**	**M**	**HIGH**
Quintana Roo	**12,131**	**RMS**	**H**	**H**	**D**	**HIGH**
Northern Hispaniola	**8,599**	**RMS/MI**	**M**	**H**	**M**	**HIGH**
Northern Puerto Rico	4,223	RMS/MI	M	M	U	M
Eastern Venezuela	**50,457**	**S**	**M-H**	**M**	**U**	**HIGH**
Northern Miskitos	85,504	S	M-H	M	M	M
Southern Miskitos	**73,238**	**S**	**M**	**H**	**M**	**HIGH**[a]
Trinidad and Tobago	**36,583**	**S**	**L-M**	**M-H**	**U**	**HIGH**
PERCENT AREA IN PRIORITY SYSTEMS	**58%**					

* Coastal system types (according to dominant habitat present): A- atoll; B- bank; M- mangrove continental forest; MI- mangrove island forest; MX- mixed mangrove-reef-seagrass; RF- high-energy rocky shore/fringing reef; RI- island reefs; RMS- mixed shore/fringing reef; S- seagrass; O- other such as upwelling areas, beaches and rocky platforms.

[a] The needs of prioritizing, and the fact that the Southern Miskitos has a greater habitat diversity and higher rank on feasibility for conservation made the experts prioritize this system within the seagrass-dominated of Central America. However, the experts recognize the importance of the mangrove forests, coastal lagoons, and flooded plains with pine trees of the Norhern Miskitos within the region.

- the establishment of marine protected areas as a component of management within coastal systems;

- the creation of linkages between marine protected areas and adjacent coastal and upland sites to control land-based sources of pollution and maintain natural hydrological cycles; and

- the protection of nearshore coastal habitats and biological resources.

The translation of ecological information that provides "ecological end-points" or measures for success of management or policy actions is key in beginning the process of site-based conservation planning. The conceptual goals addressed to mitigate threats to coastal systems require sound technical and scientific knowledge to translate into effective management strategies. A system of marine protected areas throughout the ecoregion should: allow no extractive uses; be representative of all biogeographic, ecosystem, and species units in the ecoregion; be self-sustaining; and be protected from damaging influences from outside the reserve. In order to design such a system of marine protected areas, key issues to consider are: volume/edge ratio, proportion of total area protected, number/size of units, spacing of units, the limits of knowledge about the area, and enforcement.

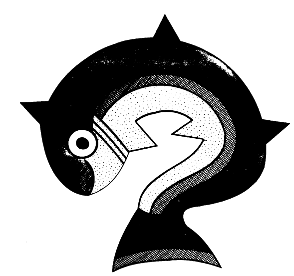
All marine design criteria can be addressed if there are clearly articulated goals from the start. No reserve design will accommodate the biology of all species and, thus, key species may need to be identified for establishing reserve design criteria. There is at present very little knowledge concerning the structure and functioning of marine ecosystems. It is clear, however, that they are complex and that both abiotic and biotic factors play a major role in shaping the relationships between organisms and their environment. There is more complete information available on the detrimental effects that exploitation can have on marine ecosystems and coral reefs in particular.

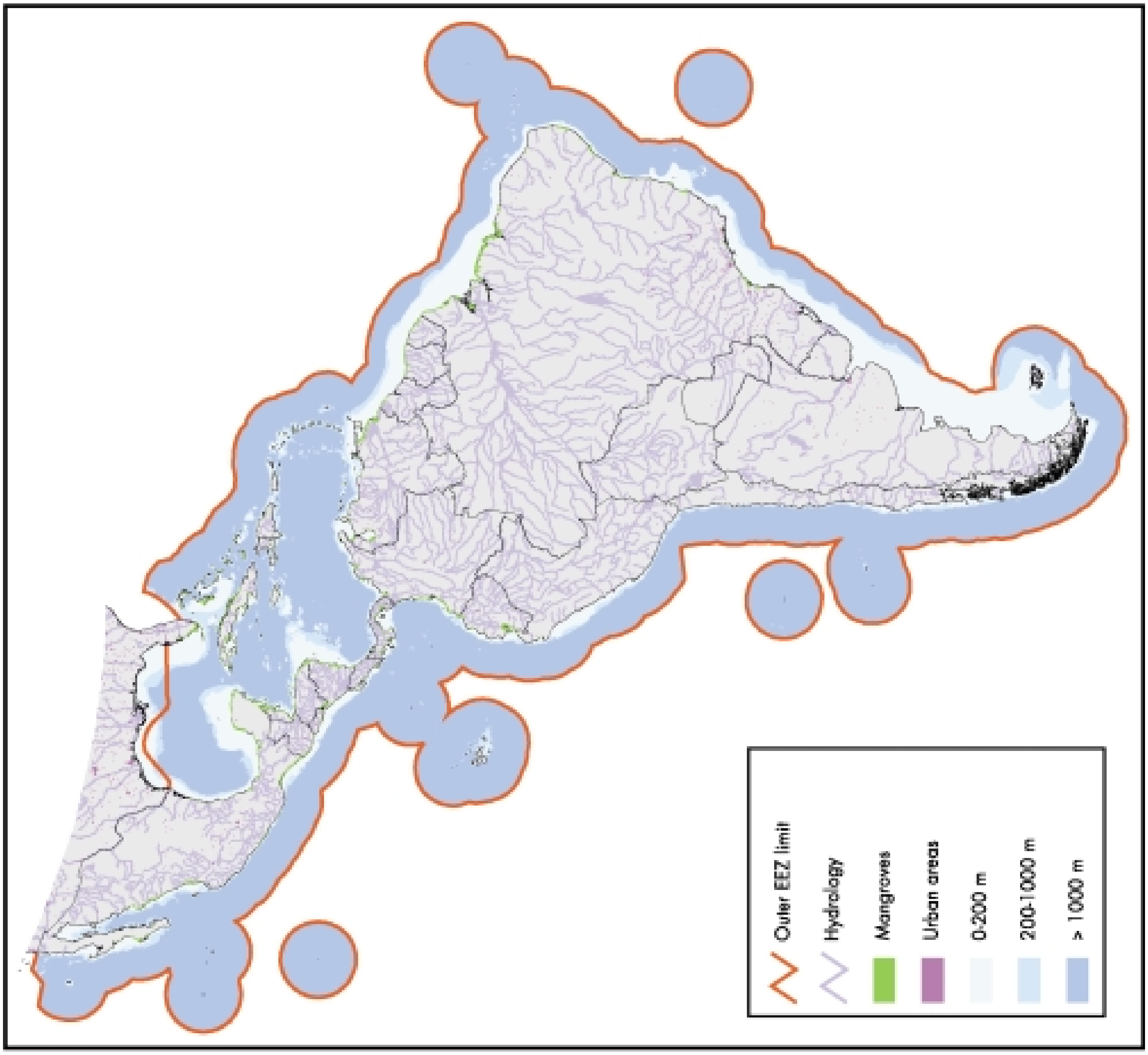
It is also clear that traditional management of marine ecosystems has failed to protect the environment from the destructive effects of human exploitation. This is principally a result of inadequate knowledge and lack of enforcement or compliance with regulations. In many cases, sound management has been attempted; however, there has not been funding to allow enforcement of the regulations. Moreover, people are usually resistant to regulations, particularly at the onset.

Given the overwhelming evidence, the prudent course of action with regard to coastal resources, is to set aside some portion of the coastal shelf area for protection. While experts may not understand the best way to design and place a reserve, it is understood that protected areas are needed. The understanding of marine reserves is likely a two-step process involving the creation and study of the reserve. These two processes are usually not linked. The first step is generally a political, economic, and social decision while the second step is a scientific endeavor. While knowledge about marine fishery reserves can inform those who make decisions about the formation of reserves, it is usually the political, economic, and social considerations that take precedence. One of the most effective ways to understand human impacts on the marine environment is to set aside areas protected from consumptive activities. Protected areas may be at the core of broader coastal system management and conservation.

