Puerto Rico
Wetland Resources

The island of Puerto Rico, located in the northern Caribbean Sea, and its principal offshore islands of Vieques, Culebra, and Mona have abundant wetland resources. The subtropical climate, abundant rainfall, and complex topographic and geologic features of these islands give rise to wetlands ranging from the rare and unusual cloud forests in the highlands to extensive mangrove forests, seagrasses, and coral reefs along the northern and southern coasts. However, wetland resources of Puerto Rico have declined during the last several hundred years as a result of an increase in agricultural development, population, and tourism. Some types of wetlands, such as the bloodwood (*Pterocarpus officinalis*) forests (fig. 1), have been reduced to only a few remnants.

Wetlands are among the most biologically productive areas in the islands. The wetlands associated with the rain forest in the interior highlands of Puerto Rico contain many rare plant and animal species not found in other parts of the island. Runoff from wetlands in the higher elevations of the island provides a source of water used for public supply by several cities. Coastal wetlands, such as mangrove forests, seagrass beds, and coral reefs, provide breeding grounds and nursery areas for a variety of juvenile fish, crustaceans, and other species in the food web (López and others, 1988). In this manner, coastal wetlands contribute to the biological productivity of shallow marine waters around the islands. Wetlands also stabilize shorelines by trapping and holding unconsolidated sediments and dampen potentially damaging storm surges and wave action.

The value of Puerto Rican wetlands to wildlife is well documented. For example, the salt flats of Cabo Rojo, on the southwestern coast, provide resting and feeding areas for thousands of migratory shorebirds en route between North and South America. Before the drainage of coastal wetlands for agricultural purposes, freshwater marshes like those of the Laguna Cartagena, Laguna Guánica, and Ciénaga El Anegado provided habitat for more than 100 species of resident and migratory birds. The wetlands of the central highlands are the last stronghold of the endangered Puerto Rican parrot. Even wetlands like those within metropolitan San Juan (Laguna La Torrecilla, Torrecilla Baja, Laguna de Piñones to Punta Vacia Talega) provide excellent wildlife habitat, support economically valuable fisheries, and provide recreation and educational opportunities for an urban populace. Thirty-eight species of finfish and shellfish and 46 bird species, some rare or endangered like the yellow-shouldered blackbird, brown pelican, masked duck, West Indian whistling duck, and white-crowned pigeon, have been observed in the area. Also, the beaches associated with these urban wetlands provide nesting sites for the endangered hawksbill and leatherback turtles (del Llano and others, 1986).

Figure 1. Bloodwood trees at Pterocarpus Forest near Humacao, Puerto Rico. *(Photograph courtesy of Conservation Trust of Puerto Rico.)*

TYPES AND DISTRIBUTION

Wetlands are lands transitional between terrestrial and deepwater habitats where the water table usually is at or near the land surface or the land is covered by shallow water (Cowardin and others, 1979). The distribution of wetlands and deepwater habitats in Puerto Rico is shown in figure 2*A*; only wetlands are discussed herein.

Wetlands can be vegetated or nonvegetated and are classified on the basis of their hydrology, vegetation, and substrate. In this summary, wetlands are classified according to the system proposed by Cowardin and others (1979), which is used by the U.S. Fish and Wildlife Service (FWS) to map and inventory the Nation's wetlands. At the most general level of the classification system, wetlands are grouped into five ecological systems: Palustrine, Lacustrine, Riverine, Estuarine, and Marine. The Palustrine System includes only wetlands, whereas the other systems comprise wetlands and deepwater habitats. Wetlands of the systems that occur in Puerto Rico are described below.

System	Wetland description
Palustrine	Nontidal and tidal-freshwater wetlands in which vegetation is predominantly trees (forested wetlands); shrubs (scrub-shrub wetlands); persistent or nonpersistent emergent, erect, rooted herbaceous plants (persistent- and nonpersistent-emergent wetlands); or submersed and (or) floating plants (aquatic beds). Also, intermittently to permanently flooded open-water bodies of less than 20 acres in which water is less than 6.6 feet deep.
Lacustrine	Nontidal and tidal-freshwater wetlands within an intermittently to permanently flooded lake or reservoir larger than 20 acres and (or) deeper than 6.6 feet. Vegetation, when present, is predominantly nonpersistent emergent plants (nonpersistent-emergent wetlands), or submersed and (or) floating plants (aquatic beds), or both.
Riverine	Nontidal and tidal-freshwater wetlands within a channel. Vegetation, when present, is same as in the Lacustrine System.
Estuarine	Tidal wetlands in low-wave-energy environments where the salinity of the water is greater than 0.5 part per thousand (ppt) and is variable owing to evaporation and the mixing of seawater and freshwater.
Marine	Tidal wetlands that are exposed to waves and currents of the open ocean and to water having a salinity greater than 30 ppt.

