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

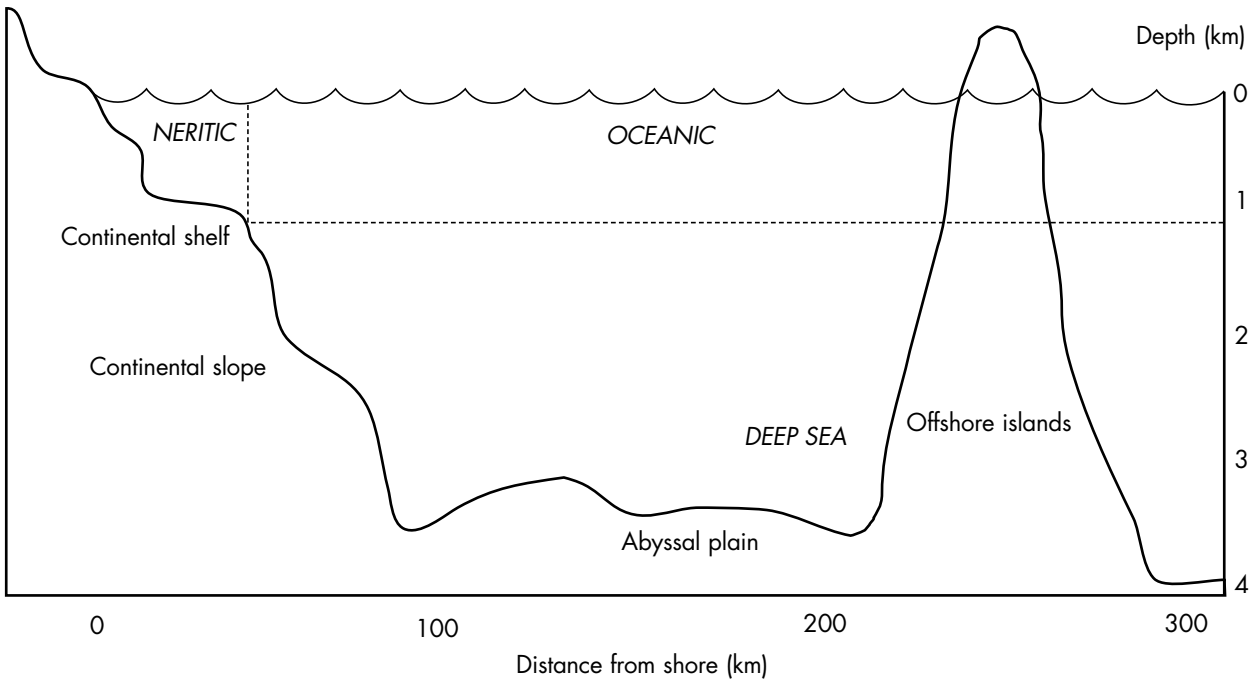
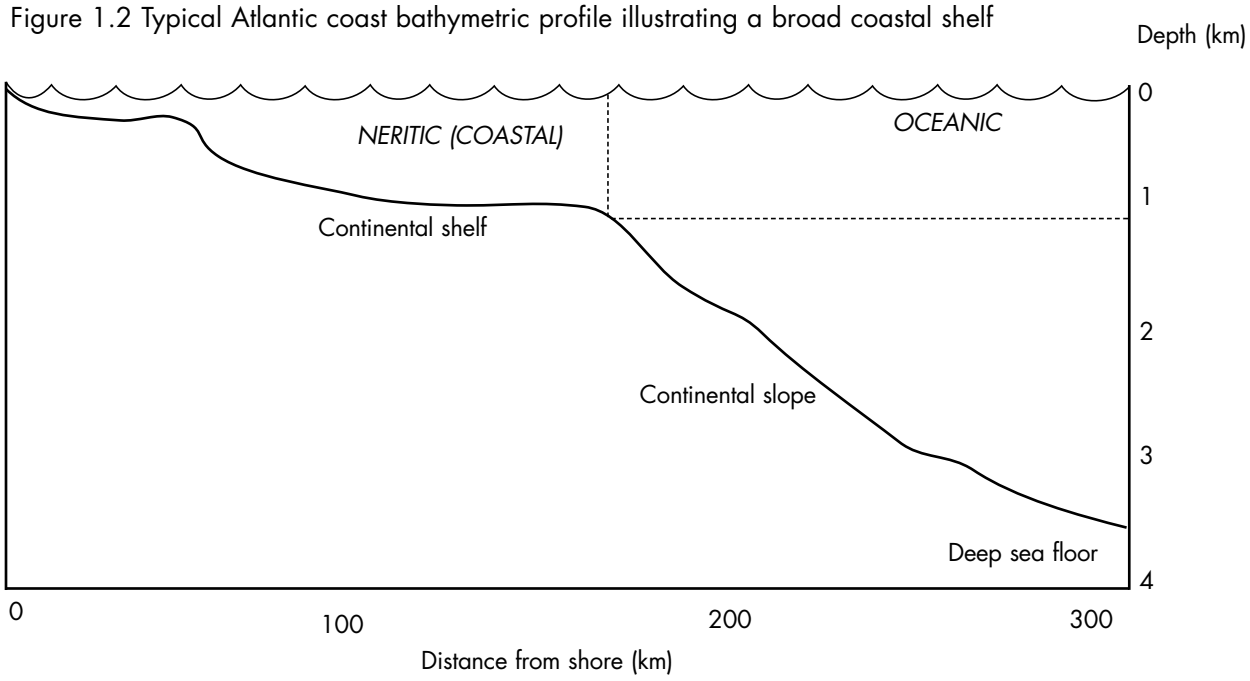


Figure 1.2 Typical Atlantic coast bathymetric profile illustrating a broad coastal shelf



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

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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

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Table 1.1 Geographic indicators of Provinces and Ecoregions

Province / Ecoregion	Area of Ecoregion (km^2) and % of Province		Coastline Length (km) and % of Province		Area of Mangroves (km^2) and % of Province		Mangrove Coastline Length (km) and % of Province		Area of Bathymetry (km^2) 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 Cali-

fornia 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 bentickı* 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. cooki 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 Ecore-

gion 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 Notothenid family, which has the highest (17) number of species. Four species of fish (*Salilota australis, Micromesistius australis, Macruronus magellanicus,* and the notothenid *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 Are-

nas 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 config-

uration 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.