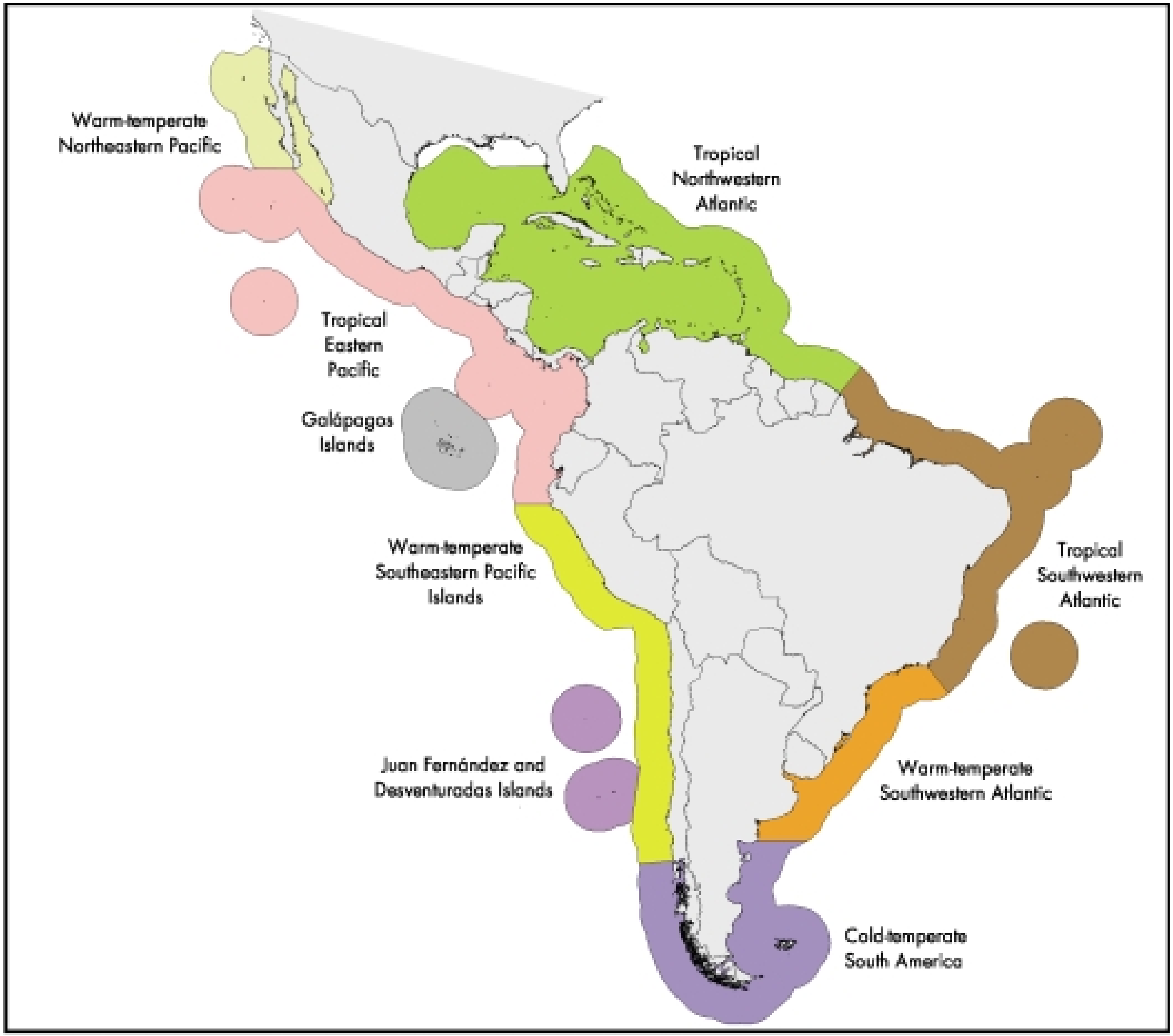
Appendix A

Maps

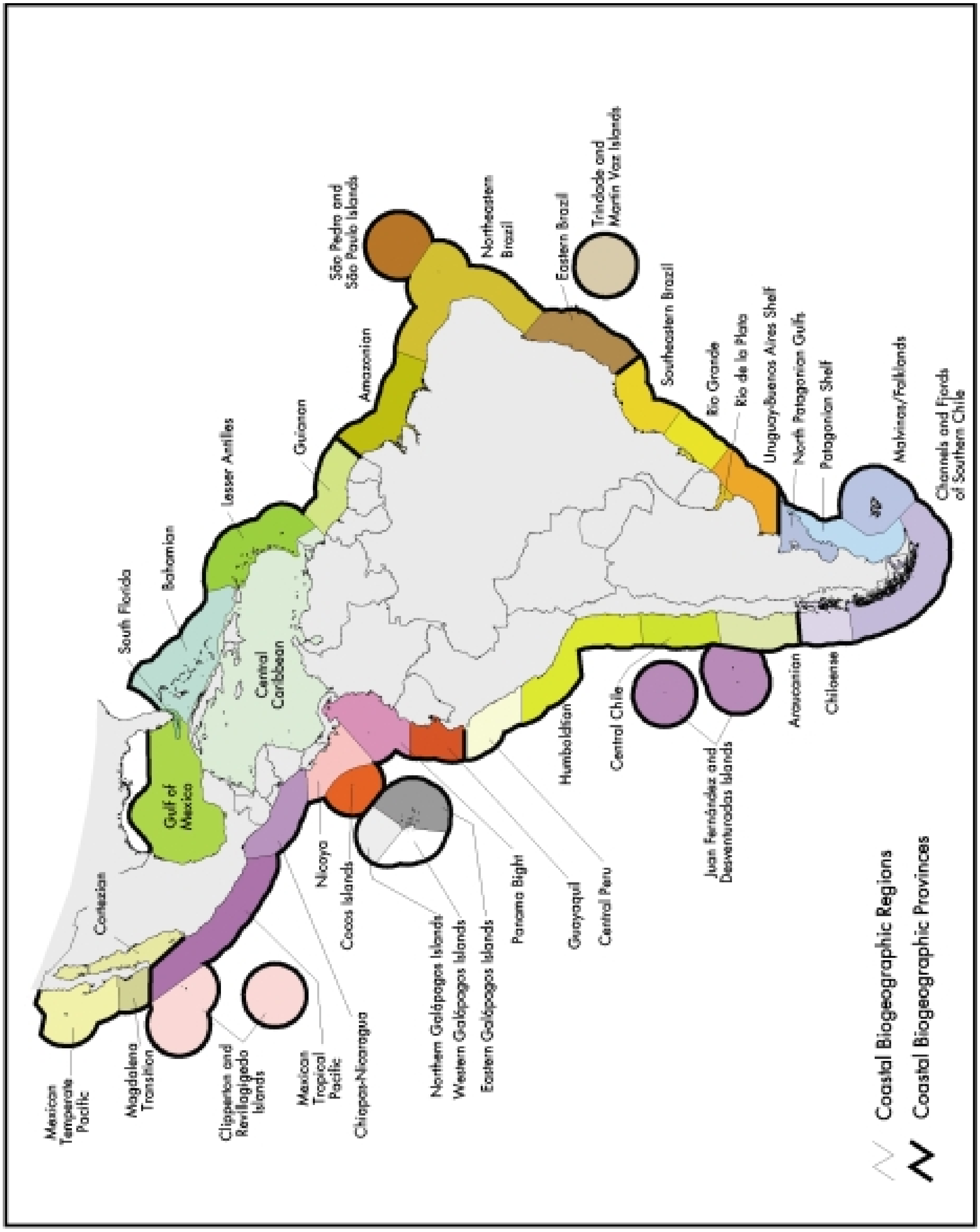




Map A-1 Map of the study area

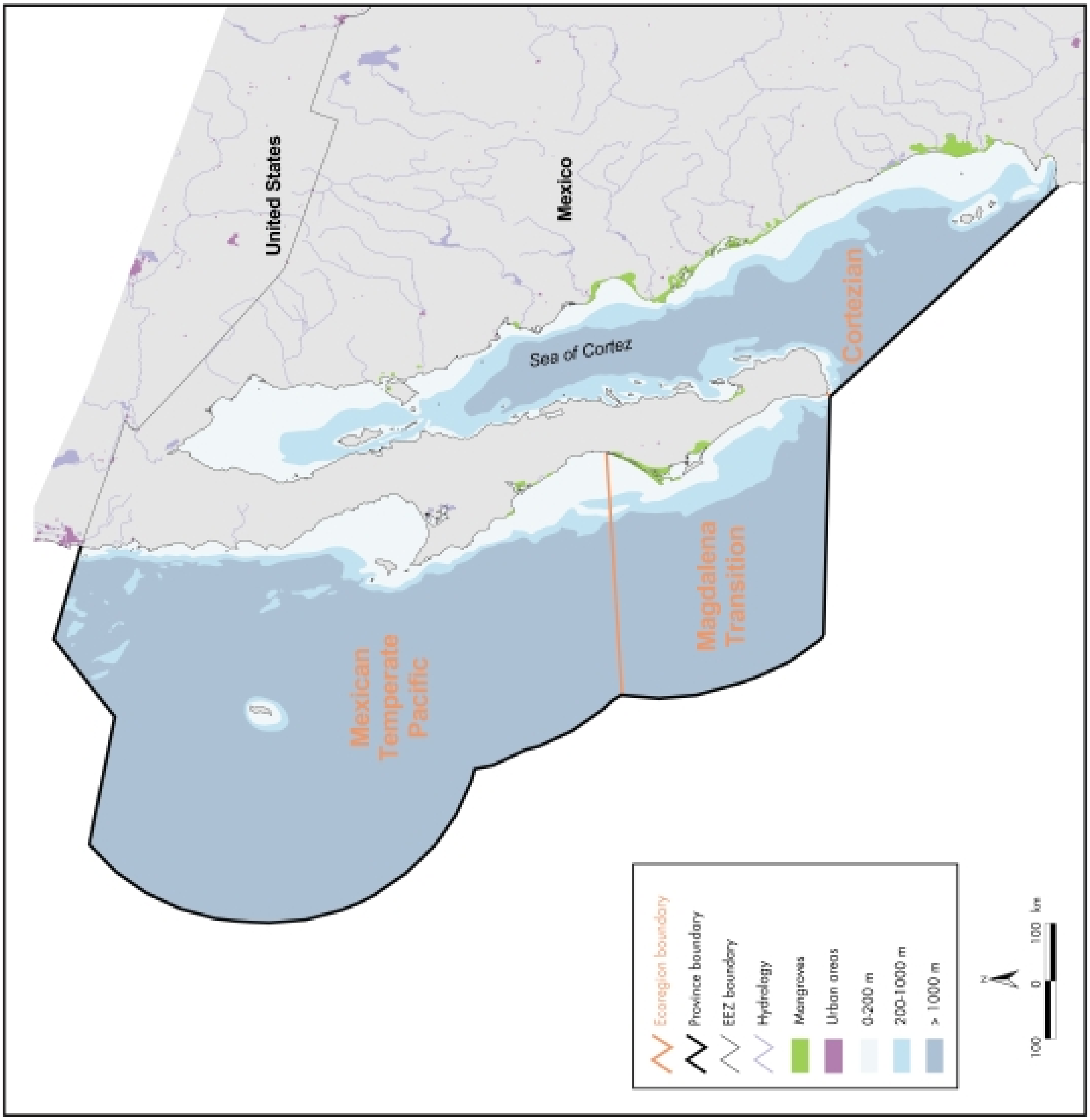


Map A-2 Coastal Biogeographic Provinces of Latin America and the wider Caribbean

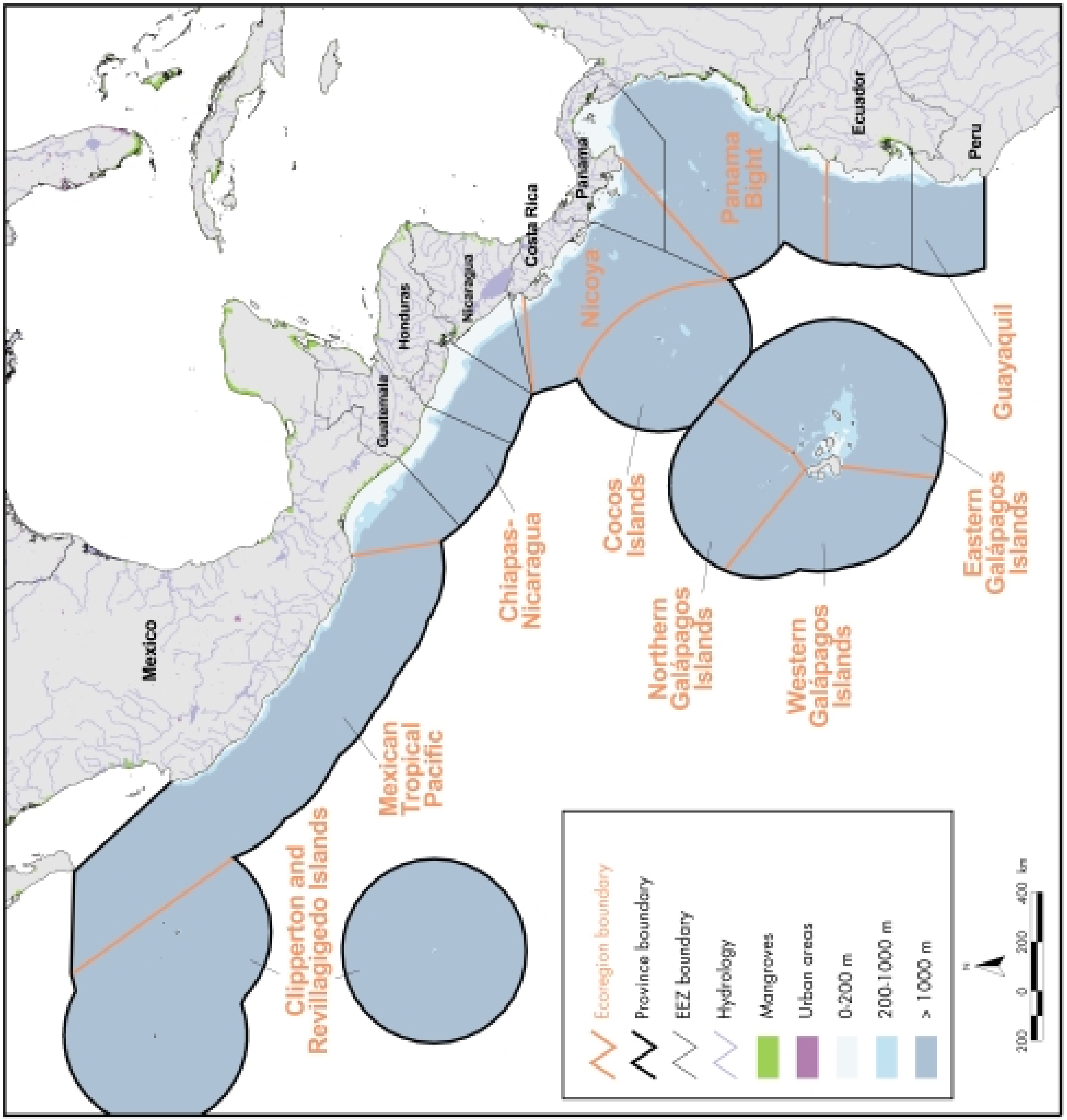


Map A-3 Map of study area with Coastal Biogeographic Regions (or Marine Ecoregions)