In Puerto Rico, the Lacustrine and Riverine Systems consist largely of deepwater habitats. Lacustrine wetlands are limited to shallow areas of lakes and reservoirs. Riverine wetlands are limited to the shallows of river channels and canals. Where the stream current is swift, these wetland areas typically are nonvegetated. When vegetated, lacustrine and riverine wetlands generally are characterized by plants that grow in aquatic beds on or below the surface of the water. Some of the more common plants in these wetlands

are rooted aquatic plants, such as water lily, fanwort, pondweed, hornwort, and southern naiad, and floating aquatic plants such as duckweed, bladderwort, and water hyacinth.

Most of the wetlands in Puerto Rico and its principal offshore islands are palustrine or estuarine. One type of palustrine wetland that is of particular interest in Puerto Rico is the bloodwood forest. Bloodwood forests, which are common in parts of Central and South America, are now rare in Puerto Rico. Bloodwood trees tolerate low salinity and can grow in nearly pure stands at the brackish limits of the Estuarine System or form swamps (forested wetlands) in the interior. Bloodwood forests share numerous characteristics with cypress swamps of the Southeastern United States. Like cypress, bloodwood trees exist in nearly pure stands or mixed with a variety of other species of trees and shrubs. Epiphytes (plants that grow on other plants) are common on the trees, and typically ferns are the prevalent understory species (Alvarez-López, 1990). Growth forms of these two trees are similar; both cypress and bloodwood can develop buttressed trunks and commonly have modified surface roots that form kneelike structures (Bacon, 1990). The largest of the remaining bloodwood forests in Puerto Rico is the Pterocarpus Forest (fig. 1), which has an area of 370 acres and is located near Humacao on the eastern coast. Much smaller stands of bloodwood trees exist in the Sierra de Luquillo Mountains (fig. 2*B*) and at sites near Dorado, Mayagüez, and Patillas (fig. 2*A*).

Three other important palustrine wetland types, the cloud forest, colorado forest, and palm forest (forested or scrub-shrub wetlands), exist throughout Puerto Rico on the high mountain slopes. On the highest mountaintops are the cloud forests, in which gnarled evergreen trees 15 to 20 feet tall predominate. The more common trees in these areas include roble de sierra, nemocá, jusillo, oreganillo, and guayabota (Ewel and Whitmore, 1973). Trees in the cloud forest stay moist from nearly continuous cloud cover and support an abundance of epiphytic growth. Palo colorado, called titi in the Southeastern United States, is the dominant tree species in colorado forests, which are most common at elevations greater than about 2,500 feet and below cloud forests. This species is shrublike in the

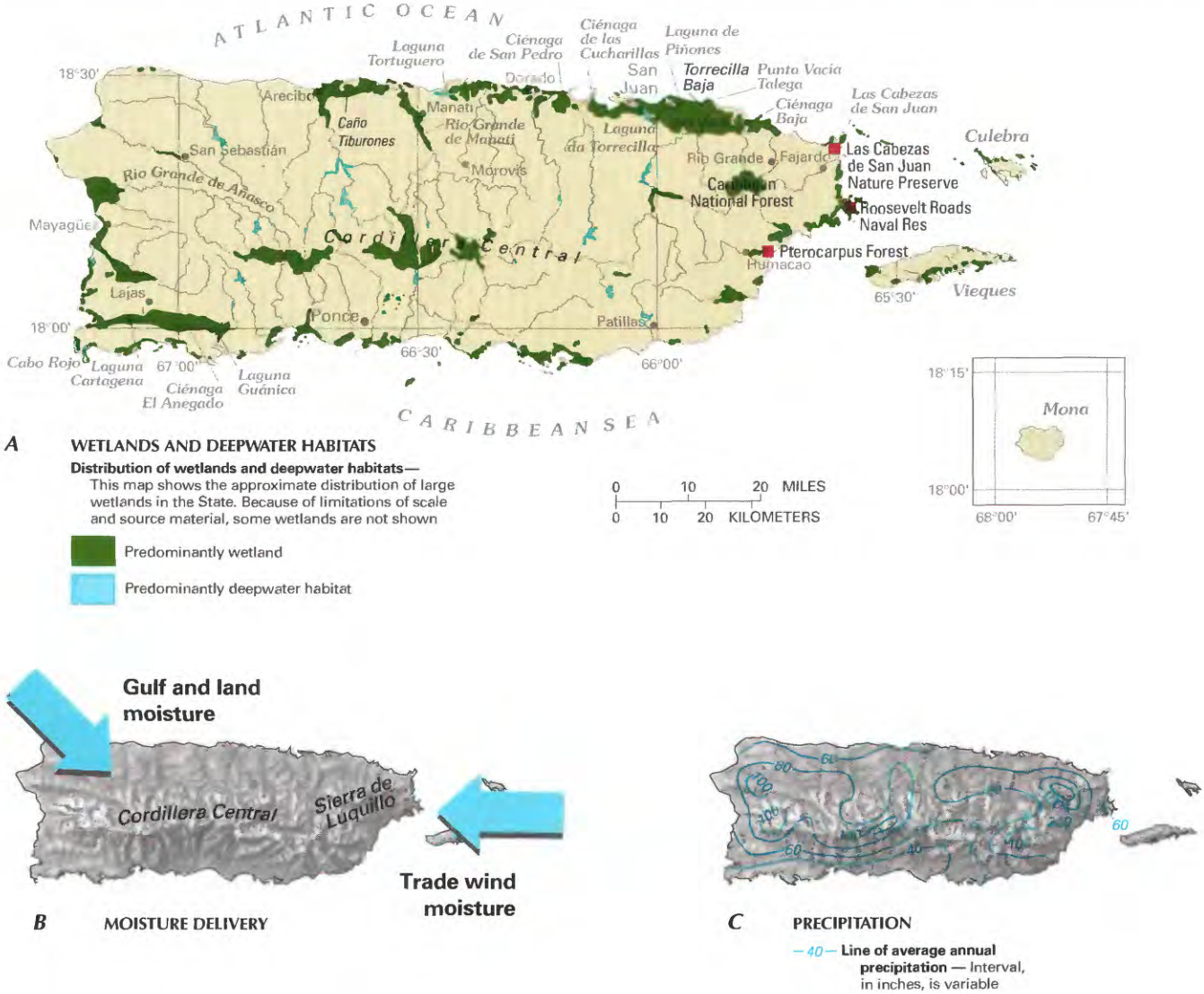

Figure 2. Wetland distribution in Puerto Rico and physical and climatic factors that affect wetland distribution in the Commonwealth. ***A***, Distribution of wetlands and deepwater habitats. ***B***, Principal sources and patterns of delivery of moisture into Puerto Rico. ***C***, Average annual precipitation in Puerto Rico. *(Sources: A, T.E. Dahl, U.S. Fish and Wildlife Service, unpub. data, 1991. B, Colón-Dieppa and others, 1991. C, Colón-Dieppa, 1986.)*

United States, but in Puerto Rico it can grow to a height of more than 30 feet and have a trunk diameter of more than 6 feet (Lugo and Brown, 1988). At elevations between 1,500 and 3,000 feet, mountain slopes generally are covered by palm forests, where nearly pure stands of sierra palms predominate. The sierra palm is also an important component of flood-plain wetlands. Some investigators believe that these montane palm forests are an early successional stage in areas subject to landslides or other forms of severe erosion (Beard, 1955). Although the total acreage of Puerto Rico's montane wetlands is unknown, the Caribbean National Forest in the Cordillera Central supports an estimated 933 acres of cloud forest, 8,490 acres of colorado forest, and 5,088 acres of palm forest.

Freshwater marshes (palustrine emergent wetlands) are common throughout the island, especially along the northern coast. In some areas, these freshwater marshes have been drained for sugar cane cultivation and pasture. Among the largest freshwater marshes are Caño Tiburones near Arecibo, Laguna Cartagena at Lajas, Ciénaga de San Pedro and Ciénaga de las Cucharillas along the northern coast, and Ciénaga Baja near Río Grande. In the deeper marshes, cattail is the most common emergent plant, although sawgrass and giant sedge also are common. The shallower marshes have a more complex species composition and soils that are saturated for shorter periods during the year. Common plants in shallow marshes are swamp fern, sedges, river grass, spike rush, panic grass, joint grass, and beakrush (U.S. Army Engineer Environmental Laboratory, 1978). The large marsh complex at Laguna Tortuguero near Manatí is the only documented spring- and seep-fed marsh in Puerto Rico (Quiñones-Márquez and Fusté, 1978). Water that enters the limestone aquifers in the karstic region of the island's interior discharges upward in the form of springs and seeps and keeps the soil saturated. Nearly 700 plant species, many of which are rare, endangered, or endemic to Puerto Rico, have been identified in this marsh (Lugo and Brown, 1988).