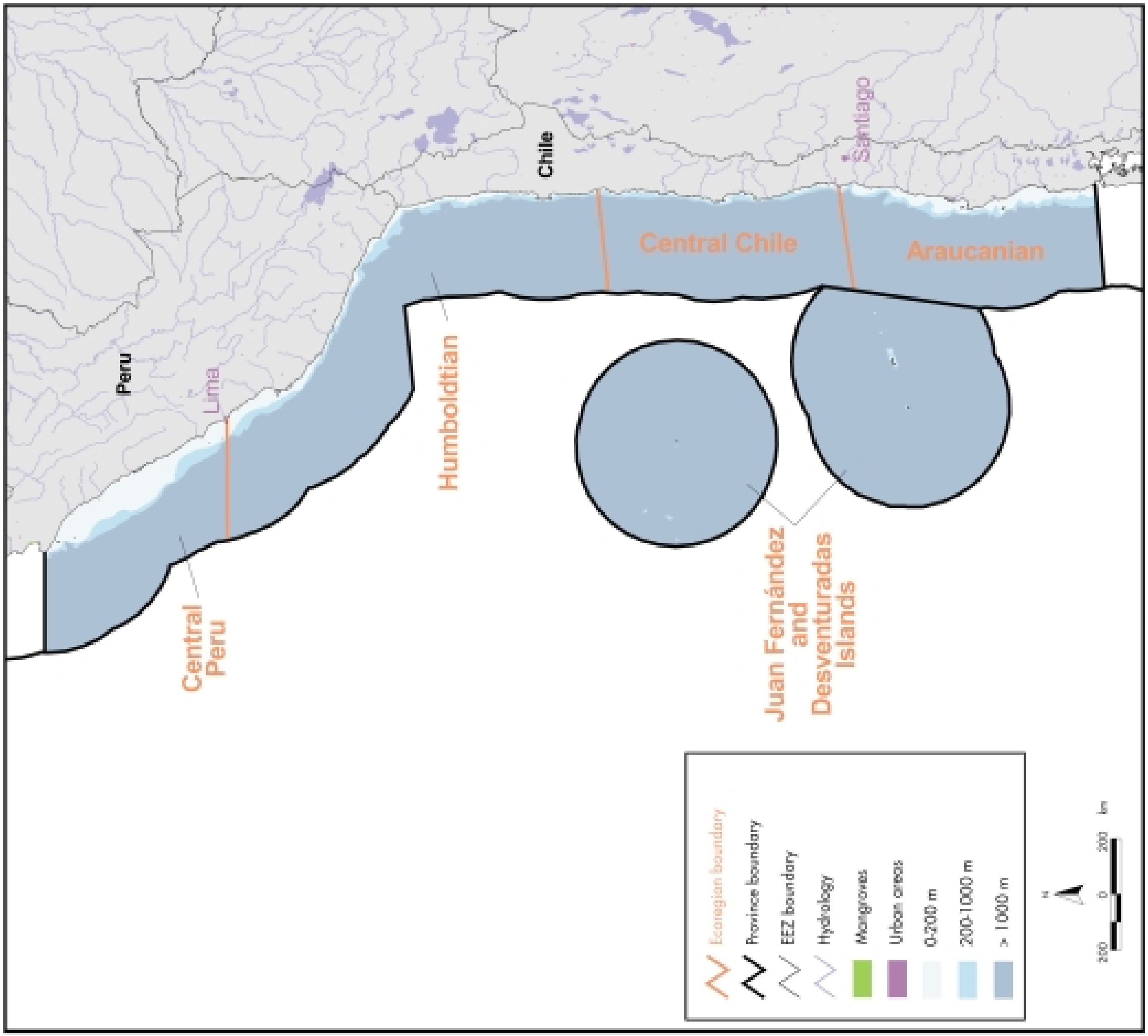
Map A-4 Map of Coastal Biogeographic Regions (or Marine Ecoregions) designated as highest priority for conservation within each Coastal Biogeographic Province



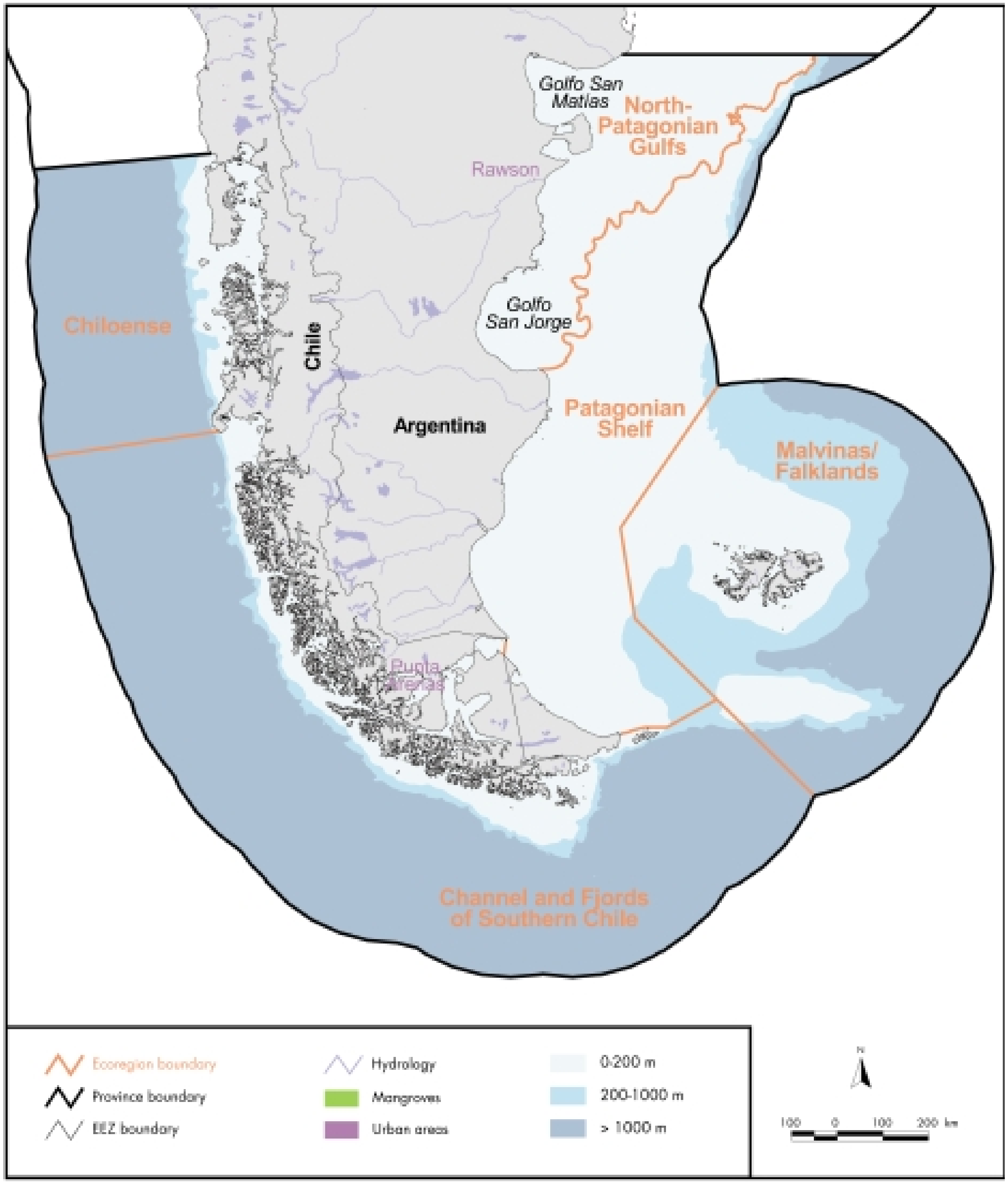
Map A-5 Warm-temperate Northeastern Pacific Coastal Biogeographic Province and its Ecoregions



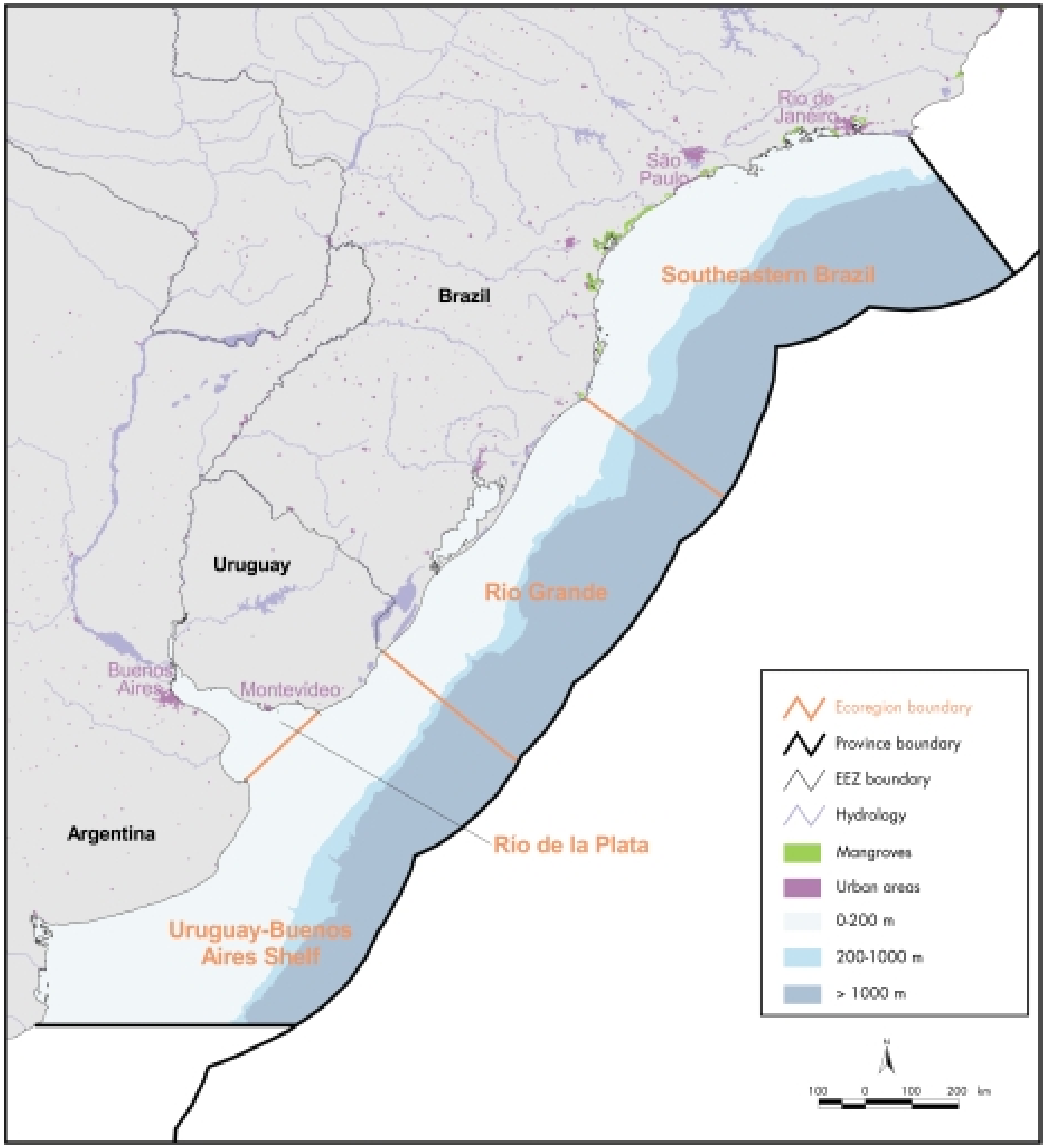
Map A-6 Tropical Eastern Pacific and Galápagos Coastal Biogeographic Provinces and their Ecoregions