The most extensive estuarine wetlands are the mangrove forests (forested or scrub-shrub wetlands) in which red, black, and white mangrove and buttonwood predominate. Mangroves stabilize nearshore overwash islands, fringe the coastal shoreline, form extensive forests along estuarine rivers, and grow in basins that trap saltwater (Lugo and Brown, 1988). The largest mangrove stand in Puerto Rico is located just east of metropolitan San Juan in an area that includes about 2,500 acres of wetlands, beaches, and associated open-water habitats. In areas along the southern coast of the island, which are subject to drier climatic conditions, salt flats or salinas wetlands (primarily unconsolidated-shore wetlands) commonly exist, generally in association with mangrove-dominated habitats. These extremely saline environments develop where tidal saltwater is trapped and evaporated. The high salt content of soils in the flats can be tolerated by only a few plants, and the most saline of the flats are nonvegetated. An excellent example of this wetland type is the wetland at Cabo Rojo, in the extreme southwestern part of Puerto Rico.

Estuarine marshes (emergent wetlands) are uncommon in Puerto Rico. They usually form a narrow transition zone between mangrove-dominated wetlands and adjacent freshwater wetlands. Plant species in estuarine marshes typically include sawgrass, cattails, and leather ferns.

Open-water areas of the Estuarine and Marine Systems contain deepwater habitats and wetlands. The substrate and associated plants, rocks, or coral of a permanently flooded area constitute deepwater habitat, whereas areas that are exposed during even the lowest spring tide are classified wetland. In Puerto Rico, open-water estuarine wetlands can be nonvegetated or vegetated. The non-vegetated estuarine wetlands are primarily beaches, sand bars, and tidal flats (unconsolidated-shore wetlands), and the vegetated wetlands are mostly seagrass beds (aquatic-bed wetlands). Similarly, Puerto Rico's marine wetlands include unconsolidated shore and aquatic-bed wetlands, and in areas where coral reefs are exposed at extreme low tides, they too are considered wetlands.

HYDROLOGIC SETTING

The hydrologic setting of Puerto Rico is the major factor that controls the diversity and uniqueness of wetlands on the island. Local geohydrologic characteristics differ throughout the island largely because of variations in the geology, topography, and climate. In the mountainous Cordillera Central and Sierra de Luquillo (fig. 2*B*), which have peak elevations that exceed 4,300 feet above sea level, rainfall and runoff rates are high. The axis of the central mountain range, the Cordillera Central, trends east-west, and the core of the mountains is composed primarily of folded, faulted, intrusive volcanic rocks and sedimentary rocks. Along the northern flank of the mountains, a series of northward-dipping limestone formations dissected by streams and collapsed subterranean drainage features forms a band of mature karst topography that extends nearly to the coastline. These limestone formations constitute some of the most productive aquifers on the island. A flat coastal plain lies near the coast in many parts of the island. The coastal plain is particularly prominent along the southern coast where fan deltas from the southern drainages coalesce. In addition to alluvial fans, there are landslide, marine-terrace, coastal-dune, beach, swamp, and other recent deposits that overlie the older rocks on both the northern and southern coasts (P.G. Olcott, U.S. Geological Survey, written commun., 1993). On the eastern end of the island, the topography is characterized by steep-sided valleys and on the western end by broad, alluvial valleys that overlie volcanic rocks and limestone lenses.

The climate is classified as subtropical according to the life zone maps of the Holdridge classification system commonly used in Puerto Rico (Ewell and Whitmore, 1973). Winter is the coolest and driest season. During winter, there generally are at least 2 months of low precipitation when the region is under the influence of a subtropical high-pressure system. Precipitation in winter and spring generally is associated with moisture-laden frontal systems that approach the islands from the northwest (fig. 2*B*). Summers are hot and humid. During summer, the islands are no longer under the influence of high atmospheric pressure, and there is a steady westward flow of moist air from the Atlantic Ocean (the trade winds) that is the primary source of summer and fall precipitation.

Precipitation on Puerto Rico's main island varies geographically as well as seasonally. Average annual precipitation ranges from less than 35 inches in some southwestern coastal valleys to more than 200 inches in parts of the montane rain forests (fig. 2*C*) and averages about 70 to 72 inches per year islandwide. The geographic variation in precipitation is primarily the result of topography and the predominant weather patterns. The northern and southern parts of Puerto Rico's main island are separated by an east-west-trending mountain range, the Cordillera Central, which joins the southwest-northeast-trending Sierra de Luquillo in the eastern part of the island. Precipitation rates are high in the mountains because when atmospheric moisture in the weather systems is forced up the slopes into the cooler air of the higher elevations, the moisture condenses and falls as rain. Along much of the southern coast, annual rainfall totals are low relative to the rest of the island because this area lies in the rain shadow of the surrounding mountains, which intercept the prevailing westward- or southeastward-moving weather systems.

The ratio of precipitation to evapotranspiration also is a factor that affects the type and diversity of wetlands in Puerto Rico. As the ratio of precipitation to evaporation increases, the diversity of wetlands also increases. For example, on the leeward (southern) side of the island, where precipitation is low and evapotranspiration is high, estuarine wetlands predominate. On the windward (northern) side of the island, where precipitation is high, palustrine wetlands

are more common. These freshwater wetlands extend along perennial streams from coastal basins inland to some of the mountain slopes and exist in the rain forests at higher elevations (Zack and Román-Más, 1988).

In the northern part of Puerto Rico, freshwater wetlands receive nearly continuous precipitation in the montane rain forests, and wetlands on the coastal plain receive overland runoff and ground-water discharge from the limestone aquifer system (fig. 3). Near the coast, estuarine wetlands receive water from both the ocean and inland sources. In the coastal wetlands on the northern side of the island, direct precipitation is insignificant relative to the other moisture sources. However, the farther inland a wetland is and the greater its elevation, the more important direct precipitation becomes (Lugo and others, 1980).

Because the southern part of Puerto Rico receives less precipitation and has higher evapotranspiration rates than the northern part of the island, it is considered arid in relation to other parts of the island. Even though precipitation is not abundant in this part of the island, it is important to coastal-plain wetlands. Precipitation produces surface runoff, fills the rivers, and recharges the ground-water system. Overland flow, streamflow, and ground water are major sources of moisture for the southern coast's freshwater wetlands and are important sources for its estuarine wetlands. The ground-water system of southern Puerto Rico is entirely contained in the sedimentary aquifers of the coastal plain. Recharge to the aquifers occurs where the coastal plain meets the southern flank of the mountains at river valleys. The southerly flowing rivers are generally ephemeral, reaching the Caribbean Sea and the estuarine wetlands only during periods of high flow in summer and fall. At other times of the year, ground water discharges to the sea and is the only major source of moisture for nontidal wetlands.

Ground water in the valleys on the eastern and western ends of Puerto Rico generally is limited to local alluvial aquifers and is eventually discharged to the ocean. This ground-water discharge supports narrow, discontinuous wetlands along the coast in these areas.

The principal types of wetlands in Puerto Rico and their distribution with respect to elevation are shown in figure 3. The almost continuous precipitation and thin soil layers over insoluble rocks in the higher mountain elevations assure water saturation of the root zone, as well as nearly continuous water-vapor saturation of the atmosphere surrounding the canopy of the montane wetlands. This abundance of water also provides high runoff volumes for the successional wetlands at lower elevations. The water moves downslope into rivers, where it recharges the limestone aquifers. Farther downgradient, the aquifers discharge to rivers and springs, providing water for the lowland and coastal wetlands.

TRENDS

Reliable estimates of Puerto Rico's original wetland acreage are not available, but the wetlands of the island have been greatly reduced in number and size as a result of agricultural development and the growth in population. Virtually every wetland, with the exception of those in the highlands, has been damaged to some extent by attempts to drain the land for other uses. The small size of many of the wetlands increases their susceptibility to destruction (Lugo and Brown, 1988).

More than one-half of the original 30,000 acres of mangrove forests in Puerto Rico has been destroyed. Although mangrove forests are protected by law (Lugo, 1988), mangrove wetlands continue to be filled for housing developments, transportation facilities, highways, and landfills. Some mangrove wetlands are also destroyed by excavation for marinas and canals. A proposed expansion of Luis Muñoz Marín International Airport at Isla Verde would destroy an additional 160 acres of mangrove forest (Fernando J. Rodriguez and Associates, 1991).

Only a few bloodwood forests remain in Puerto Rico. Cintrón (1983) estimated that by 1977, only 14 stands of bloodwood trees having a combined area of about 600 acres existed on the island. Although the species probably was, at one time, distributed throughout the highlands of the interior, it is now limited to the Sierra de