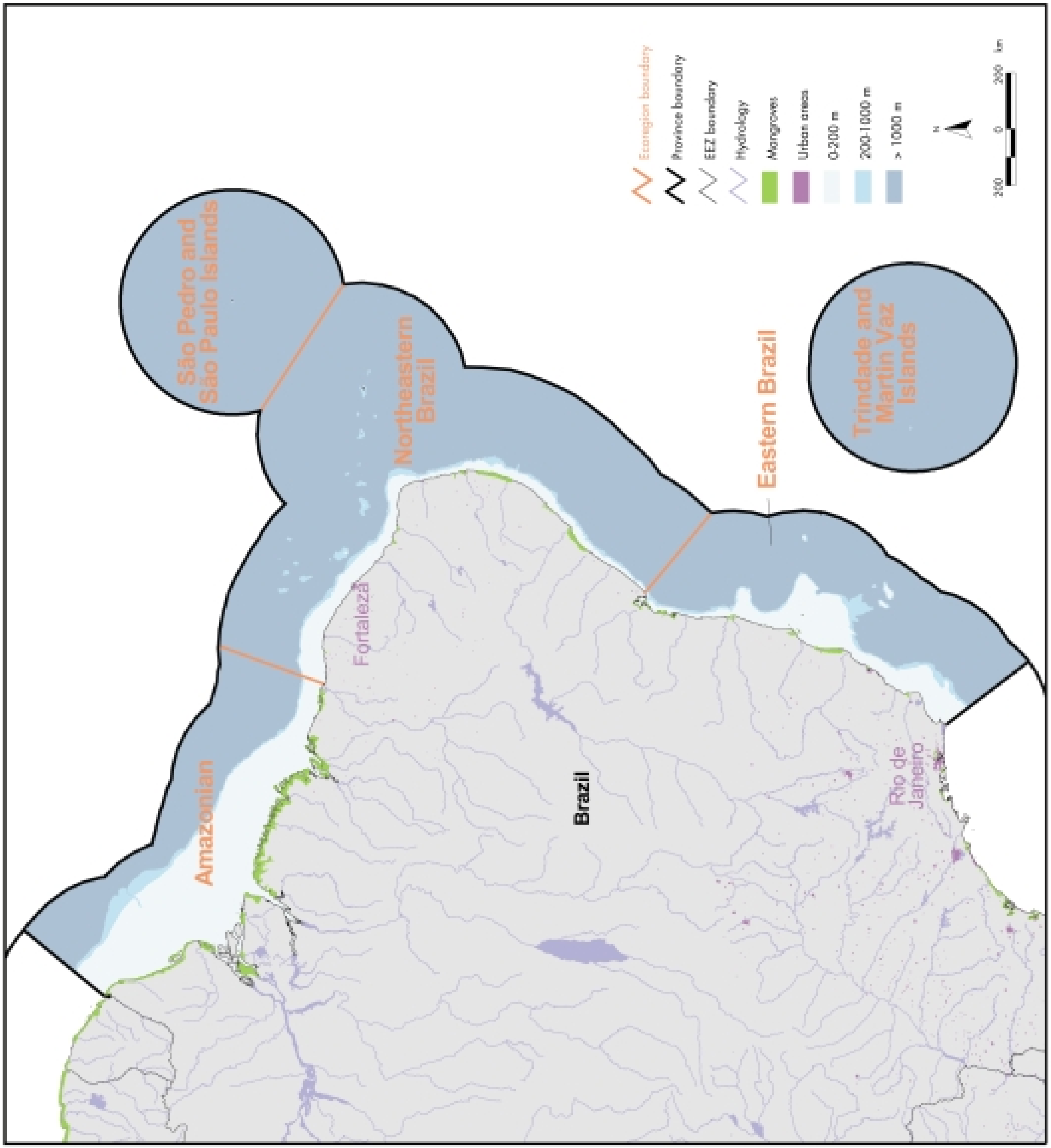
Map A-7 Warm-temperate Southeastern Pacific and Juan Fernández and Desventuradas Islands Coastal Biogeographic Provinces, and the Ecoregions of the former



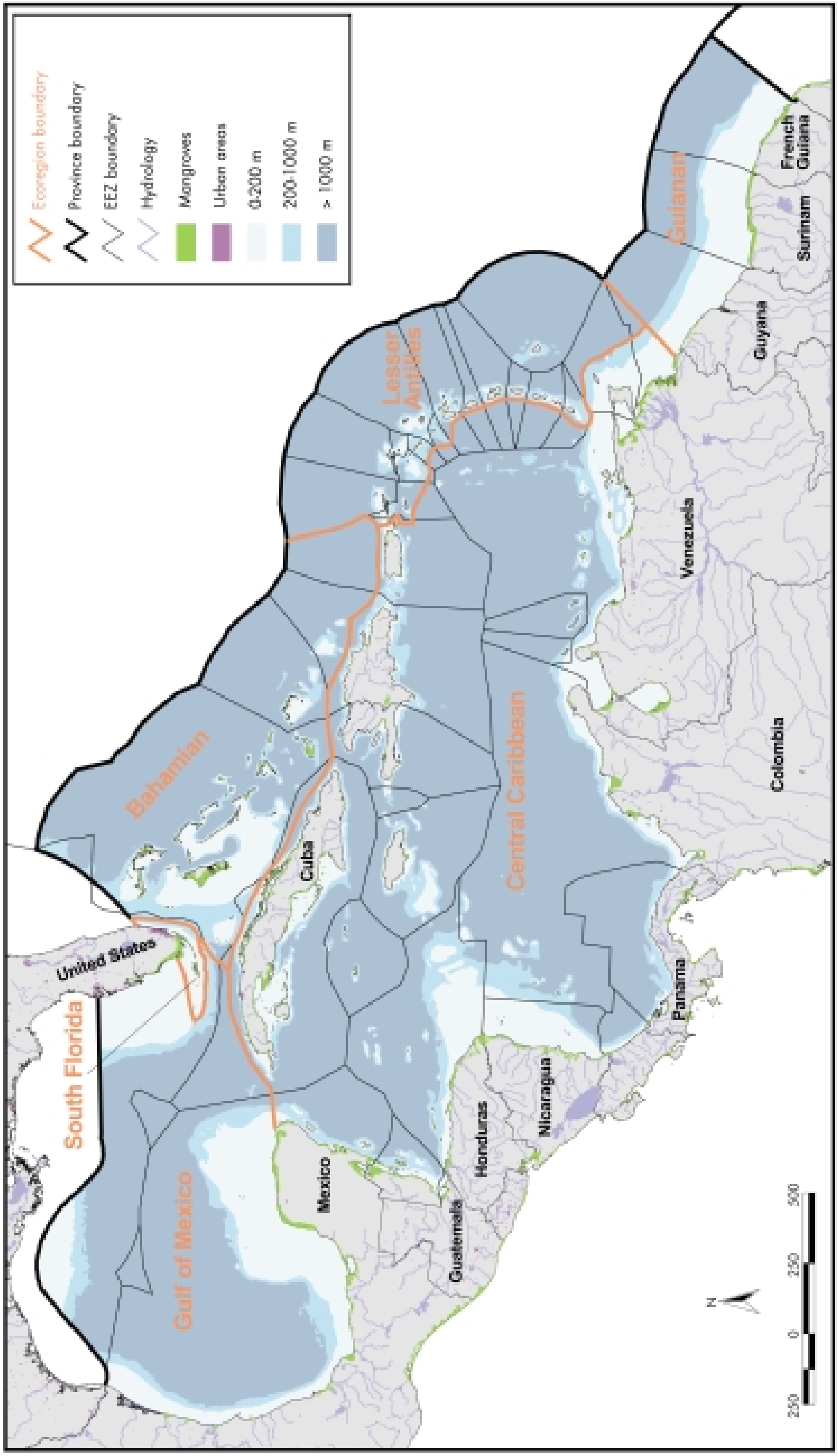
Map A-8 Cold-temperate South America Coastal Biogeographic Province and its Ecoregions



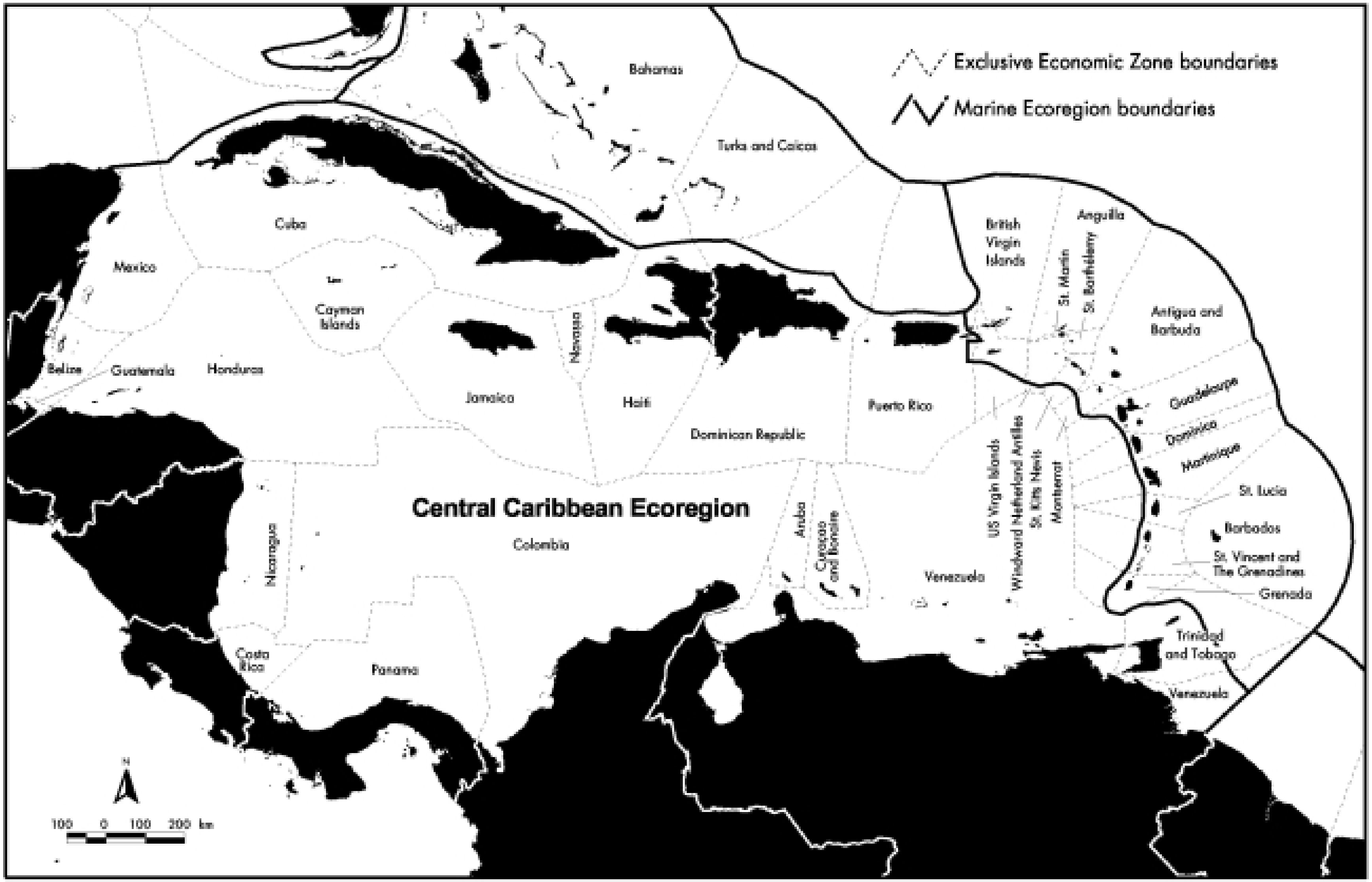
Map A-9 Warm-temperate Southwestern Atlantic Coastal Biogeographic Province and its Ecoregions



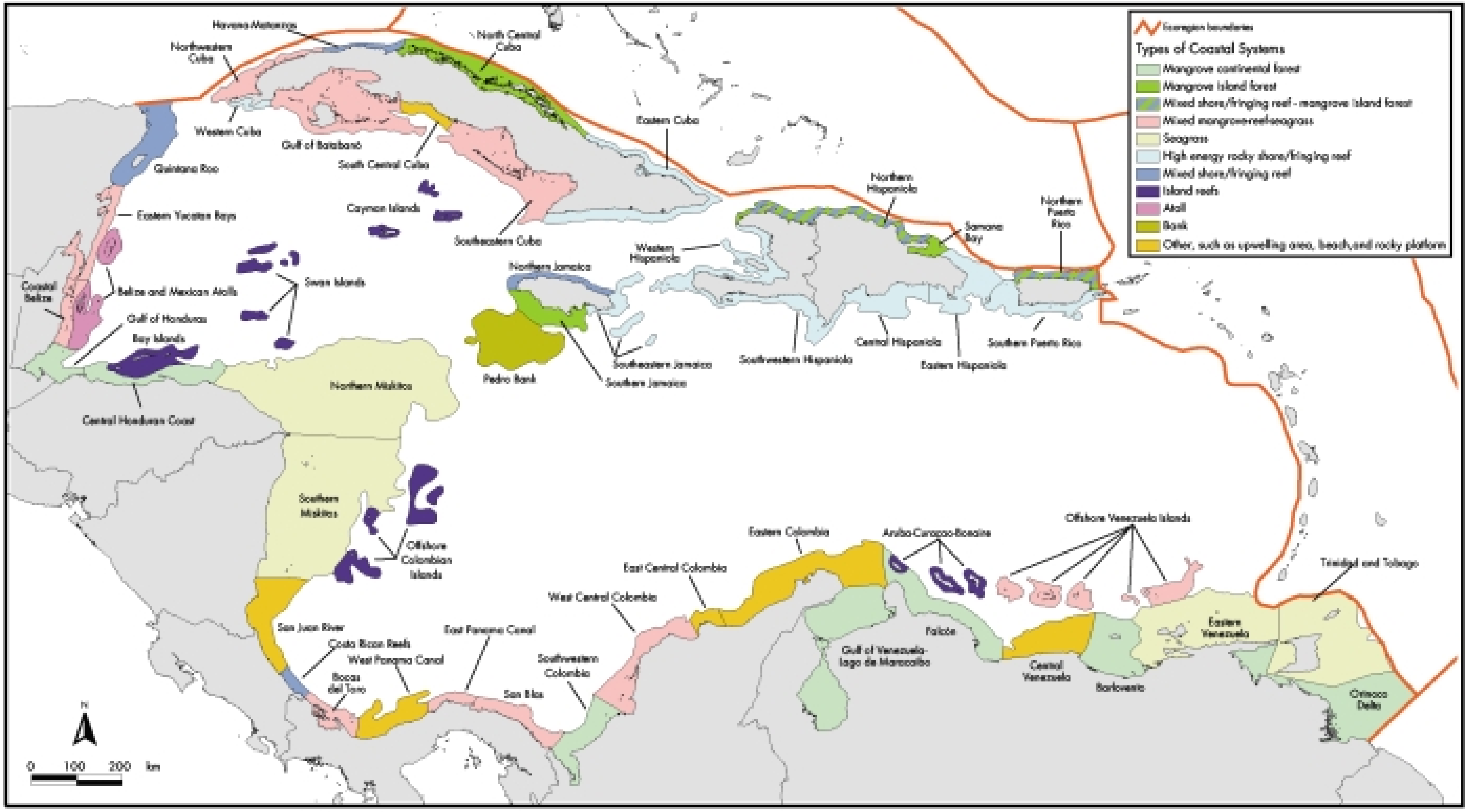
Map A-10 Tropical Southwestern Atlantic Coastal Biogeographic Province and its Ecoregions



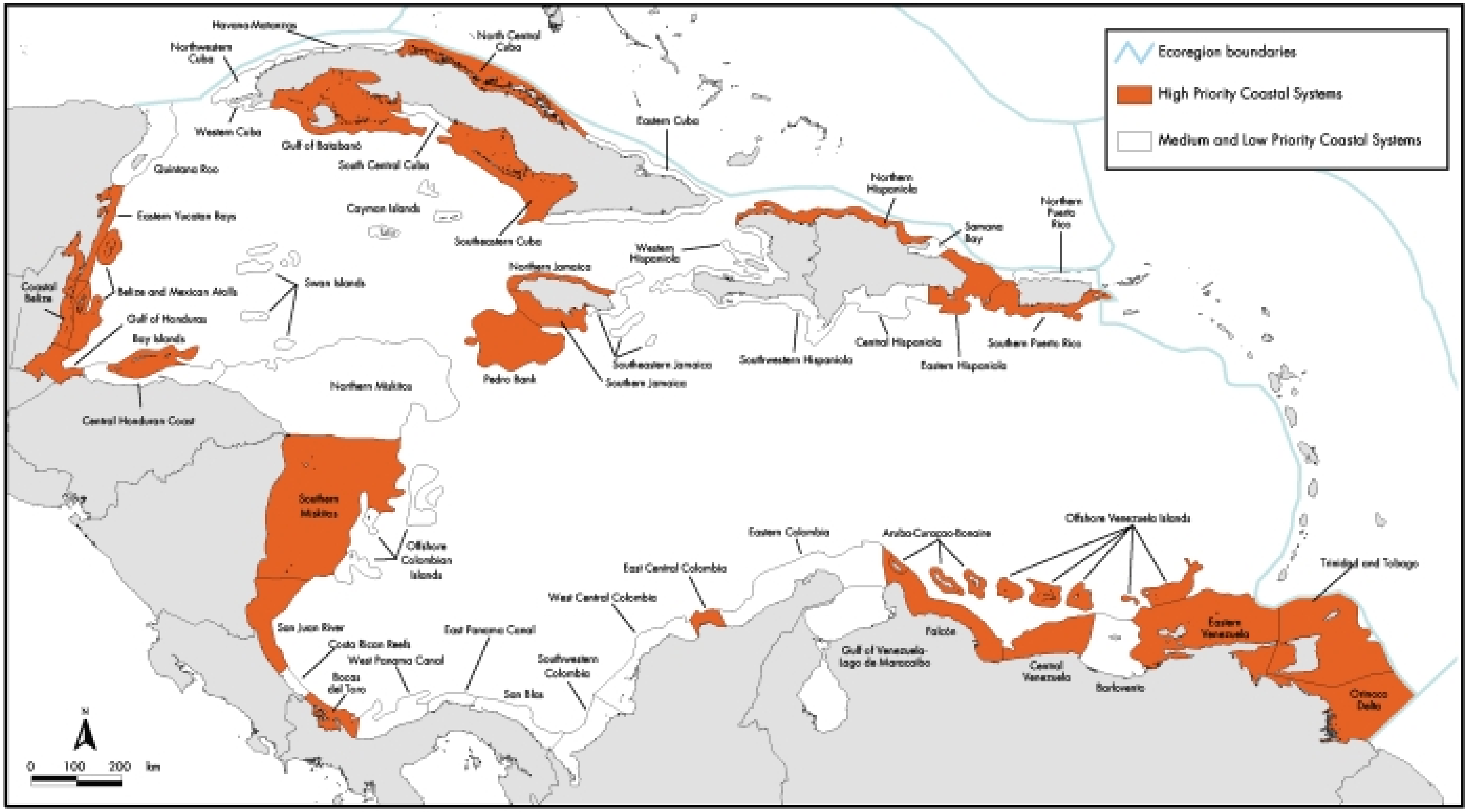
Map A-11 Tropical Northwestern Atlantic Coastal Biogeographic Province and its Ecoregions



Map A-12 Map of the Central Caribbean Coastal Biogeograpic Region (or Marine Ecoregion) with countries and EEZ boundaries



Map A-13 Types of coastal systems of the Central Caribbean Coastal Biogeographic Region (or Marine Ecoregion) and their classification according to their dominant habitat



Map A-14 High priority Coastal Systems of the Central Caribbean Marine Ecoregion. This result is based on the current information on urgency for conservation, feasibility for conservation investments and position relative to the principal ocean currents (see Tables 3.2-3.4 for more details)

COASTAL SYSTEMS CAN be categorized in terms of their dominant natural community types. In the 51 coastal systems delineated in the Central Caribbean ecoregion, the following types are present:

- Mangrove-dominated coastal systems with both continental forest and island forest systems;
- Coral reef-dominated coastal systems with island reef systems, banks, atolls, high-energy rocky shore/fringing reef systems, and mixed-shore fringing reef systems;
- Mixed coastal systems that include large shallow bays, and numerous offshore islands with coral reefs, seagrass beds, and mangrove forests;
- Seagrass-dominated coastal systems;
- Beach-dominated coastal systems;
- Upwelling systems; and
- Rocky platform-dominated coastal systems.

Mangrove Coastal Systems

Mangrove-dominated systems are described by the total shelf area (in km^2), the total coastline extent (in km), and the mangrove coastline extent (in km). Mangrove coverage was obtained first from the Biodiversity Support Program's mangrove geographic priority setting exercise, and then modified by local experts and additional data sources.

Mangrove coastal systems were divided into two general categories: continental forests and island forests. The list is arranged by size, starting with coastal systems having the greatest extent of mangrove coastline to the coastal systems containing the smallest.

Mangrove Continental Forest Systems

Orinoco River Delta

This system has an area of 28,690 km^2, coastline length of 1,920 km, and mangrove-coastline length of 1,830 km. This coastal system comprises the extensive Orinoco River delta (a 20,000-km^2 area) and a large estuary (San Juan River), both fringed by 495,000 ha of mangrove forests and the Gulf of Paria bounded at the east by the island of Trinidad. The Orinoco delta is the only delta that remains practically undisturbed in the tropical Americas.