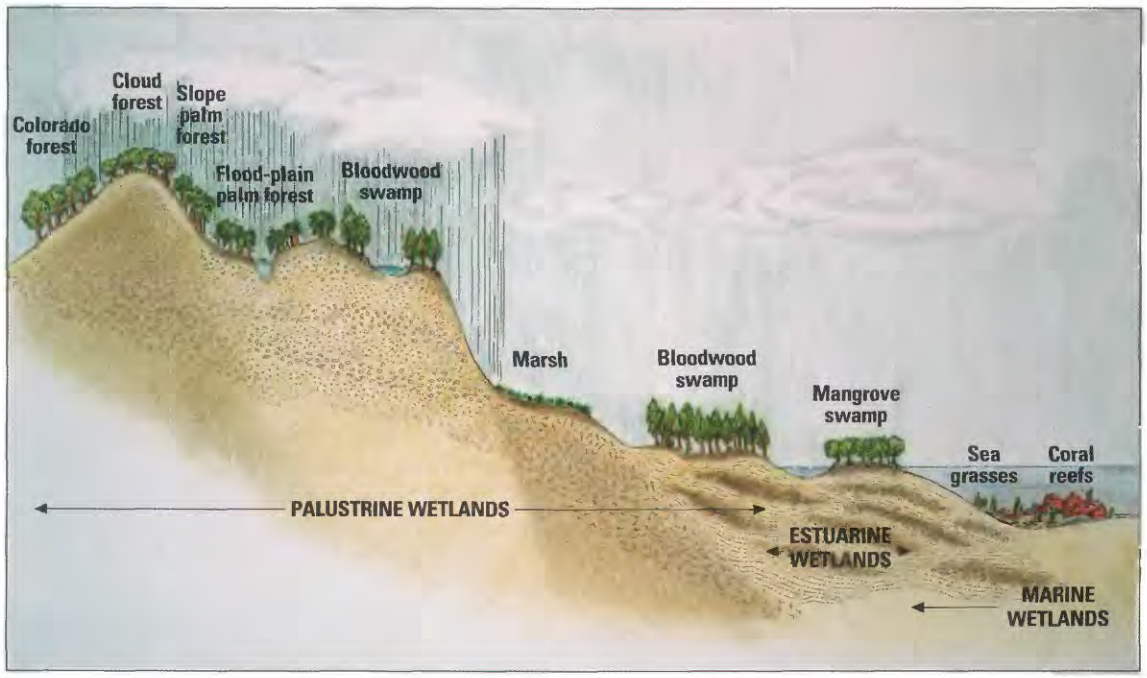

Figure 3. Generalized geohydrologic setting of wetlands in Puerto Rico. *(Source: Wetland types from Lugo and Brown, 1988.)*

Luquillo (Alvarez-López, 1990). A number of coastal stands that were documented earlier this century no longer exist. Although the large bloodwood forest at Humacao was recently brought under public ownership, most wetlands of this type are privately owned.

Over a period of several hundred years, large acreages of palustrine wetland were converted to agricultural use in the coastal-plain regions of Puerto Rico. For example, the Caño Tiburones wetland originally covered more than 6,000 acres but has, since 1917, been drained by pumping for land reclamation (Zack and Class-Cacho, 1984). The remaining mangrove swamp encompasses about 250 acres (A.L. Zack, U.S. Geological Survey, written commun., 1994). This trend has been reversed in recent years because of the declining profitability of sugar cane production. Agricultural areas that required intensive water management by draining and pumping are now being allowed to go fallow. Water levels in these areas have risen, and the abandoned farms are reverting to marsh. However, many of these areas are now subject to conversion for commercial development.

CONSERVATION

Many government agencies and private organizations participate in wetland conservation in Puerto Rico. The most active agencies and organizations and some of their activities are listed in table 1.

Federal wetland activities.—Development activities in Puerto Rico wetlands are regulated by several Federal statutory prohibitions and incentives that are intended to slow wetland losses. Some of the more important of these are contained in the 1899 Rivers and Harbors Act; the 1972 Clean Water Act and amendments; the 1985 Food Security Act; the 1990 Food, Agriculture, Conservation, and Trade Act; the 1986 Emergency Wetland Resources Act; and the 1972 Coastal Zone Management Act. In the following description of wetland-related Federal legislation, regulations that apply to States also apply to Puerto Rico.

Table 1. Selected wetland-related activities of government agencies and private organizations in Puerto Rico, 1993

[Source: Classification of activities is generalized from information provided by agencies and organizations. •, agency or organization participates in wetland-related activity; . ., agency or organization does not participate in wetland-related activity. MAN, management; REG, regulation; R&C, restoration and creation; LAN, land acquisition; R&D, research and data collection; D&I, delineation and inventory]

Agency or organization	MAN	REG	R&C	LAN	R&D	D&I
FEDERAL						
Department of Agriculture						
Consolidated Farm Service Agency	. .	•	. .	. .	. .	. .
Forest Service	•	. .	•	•	•	•
Natural Resources Conservation Service	. .	•	•	. .	•	•
Department of Commerce						
National Oceanic and Atmospheric Administration	•	•	. .	. .	•	. .
Department of Defense						
Army Corps of Engineers	•	•	•	•	•	•
Military reservations	•	. .	. .	. .	. .	. .
Department of the Interior						
Fish and Wildlife Service	•	. .	•	•	•	•
Geological Survey	. .	. .	. .	. .	•	. .
National Biological Service	. .	. .	. .	. .	•	. .
National Park Service	•	. .	•	•	•	•
Environmental Protection Agency	. .	•	. .	. .	•	•
COMMONWEALTH						
Department of Environmental and Natural Resources	•	•	•	•	•	•
PRIVATE						
Conservation Trust of Puerto Rico	•	. .	. .	•	•	. .