Gulf of Venezuela/ Lago de Maracaibo

This system has an area of 29,300 km^2, coastline length of 1,430 km, and a mangrove-coastline length of 650 km. This large estuary connects the lake of Maracaibo with the outer Gulf of Venezuela. The inner lake is highly developed with oil terminals, refineries, and oil wells. The Lago de Maracaibo and its canal have extensive mangrove forests and tidal wetlands. This system comprises estuarine wetlands in the southern region of the lake with a mangrove forest area of 15,000 ha. The area was renowned for abundant fisheries resources as well as more than 70 species of shore and sea birds, including flamingos.

Gulf of Honduras

This system has an area of 6,150 km^2, coastline length of 400 km, and mangrove-coastline length of 310 km. In the southernmost end of the Yucatán Peninsula, the Gulf of Honduras comprises the coastal areas of southern Belize, the Caribbean Guatemala, and northern Honduras. There are extensive mangrove forests and coastal wetlands along coastal margins as well as a number of offshore mangrove cays.

Southwestern Colombia

This system has an area of 9,708 km^2, coastline length of 486 km, and mangrove coastline length of 293 km. This coastal system is made up of a relatively narrow shelf in the most western portion of Colombia. Mangroves are located in the western half, particularly in the Gulf of Darién.

Central Honduran Coast

This system has an area of 11,240 km^2, coastline length of 400 km, and mangrove-coastline length of 260 km. The Central Honduran coast contains many coastal lagoons and riverine estuaries, some of which have been severely degraded by overfishing, destruction of mangroves, and by pollution from sewage and agrochemical runoff. The extensive alluvial plains are the center of Honduras' agricultural export production and deforestation has altered hydrological regimes and increased siltation.

Barlovento

This system has an area of 50,450 km^2, a coastline length of 410 km, and mangrove coastline length of 250 km. The Barlovento coastal area is made up of a wide shelf (10 to 40 km wide) with mangroves (fringing five coastal lagoons) and coral reefs at Piritu islets. Coastal upwelling may reach the eastern part of this system. Mangrove coverage is about 189,400 ha.

Falcón

This system has an area of 14,640 km^2, a coastline length of 490 km, and a mangrove-coastline length of 140 km. The Falcón coastal system of Venezuela includes the Trieste Gulf at its eastern end. The coastal shelf varies in width from 20 to 60 km. Along this coastal system are 16 km of the most developed coral reefs of continental Venezuela. In Morrocoy, part of this reef system is a marine protected area. There is a coastal upwelling zone at the western end of the system. Thirty thousand hectares of mangrove fringe the Morrocoy coast.

Mangrove Island Forest Systems

North Central Cuba

This system has an area of 17,370 km^2, a coastline length of 3,570 km, and mangrove-coastline length of 3,013 km. North Central Cuba includes the archipelago Sabana-Camagüey or Jardines del Rey, which is the largest array of keys and islets in Cuba. The coastal system includes smaller islands and mainland areas fringed by mangroves. The shallow areas of the coastal system experience intense evaporation. The high salinities are tidally diluted in the exchange with open oceanic water. Seagrass and muddy bottoms are extensive. Fisheries resources, seabirds, and shorebirds are abundant; hundreds of kilometers of pristine sandy beaches cover the seaward side of the islands and keys. A unique tidal delta is located in Esquivel Key.

Northern Hispaniola

This system has an area of 8,590 km^2, a coastline length of 780 km, and mangrove-coastline length of 156 km. Northern Hispaniola comprises the northern coasts of Haiti and most of the western portion of the Dominican Republic. Rocky shores, sandy beaches, and mangrove forests (especially in the Dominican Republic's Monte Cristi area) dominate the coastline. Mangroves thrive in both fringing and riverine forests, and are important in fisheries production along the narrow shelf area of the system.

Southern Jamaica

This coastal system has an area of 7,490 km^2, a coastline length of 300 km, and mangrove-coastline length of 144 km. This system covers the southern half of Jamaica with rocky shores and fringing mangroves covering most of the length of the shoreline. There are several large estuaries at the mouth of the Black River and numerous smaller mangrove coastal wetlands. Much of the historic mangrove areas have since been filled in for urban development in the eastern end of the coastal system.

Samaná

This system has an area of 2,090 km^2, a coastline length of 200 km, and mangrove-coastline length of 77 km. The large mangrove complex in the Dominican Republic's Samaná Bay is located at the western end of the inlet. Much of the shoreline is rocky with fringing mangroves to the eastern end of the bay. Mangrove forests in Samaná Bay dominate the mouths of several large rivers.

Northern Puerto Rico

This system has an area of 3,840 km^2, a coastline length of 240 km, and mangrove-coastline length of 68 km. The northeastern coast of Puerto Rico has the highest concentration of mangrove swamps in the country. The north coast receives year-round rainfall and has an indented coastline with several major river deltas and estuaries. Fifty-eight percent of the total island runoff drains into six north coast estuaries comprising a total area of 15,358 ha, of which 1,825 ha (or 11.9%) are still mangroves. The sand spit at the mouth of the Río de la Plata forms a barrier coast, yet the northwest coast is a series of rocky, karst-eroded limestone cliffs that form a secondary shore type as a result of wave erosion.

Coral Reef-dominated Coastal Systems

Coral reefs have often been the target of conservation efforts as a natural community of exceptional diversity. However, coral reefs do not occur in isolation. Reef communities are dependent on surrounding ecosystems for the transfer of animals, propagules, and energy. Adjacent seagrass and mangrove areas serve as nurseries for juvenile fish that will later take up residence on the reef. Coastal systems dominated by coral reefs vary greatly throughout the ecoregion depending on shelf morphology, wave energy, and coastal runoff.

Coral reef-dominated coastal systems have been sub-divided in: atoll systems; bank systems; small island reef systems; high-energy rocky shore/fringing reef systems; mixed-shore/fringing reef systems; and mixed mangrove-seagrass-reef systems.

Small Island Reef Systems

Small island systems with associated reef communities are arranged according to area from largest to smallest.

Offshore Colombian Islands

This system has an area of 11,446 km^2, a coastline length of 51 km, and mangrove-coastline length of about 5 km. The offshore Colombian Islands make up about 1,500 km^2 of banks (Quitasueño, Serrana, and Roncador), shoals, oceanic islands (San Andrés and Providencia), and two atolls (Courtown and Albuquerque). The two archipelagos have an atoll origin and are aligned to the north-northeast along the Nicaragua Rise. Mangroves are limited, but coral reefs are extensive, about 180 km of fringing reef described as very exuberant.

Bay Islands

This system has an area of 6,284 km^2, a coastline length of 193 km, and mangrove-coastline length of 190 km. Three major "high" islands dominate this coastal system: Roatán, Guanaja, and Utila as well as numerous smaller cays such as Cayos Cochinos. Both Roatán and Santa Elena contain significant mangrove wetlands. Roatán is also the center of the Honduran fishing industry. The coral reefs around and between the islands make up the southern extension of the Meso-American barrier reef that stretches from Quintana Roo, Mexico, to eastern Honduras.

Swan Islands

This system has an area of 5,453 km^2, and a coastline length of 6 km with no mangrove forests. Shallow bank areas with reefs surround these small and relatively remote islands. This is the location of the last known sighting of the Caribbean monk seal in the 1970s. The area is primarily used by fishermen and, reportedly, has depleted reef fish stocks.

Aruba-Curaçao-Bonaire

This system has an area of 4,500 km^2, a coastline length of 319 km, and mangrove-coastline length of 23 km. Coral reefs are located along the southern coasts of Aruba and Curaçao, and around the entire island of Bonaire—136 km in total length. Mangroves are limited to small formations within some bays. In addition, rivers are lacking and shore birds are abundant, particularly flamingos (Bonaire).

Cayman Islands

This system has an area of 3,380 km^2, a coastline length of 187 km, and a mangrove-coastline length of 48 km. This coastal system is made up of three islands with fringing reefs: Grand Cayman, Cayman Brac, and Little Cayman. Reefs are protected in areas of Grand Cayman for scuba diving and the area represents one of the most popular Caribbean diving destinations.

Atolls and Banks

Belize and Mexican Atolls

This system has an area of 9,438 km^2, a coastline length of 366 km, and a mangrove-coastline length of 366 km. Four atolls (Chinchorro Bank, Turneffe Atoll, Lighthouse Atoll, and Glover's Reefs) comprise a unique system of atolls off the coast of Mexico and Belize. Reefs are highly developed. Chinchorro Bank is located 30 km off the coast of Quintana Roo, and is 800 km^2 in area. Sand and soft-bottom marine communities mainly cover the inner lagoon of the atoll. The Belizean atolls are more distant from the coast and have larger emerged areas, forming islands and keys, often with fringing mangrove communities.

Pedro Bank

This bank has an area of 20,133 km^2. The Pedro Banks belong to Jamaica and are made of an unusually shallow bank with sandy areas and patch reefs. The maximum depth is only about 40 m. Fishermen use the small, ephemeral cays on the southern end of the bank. This is an important regional fisheries resource for queen conch and lobster.

High-Energy Rocky Shore/Fringing Reef Systems

Eastern Cuba

This system has an area of 12,447 km^2, a coastline length of 939 km, and a mangrove-coastline length of 92 km. This system extends along the north- and southeast coasts of Cuba. Rocky shores with steep cliffs dominate the shoreline with occasional pocket beaches. The shelf is very narrow with spur-and-groove reefs fringing the coastline and dropping sharply to abyssal depths, particularly in the southern coast. However, there are four bays (Guantanamo, Santiago de Cuba, Nipe, Nicaro) that provide shallow estuarine habitats. Fringing and riverine mangrove forests are extensive in Guantanamo and Nipe bays. Several seasonal rivers drain in this coastal system.

Southwestern Hispaniola

This system has an area of 11,757 km^2, a coastline length of 676 km, and a mangrove-coastline length of 142 km. Steep cliffs that can reach heights of more than 100 m characterize the coast of southwestern Hispaniola. Coral reef development is limited along this narrow, high-energy coastline, and mangrove growth is confined to a few protected bays. There are a number of small bays west of Aquin, with offshore cays and fringing coral reefs. Northwest of Pointe l'Abacou in Haiti, there are at least two marine terraces, one of which shows evidence of differential uplift.

Eastern Hispaniola

This system has an area of 11,314 km^2, a coastline length of 325 km, and a mangrove-coastline length of 60 km. From the Bahía de Samaná to Cabo Engaño in the Dominican Republic, the coast is low and is surrounded by intermittent reefs. The remaining coast is almost continuously cliffed with the cliff height varying from less than one meter to approximately 18 m. A large lagoon system is formed between the island of Saona and the peninsula making up Parque Nacional del Este.

Central Hispaniola

This system has an area of 8,942 km^2, a coastline length of 325 km, and a mangrove-coastline length of 46 km. The central coast of Hispaniola includes several large river deltas and extensive rocky shorelines with some isolated, well-developed reefs to 30 m in depth. This coastal system contains some of the largest cities and industrial developments in the Dominican Republic, including the capital, Santo Domingo.

Western Hispaniola

This system has an area of 8,372 km^2, a coastline length of 755 km, and a mangrove-coastline length of 131 km. The north coast of Haiti's Jacmel Peninsula consists of rocky cliffs ranging from 10 to 18 m in height. Coral reefs are relatively rare and, like mangroves, are mainly confined to sheltered locations. Gonâve Island is a large island off the coast of Haiti, stretching 57 km in length and up to 15 km in width. The island is almost entirely bounded by coral reefs except for the high, rocky cliffs along the northwestern end. The alluvial lowlands of the western coast of Hispaniola have flat, marshy shores with fringing mangrove.