Section 10 of the Rivers and Harbors Act gives the U.S. Army Corps of Engineers (Corps) authority to regulate certain activities in navigable waters. Regulated activities include diking, deepening, filling, excavating, and placing of structures. The related section 404 of the Clean Water Act is the most often-used Federal legislation protecting wetlands. Under section 404 provisions, the Corps issues permits regulating the discharge of dredged or fill material into wetlands. Permits are subject to review and possible veto by the U.S. Environmental Protection Agency (EPA), and the FWS has review and advisory roles. Section 401 of the Clean Water Act grants to States and eligible Indian Tribes the authority to approve, apply conditions to, or deny section 404 permit applications on the basis of a proposed activity's probable effects on the water quality of a wetland.

Most farming, ranching, and silviculture activities are not subject to section 404 regulation. However, the "Swampbuster" provision of the 1985 Food Security Act and amendments in the 1990 Food, Agriculture, Conservation, and Trade Act discourage (through financial disincentives) the draining, filling, or other alteration of wetlands for agricultural use. The law allows exemptions from penalties in some cases, especially if the farmer agrees to restore the altered wetland or other wetlands that have been converted to agricultural use. The Wetlands Reserve Program of the 1990 Food, Agriculture, Conservation, and Trade Act authorizes the Federal Government to purchase conservation easements from landowners who agree to protect or restore wetlands. The Consolidated Farm Service Agency (formerly the Agricultural Staibilization and Conservation Service) administers the Swampbuster provisions and Wetlands Reserve Program. The Natural Resources Conservation Service (formerly the Soil Conservation Service) compliance with Swampbuster provisions and assists farmers in the identification of wetlands and in the development of wetland protection, restoration, or creation plans.

The 1986 Emergency Wetland Resources Act and the 1972 Coastal Zone Management Act and amendments encourage wetland protection through funding incentives. The Emergency Wetland Resources Act requires States to address wetland protection in their Statewide Comprehensive Outdoor Recreation Plans to qualify for Federal funding for State recreational land; the National Park Service provides guidance to States in developing the wetland component of their plans. Coastal and Great Lakes States that adopt coastal-zone management programs and plans approved by the National Oceanic and Atmospheric Administration are eligible for Federal funding and technical assistance through the Coastal Zone Management Act.

Federal agencies acquire and manage wetlands at numerous locations in Puerto Rico. The Caribbean National Forest, administrated by the U.S. Forest Service, encompasses the rain forest wetlands of El Yunque and the surrounding highlands. The FWS also actively manages wetlands as part of the National Wildlife Refuge system and has recently acquired the freshwater wetlands of Laguna Cartagena. Management and restoration plans for the lagoon are being developed cooperatively with the municipality of Lajas. The U.S. Navy manages wetlands on their reservations at Roosevelt Roads and on the island of Vieques.

Commonwealth wetland activities.—Many of Puerto Rico's wetlands are in public ownership. Theoretically, under the Spanish law still in effect, all mangrove forests are owned by the Commonwealth of Puerto Rico because they are within the maritime (intertidal) zone (Lugo, 1988). Large areas of mangrove forests, having been set aside years ago as a future source of fuel, are managed by the Puerto Rico Department of Environmental and Natural Resources as part of the Commonwealth forest system. Wetland management by the Department is not limited to estuarine habitats. Freshwater wetlands in the Pterocarpus Forest and Laguna Tortuguero are also under the Department's control.

Under the authority of the Coastal Zone Management Act, the

Commonwealth has developed a comprehensive management plan of which wetland protection, particularly of mangrove wetlands, is an integral part. Certification of consistency with the plan is required before any Federal permits or licenses are granted for activities in the coastal zone. The Planning Board of the Commonwealth is the primary agency responsible for administration of the plan.

A number of other planning documents have been developed to guide wetland-management activities. The Department of Environmental and Natural Resources, FWS, and EPA have independently prepared prioritized listings of important wetland-resource areas. The Natural Heritage Program within the Department of Environmental and Natural Resources has also developed restoration and management plans for wetlands of exceptional importance such as those at Caño Tiburones and Laguna Guánica.

Private wetland activities.—The Conservation Trust of Puerto Rico is the principal private organization actively involved in the preservation and management of wetlands in Puerto Rico. The Conservation Trust is a privately funded institution that acquires and manages wetlands and other historical properties of notable and cultural significance in Puerto Rico. For example, the Conservation Trust, in cooperation with the Puerto Rico Department of Environmental and Natural Resources, manages the Department's lands at Las Cabezas de San Juan Nature Reserve near Fajardo at the eastern end of the island.

References Cited

Alvarez-López, Migdalia, 1990, Ecology of *Pterocarpus officinalis* forested wetlands of Puerto Rico, *in* Lugo, A.E., Brinson, Marlo, and Brown, Sandra, eds., Forested wetlands, Ecosystems of the World, v. 15: New York, Elsevier, p. 251–265.