Southern Puerto Rico

This system has an area of 8,066 km^2, a coastline length of 348 km, and a mangrove-coastline length of 177 km. The Southern Puerto Rico coastal system has extensive reef development with several fringing reefs and well-developed offshore reefs. The southern coast has a broad shelf and extensive offshore reef development where the influence of terrestrial runoff is low and currents are strong. Coastline features are related to coastal geology with coastal lands formed by limestone bedrock, igneous rock, or sediment fans and alluvial plains of unconsolidated material. The limestone forms a rocky irregular coast with small sand and gravel beaches

Southeastern Jamaica

This system has an area of 5,563 km^2; a coastline length of 132 km, and a mangrove-coastline length of 37 km. The system includes the Morant Cays, 37 km southeast of Kingston and several submerged banks off the southeastern coast of Jamaica. Modern coral reefs exist only as patches and are located inshore of the shelf edge.

Mixed-Shore/Fringing Reef Systems

Northern Hispaniola

This system has an area of 8,599 km^2; a coastline length of 249 km, and a mangrove-coastline length of 68 km. High sea cliffs, and a large offshore island—Tortue Island, 37 km long and reaching 7 km wide—dominate this coastal system. From Haiti's Port-de-Paix to the Dominican Republic, the coast is approximately equally divided into sections bounded by cliffs and lowlands. Low, mangrove-fringed coastline, beginning near Cap Haïtien, continues, practically uninterrupted into the Dominican Republic as far east as Punta Mangle. Coral reef formations are common and, in the case of the broad bight in the northeastern portion of the system, the reef may extend as much as 12 km offshore. Due to the scarcity of large intact fringing mangrove forests in the insular component of the Central Caribbean, this coastal system is also included on the list of island mangrove systems.

Quintana Roo

This system has an area of 7,022 km^2, a coastline length of 254 km, and a mangrove-coastline length of 100 km. This coastal system in Mexico encompasses about 200 km of mainland coast, several smaller keys and a large island (Cozumel) fringed by mangroves with poorly to well-developed fringing reefs. The most northern cay, Isla Contoy, faces the Yucatán Channel, through which Caribbean oceanic waters enter the Gulf of Mexico. These conditions result in large seabird colonies on Isla Contoy. The seabirds can feed in the enriched waters of the eastern Yucatán's frontal system and reside and nest on the island.

Western Cuba

This system has an area of 1,899 km^2. This system faces the Yucatán Channel, where the water flowing from the Caribbean Basin funnels to the eastern Gulf of Mexico and the Florida Straits, forming the powerful Gulf Stream. The coastline to the south is mostly rocky with long sandy beaches facing a narrow shelf that drops steeply to the southern entrance of the Yucatán Channel. Reefs fringe the entire edge of the shelf.

Northern Puerto Rico

This system has an area of 3,849 km^2, a coastline length of 254 km, and a mangrove-coastline length of 100 km. The northern coast of Puerto Rico has areas of developed fringing reefs with a mixed coastline of rocky shores, beaches, and mangroves in bays and inlets.

Northern Jamaica

This system has an area of 3,382 km^2, a coastline length of 293 km, and a mangrove-coastline length of 80 km. Modern coral reefs are dominant where they form a discontinuous fringe at the edge of the coastal shelf. The shelf is narrow, extending only about one kilometer offshore. Short, seasonal streams cross the northern coastal plain. These streams originate at the foot of limestone hills, against which the coastal plain abuts. The eastern section of coast, drained by rivers from the Blue Mountains, is the exception. Man has shaped the present coastline as land has been reclaimed to facilitate housing and the development of amenities for tourism. Many of these reclamation projects have resulted in filled-in coastal wetlands, such as in the Montego Bay area.

Havana-Matanzas

This system has an area of 2,270 km^2, a coastline length of 280 km, and a mangrove-coastline length of 31 km. An extensive rocky shore with terraces and cliffs with extended beaches characterize this coastal system. The coastal system is relatively narrow, the shelf ranging 1-3 km in width. Cuba's largest coastal population resides in the cities of Havana and Matanzas, close to the bays with the same names.

Costa Rican Coral Reefs

This system has an area of 1,719 km^2, a coastline length of 92 km, and a mangrove-coastline length of 19 km. This is a small coastal system that stretches from Punta Limón to the Panamanian border east of Punta Mona. Sandy beaches are located in the western and eastern ends of this system, separated by long extensions of grass and inundated wetlands. A small mangrove formation is situated close to Panama. Fringing reefs are not well developed.

Seagrass-dominated Coastal Systems

Despite that the Northern Miskitos and the Southern Miskitos were classified as the same type of coastal system, their delineation was based on the following criteria: a) although they share a dominant habitat type (seagrass), the combination of habitats is different (in the Northern, terrestrial runoff and coastal geomorphology combine to sustain more extensive coastal wetlands while in the Southern, the oceanic influence is greater and so patch reefs and seragrass are more developed), b) very large coastal systems are not adequate for good management, c) the boundary between them was ultimately placed in the countries' border for facilitating their management.

Northern Miskitos

This system has an area of 85,504 km^2, a coastline length of 216 km, and a mangrove-coastline length of 64 km. Coral reefs, extensive lagoons, wetlands, and long barrier beaches in an expansive savanna characterize this area which plays a central role in the health and sustainability of Honduras' fisheries. For the most part, as a result of its inaccessibility, the area has been spared the combined impacts of deforestation, intensive agriculture, and overexploitation of fish and wildlife that has transformed much of the rest of Honduras' coastal areas.

Southern Miskitos

This system has an area of 73,238 km^2, a coastline length of 481 km, and a mangrove-coastline length of 332 km. The coastline has a large area of coral reefs which varies from small patches and pinnacles to large (tens of meters in diameter), complicated platforms and well-defined belts that are distributed across virtually the entire shelf. Extensive areas of seagrass exist in continental shelf waters and provide grazing pasture for green sea turtles nesting along the coast. Hawksbill turtles nest sparsely along the coast; Nicaragua may be the last refuge for this species in the Caribbean.

Eastern Venezuela

This system has an area of 50,457 km^2, a coastline length of 949 km, and a mangrove-coastline length of 65 km. This coastal system has ample shelf area. Mangrove formations (total area of 10,000 ha) lie offshore Margarita Island and include the Gulf of Cariaco. There are three main reef formations: Los Testigos, Los Frailes, and Mochima (10-km long altogether). In addition, there is a coastal upwelling with high biological productivity (the estimated biomass of pelagic fish is approximately two million tons, with 90,000 tons of sardines and large populations of dolphins and whales outstanding for the ecoregion). Sea turtles nest at sites in Margarita, Paria Peninsula, while numerous seabirds nest in Los Testigos, Los Frailes, and La Restinga.

Trinidad and Tobago

This system has an area of 36,604 km^2, a coastline length of 552 km and a mangrove-coastline length of 72 km. This coastal system includes the wide shelf area around the islands of Trinidad and Tobago, separated arbitrarily from the Venezuela coastline. Tobago (36-km long) boasts fringing reefs as well as mangroves (5,286 ha) in the Caroni Swamp. This system is located upstream from the rest of the Caribbean. The North Equatorial Current flows to the west through the islands while the input of freshwater and sediment from the Orinoco River strongly influences the coastal environment.

Mixed Coastal Systems

Some coastal systems are complex bays and shelf areas that have reefs, mangrove forests or offshore cays, and extensive seagrass beds. These are typically large coastal systems and are described as "mixed" systems.

Gulf of Batabanó

This system has an area of 27,673 km^2, a coastline length of 1,831 km, and a mangrove-coastline length of 1,688 km. This is the largest and most habitat-diverse section of the Cuban shelf. The gulf is a shallow body (3-6 m, prevailing depths) surrounded by the main island and the Canarreos Archipelago (almost 700 hundred mangrove islets and keys and the Isle of Youth). The gulf is covered by extensive seagrass beds and numerous patch reefs; an array of islands and barrier reefs separates the gulf from the Caribbean Sea. Mangroves fringe the islands and mainland and are particularly extensive in the Zapata Swamp. All these conditions combine to provide highly diverse marine fauna and abundant populations of lobsters, seabirds, bottlenose dolphin, sea turtles, and numerous reef fish species.

Southeastern Cuba

This system has an area of 24,422 km^2, a coastline length of 1,434 km, and a mangrove-coastline length of 1,351 km. The Southeastern Cuba coastal system is the second largest system in area along the coast of Cuba. The shelf is relatively deep (12 to 15 m dominant depths, 28 m maximum) and includes two gulfs—Ana María in the west and Guacanayabo in the east—that are mainly covered by seagrass beds, muddy bottoms, and patch reefs. A chain of shoals and cays separates these two gulfs. The whole system is separated from the ocean by the fringing reefs of the Archipelago Jardines de la Reina. The ring-shaped *Oculina* reefs, on muddy bottoms of the Gulf of Guacanayabo, are unique to the island of Cuba.

Offshore Venezuela Islands

This system has an area of 13,475 km^2, a coastline length of 232 km, and a mangrove-coastline length of 222 km. This coastal system includes a diversity of natural communities including numerous mangrove-fringed offshore islands surrounded by highly developed coral reefs (187 km) at Los Testigos, La Blanquilla, La Tortuga, and La Orchila. There are two atoll reefs: Los Roques and Las Aves. Areas of coastal upwelling facilitate nesting sites for seabirds. The islands' beaches provide nesting sites for sea turtles.

West Central Colombia

This system has an area of 12,530 km^2, a coastline length of 510 km, and a mangrove-coastline length 240 km. Along much of this coastal system, there are mud flats covered by extensive mangrove areas. Mangroves are most prevalent between Santa Marta and Barranquilla, just east of the Río Magdalena and around the Bay of Cartagena. Coral reefs occur at some places along the coast, and seagrass beds occur within the Bay of Cartagena.

Eastern Yucatán Bays

This sytem has an area of 7,667 km^2, a coastline length of 901 km, and a mangrove-coastline length of 831 km. The coastal system stretches from Punta Xcalak south to northern Belize. It comprises three bays: Ascensión Bay, Espíritu Santo Bay (in Mexico), and Chetumal Bay (Mexico and Belize). The bays are the result of extensive normal faulting. The oceanographic conditions within and outside the bays differ from the rest of the coast of the Mexican Caribbean and Belize. Reefs and mangroves are well developed as are seagrass areas within the bays.

San Blas

This system has an area of 6,795 km^2, a coastline length of 356 km, and a mangrove-coastline length 50 km. Thriving coral colonies have been identified east of Colón and one of the most important mangrove zones on the Atlantic coast is found along the Golfo de San Blas.

Coastal Belize

This system has an area of 4,855 km^2, a coastline length of 360 km, and a mangrove-coastline length of 338 km. This coastal system stretches from Belize City south to the mouth of the Monkey River. The broad shelf includes extensive mangrove forests and mangrove cays, seagrass meadows, and an offshore barrier reef.

Northwestern Cuba

This system has an area of 2,844 km^2, a coastline length of 545 km, and a mangrove-coastline length of 355 km. This coastal system includes a barrier reef offshore and an extensive shelf, particularly broad in the Gulf of Guanahacabibes, a shallow-water body with numerous mangrove cays, seagrass beds, and patch reefs that stretches to the western-most end of Cuba. Barrier reefs run along the outer border of the shelf, parallel to the Archipelago Las Coloradas (225-km long) formed by hundreds of mangrove cays.

Bocas del Toro

This system has an area of 4,780 km^2, a coastline length of 633 km, and a mangrove-coastline length of 191 km. This area has more than 50 barrier islands (Archipiélago Bocas del Toro), the largest of which is more than 130 km^2. Another notable geographical feature is the Laguna Chiriquí—at 840 km^2, the largest lagoon in Panama. Mangroves and bananas are dominant along the coast and more than 300 km^2 of freshwater wetlands are located behind the mangrove fringe.

Eastern Panama Canal

This system has an area of 2,473 km^2, a coastline length of 166 km, and a mangrove-coastline length of 49 km. The shelf is very narrow and mangrove areas are scattered along the coastline. This system includes some of the most extensive reef development in the area.

Upwelling Areas, Beaches, and Rocky Platform Systems

Central Venezuela

This system has an area of 12,734 km^2, a coastline length of 209 km, and a mangrove-coastline length of 25 km. The shelf of this coastal system is relatively narrow and widens to the west. Reefs and mangroves are limited. The largest urban centers of Venezuela as well as oil refineries and ports are located here. Extensive rocky platform areas offshore characterize the area.

East Central Colombia

This system has an area of 2,330 km^2, a coastline length of 119 km, and a mangrove-coastline length of 31 km. Rocky sea cliffs with pocket beaches are found where the Andes Mountains reach the coast. Mangroves lie just west of Santa Marta, a consistent upwelling area supporting important pelagic fisheries and seabird populations.

Western Panama Canal

This system has an area of 8,486 km^2, a coastline length of 188 km, and no mangrove forests. In the west and all along the 200-km Golfo de Mosquitos, the coast is made up of a succession of small beaches, separated by cliffs. The offshore marine communities are dominated by algae-covered rocky platforms.

South Central Cuba

This system has an area of 2,849 km^2, a coastline length of 196 km, and a mangrove-coastline length of 38 km. From the Cazones Gulf (a tongue of the Caribbean Sea) east to Punta Casilda, the shelf is very narrow. This system separates the two wide shelf areas of the Gulf of Batabanó and the Gulf of Ana María. The area is characterized by rocky offshore platforms facing deep-water tongues of the ocean.

San Juan River

This system has an area of 13,065 km^2, a coastline length of 292 km, and a mangrove-coastline length of 104 km. Extensive sandy beaches and wetlands fringe the coastline. The San Juan River drains in this section and the shelf widens to the north. Extensive beaches and some of the more important turtle nesting beaches in the Caribbean characterize the area at the mouth of the San Juan River.

Eastern Colombia

This system has an area of 24,345 km^2, a coastline length of 445 km, and a mangrove-coastline length of 42 km. The Eastern Colombia sector includes the Guajira Peninsula, the country's northernmost pronounced extension. Shrub vegetation lines the coast and offshore; rocky platform areas dominate the area.

Sources and Quality of Information

THERE WERE 28 PRIMARY contributors to the project. Unfortunately, some experts were unable to attend the workshop, though all contributed detailed information.

More than 700 different sources were cited. The number used for each country varied from three to 181. A low number of sources does not necessarily translate into poor data. While it is true that there were areas such as the Lesser Antilles for which the low number of sources reflects the small amount of data available, other areas are well studied and all the requested data were already collected in a few texts.

To evaluate the quality of the information provided, each indicator was given a value of A (complete and reliable data according to the best available resources), B (reliable, but geographically incomplete data), and C (uncertain data). While there clearly were information gaps, the majority of the collected data were judged to be in the A and B categories.

Mapping Descriptions

Coastlines and Political Boundaries
Derived from ESRI's Arc/Info. version of the Defense Mapping Agency's Digital Chart of the World, the nominal mapping scale for coastlines and political boundaries is 1:1,000,000. This dataset was used in the compilation of the coastline lengths for provinces and ecoregions.

Hydrology
Hydrology information was derived from ESRI's Digital Chart of the World, at a nominal mapping scale of 1:3,000,000. This dataset was used as a visual reference of the drainage patterns in the study area.

Mangroves
This information is from the World Wildlife Foundation's mangrove database. The dataset was used in the compilation of area and coastline length of mangroves in each province and bioregion. The nominal mapping scale is 1:1,000,000.

Bathymetry
The data for Latin America is from the General Bathymetric Chart of the Oceans (GEBCO) world bathymetric database, and has a nominal mapping scale of 1:10,000,000. The data for the Caribbean is a combination of the GEBCO dataset and bathymetric data from National Geographic maps, ranging in scale from 1:250,000 to 1:1 000,000. This dataset was used for calculation of the shelf area for provinces and bioregions.

Exclusive Economic Zones (EEZs)
Exclusive Economic Zones for Latin America were derived from *The maritime political boundaries of the world: a handbook on national legislation* (Prescott, 1985). EEZs for the Caribbean were derived from *Maritime jurisdiction in the wider Caribbean* (Ratter, 1993). Nominal mapping scales vary across the study area. This dataset was used in the calculation of political responsibility for province and ecoregion areas and coastlines.

Abiotic: A non-living component of the environment.

Ahermatypic: Non-reef-building organism or species.

Aquaculture: The farming of marine and freshwater organisms.

Aquatic: Growing or living in or frequenting freshwater.

Arboreal: Inhabiting trees.

Artisanal fishery: Local subsistence fishery for subsistence or sale, usually involving small boats and low levels of technology, as opposed to large scale commercial fisheries.

Banks: A broad shallow water region, usually sandy, surrounded by deep water; associated with high levels of productivity.

Bathymetry: Pertaining to the depth and relief of water basins.

Benthic: Defining a habitat or organism found on the water bottom; demersal.

Bight Wide bay formed by a curve in a shoreline.

Biodiversity: The number of species in an area or biological collection.

Biogeography: The distribution of one or more species that is defined by abiotic factors (temperature, salinity, surface currents, etc.).

Biological productivity: A general term describing the total amount of life that an area supports; high biological productivity usually refers to a nutrient-rich habitat that supports large levels of primary producers. These serve as food for abundant grazers who are themselves food for predators.

Biota: The living components of the environment.

Carbonate geology: Rocks made from calcium carbonate or limestone. This rock is usually formed from marine sediments and coastal shallow water processes in tropical areas.

Coastal biogeographic provinces: The distribution of marine species in shallow water along the coastlines of islands and continents as defined by abiotic factors (sea surface temperature, salinity, and major ocean currents).

Coastal morphology: The form and configuration of the coast.

Continental shelf: A broad expanse of ocean bottom, associated with the submerged edge of continental plates, that slopes gently seaward (usually 100 to 200 m) from the shoreline to the shelf slope break.

Convergence zones: The line where two oceanic water masses meet, resulting in the sinking of the denser one.

Coriolis effect: The deflection of air or water bodies, relative to the solid earth beneath, as a result of the earth's eastward rotation; the deflection is to the right in the Northern Hemisphere and to the left in the Southern Hemisphere.

Cornerstone conservation sites: Geographic locations where conservation is not only necessary, but also likely to succeed; these sites can serve as examples for other conservation efforts in the region.

Demersal: A habitat or organism found on or near water bottoms; Benthic.

Density: Grams of seawater per milliliter of fluid; factors that affect density include salinity (high=denser) and temperature (cold=denser). Also, the number of organisms per area or volume unit (indicator of abundance).

Detritus: Dead organic matter; when broken up by decomposers, detritus provides energy to many coastal ecosystems.

Echinoderms: Organisms in Phylum Echinodermata; invertebrates with radial symmetry and a water vascular system (e.g. starfish, sea cucumber, sea urchins, etc.).

Ecosystem: A community or communities of plant and animal species, as well as all of the abiotic components of the environment.

Endemism: An organism or group of organisms restricted to a specific location.

Endotherm: An organism that can regulate its own internal temperature.

El Niño Southern Oscillation (ENSO): Irregular cyclical condition in which warm surface water moves into the eastern Pacific, collapsing upwelling and increasing surface-water temperatures and precipitation along the west coast of North and South America.

Estuarine: Coastal areas where freshwater enters the ocean in coastal wetlands, bays, and lagoons: areas of variable salinity at the ocean margin.

Eurythermic: An organism tolerant of a wide temperature range.

Eutrophication: The process in which excess nutrients added to system lead to algal blooms, depletion of dissolved oxygen, and often, fish kills.

Faunal composition: The entire animal population living in an area.

Geographic Information Systems (GIS): An organized collection of computer hardware, software, geographic data, and personnel designed to efficiently capture, store, update, manipulate, analyze, and display all forms of geographically referenced information.

Guano: The accumulated excrement of seabirds; collected for use as fertilizer.

Gyre: Large cyclonic currents that generally move water in a large circle from the tropics to the polar seas. Gyres can also vary in scale to include smaller circulating "rings" of water.

Hermatypic: Reef-building organisms or species.

Invertebrates: Animals lacking a backbone.

Isopleth: A line on a map connecting points at which a given variable has a specified constant value.

Isopods: Small, dorsoventrally flattened crustaceans (e.g. sea louse).

Keystone populations: Populations of organisms that are vital for the maintenance of the structure of a community.

Larval dispersal: The immature life-phase of marine organisms spent suspended in the water column for a certain period of time during which they are transported some distance from their birth site.

Macro-scale: Large-scale events or processes; measured in thousands of kilometers.

Marine: Relating to saltwater.

Meso-scale: Medium-scale events or processes; measured in tens or hundreds of kilometers for climatic and oceanographic processes.

Micro-scale: Small-scale events or processes; measured in kilometers for climatic and oceanographic processes.

Neritic: Marine environments landward of the shelf slope-break.

Nutrification: The process in which excess nutrients are added to an aquatic system. These nutrients stimulate algal blooms, the depletion of dissolved oxygen, and occasionally lead to fish kills in shallow bays. Synonymous with "eutrophication."

Oceanic: Associated with marine environments seaward of the shelf slope-break.

Oligotrophic: Nutrient poor.

Otarids: Sea lions and fur seals (also called "eared" or "walking" seals).

Phytoplankton: The photosynthesizing organisms residing in the Plankton.

Phylum/phyla: The second broadest classification of life on earth. Phylum is the next level of classification after the five kingdoms (animals, plants, fungi, protozoa, and bacteria).

Pinniped: Members of Order Pinnipedia; marine mammals with paddle-shaped flippers (e.g.: seals, eared seals, and the walrus).

Plankton: Organisms residing in the water column and incapable of moving against water currents.

Primary producers: An organism capable of using the energy derived from light or a chemical substance in order to manufacture energy-rich organic compounds.

Propagule: A reproductive phase that allows dispersal by water currents (e.g.: seed pods, etc.).

Protozoa: Members of Kingdom Protista bearing animal-like characteristics.

Stochastic: Involving chance or probability.

Terrestrial: Relating to the land.

Thermocline: The boundary of two water masses whose density differs due to temperature.

Tidal wetlands: A coastal area that experiences periodic inundation as a result of daily tides.

Trophic: A level in a food chain containing organisms of identical feeding habits with respect to the chain (e.g. herbivores).

Upwelling: The transport of deeper, nutrient-rich waters to the surface by wind or surface circulation patterns that results in increases in surface productivity. Upwelling areas are often important fishing areas.

Viscosity: The property of resistance to flow in a fluid.

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