Bacon, P.R., 1990, Ecology and management of swamp forests in the Guianas and Caribbean region, *in* Lugo, A.E., Brinson, Marlo, and Brown, Sandra, eds., Forested wetlands—Ecosystems of the World, v. 15: New York, Elsevier, p. 213–225.

Beard, J.S., 1955, The classification of tropical American vegetation types: Ecology, v. 36, no. 1, p. 89–100.

Cintrón, B.B., 1983, Coastal freshwater swamp forests—Puerto Rico's most endangered ecosystem?, *in* Lugo, A.E., ed., Los Bosques de Puerto Rico: Río Piedras, Puerto Rico, U.S. Department of Agriculture Forest Service, Institute of Tropical Forestry, p. 249–282.

Colón-Dieppa, Eloy, 1986, Puerto Rico Surface-Water Resources, *in* U.S. Geological Survey, National water summary 1985—Hydrologic events and surface water resources: U.S. Geological Survey Water-Supply Paper 2300, p. 399–406.

Colón-Dieppa, Eloy, Torres-Sierra, Heriberto, and Colón J.A., 1991, Puerto Rico floods and droughts, *in* U.S. Geological Survey, National water summary, 1988–89—Hydrologic events and floods and droughts: U.S. Geological Survey Water-Supply Paper 2375, p. 475–481.

Cowardin, L.M., Carter, Virginia, Golet, F.C., and LaRoe, E.T., 1979, Classification of wetlands and deepwater habitats of the United States: U.S. Fish and Wildlife Service Report FWS/OBS–79/31, 131 p.

Dahl, T.E., 1991, Wetland Resources of the United States: St. Petersburg Fla., U.S. Fish and Wildlife Service special map, scale 1:3,168,000.

del Llano, Manuel, Colón, J.A., and Chabert, J.L., 1986, A directory of neotropical wetlands, *in* Scott, D.A., and Carbonell, Montserrat (compilers): Cambridge, U.K., International Union for Conservation of Nature and Natural Resources and Slimbridge, U.K., International Waterfowl Research Bureau, p. 559–571.

Ewel, J.J., and Whitmore, J.L., 1973, The ecological life zones of Puerto Rico and the U.S. Virgin Islands: U.S. Forest Service Research Paper ITF–18, 72 p.

Fernando J. Rodriguez and Associates, 1991, Environmental assessment, proposed master plan report improvements—Luis Muñoz Marín International Airport (prepared for Puerto Rico Ports Authority): San Juan, Puerto Rico, Fernando J. Rodriguez and Associates, Report No. 81.06 [Revised 1992], [400 p.].

López, J.M., Stoner, A.W., García, J.R., and García-Muñíz, Iván, 1988, Marine food webs associated with Caribbean islands mangrove wetlands: Acta Cientifica, v. 2, no. 2–3 p. 94–123.

Lugo, A.E., 1988, The mangroves of Puerto Rico are in trouble: Acta Cientifica, v. 2, no. 2–3, p. 124.

Lugo, A.E., and Brown, Sandra, 1988, The wetlands of the Caribbean Islands: Acta Cientifica, v. 2, no. 2–3, p. 48–61.

Lugo, A.E., Twilley, R.R., Patterson-Zucca, Carol, 1980, The role of black mangrove forests in the productivity of coastal ecosystems in South Florida—Report to the Southern Forest Experiment Station, U.S. Environmental Protection Agency: Gainesville, University of Florida, Center for Wetlands, 281 p.

Quiñones-Márquez, Ferdinand, and Fusté, L.A., 1978, Limnology of Laguna Tortuguero, Puerto Rico: U.S. Geological Survey Water-Resources Investigations Report 77–122, 84 p.

U.S. Army Engineer Environmental Laboratory, 1978, Preliminary guide to wetlands of Puerto Rico: U.S. Army Engineer Waterways Experiment Station Technical Report Y–78–3, 77 p.

Zack, A.L., and Class-Cacho, Angel, 1984, Restoration of freshwater in the Caño Tiburones area, Puerto Rico: U.S. Geological Survey Water-Resources Investigations Report 83–4071, 33 p., 1 plate.

Zack, Allen, and Román-Más, Angel, 1988, Hydrology of the Caribbean Islands Wetlands: Acta Cientifica, v. 2, no. 2–3 p. 65–73.

FOR ADDITIONAL INFORMATION: District Chief, U.S. Geological Survey, P.O. Box 364424, San Juan, PR 00936; Regional Wetland Coordinator, U.S. Fish and Wildlife Service, 1875 Century Building, Atlanta, GA 30345

Prepared by

D. Briane Adams, U.S. Geological Survey, and John M. Hefner, U.S. Fish and Wildlife Service