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U.S. Fish and Wildlife Service Refuges

And Other Nearby Reserves In Southwestern Puerto Rico

Peter L. Weaver and Joseph J. Schwagerl

Front cover

Top, *Cabo Rojo National Wildlife Refuge. The Cabo Rojo Salt flats, critical wildlife habitat at the southwestern tip of Puerto Rico, boast a long history of wildlife use and human activity* (Photo by Jorge Salivia). Bottom, *Laguna Cartagena National Wildlife Refuge. Farming and water diversion measures around the Cartagena Lagoon in southwestern Puerto Rico have modified its water quality and regimen* (Photo by Peter L. Weaver) .

Top, *Wildlife refuge. Welcome to the U.S. Fish and Wildlife Service's Cabo Rojo National Wildlife Refuge via Mariano Rodríguez Lane* (Photo by Peter L. Weaver). Bottom, *Headquarters. First constructed to monitor regional communications, the original headquarters was the home of the U.S. Fish and Wildlife Service for 35 years* (Photo by Peter L. Weaver).

U.S. Fish and Wildlife Service Refuges

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Contents

Abstract

The main purpose of this paper is to summarize information about the Cabo Rojo and Laguna Cartagena National Wildlife Refuges in southwestern Puerto Rico. The Cabo Rojo (Headquarters and Salinas tracts) and Laguna Cartagena (Lagoon and Tinaja tracts) occupy 1174 ha and are part of the 10 231-ha Caribbean system of nine refuges. Their major geologic and physiographic features are Sierra Bermeja, the oldest mountain range in Puerto Rico, and the floodplains of the Lajas Valley. Together, the refuges combined contain 9 geologic features and 26 soils' types. Rainfall averages about 1000 mm/year and hurricanes occur periodically. Among the several vegetation types, including are mangroves, salt flats, littoral woodland, mesquite and semievergreen woodland, coastal shrub, deciduous woodland, and pasture. At least 644 plant species grow on the refuges. Eight of these species are considered rare and endangered, and have formal recovery plans. Refuge mammals include two species of native bats and six introduced species—two monkeys, a mongoose, two rats, and a mouse. Both the Cabo Rojo Salt Flats and Cartagena Lagoon are renowned as wintering habitat for migratory birds where >200 resident and migratory birds have been observed, including 12 island endemics. Moreover, several other species are listed as rare and endangered, or of conservation concern, or as target species for management. Among the reptiles are seven lizards, two geckos, and three turtles (one terrestrial and two marine). Five amphibians (one toad and four frogs) and 18 species of fish (fresh and brackish water) are also present. Six of the wildlife species have formal recovery plans.

The major management activities on the refuges include protection against fires, habitat restoration, public education, special uses, and water management at the Cartagena Lagoon and the Salinas salt flats. Habitat recovery has been stimulated through fire control, through livestock removal, and by planting >9,000 trees of nearly 80 species. Public education encompasses nearly 20,000 visits annually to interpretative centers at the Headquarters and Salinas tracts; moreover, another 2,600 visitors frequent the refuges to observe wildlife and take nature photographs, and nearly 4,900 others participate in educational and interpretative programs. Special use permits have been issued to 174 users since 1979, mostly for administrative matters or environmental research. Finally, water management at the Cartegena Lagoon remains a problem, partly because of historical events and partly due to current difficulties.

In addition to the U.S. Fish and Wildlife Service (F&WS) refuges, six other major protected areas occupy about 6800 ha along the southwestern coast: Punta Guaniquilla Natural Reserve, Boquerón Wildlife Refuge, Los Morrillos de Cabo Rojo, Boquerón Forest, Parguera Natural Reserve, and Guánica Forest. An additional 23 bird species not recorded on the refuges have been observed in these protected areas. The F&WS refuges and the protected areas provide critical wildlife habitat in Puerto Rico's southwest—an area that is experiencing a rapid increase in human population.

Keywords: Cabo Rojo Wildlife Refuge, Laguna Cartagena Wildlife Refuge, fauna, flora, climate, geology, soils, management.

List of Figures

List of Tables

List of Tables (continued)

Background Information

Introduction

The U.S. Fish and Wildlife Service (F&WS) in the U.S. Department of the Interior administers the national wildlife refuge system, which grew from a single 1.2-ha refuge in 1903 to 390 refuges totaling 137 380 km^2 by 1979 (Doyle 1979). The first refuge, Pelican Island in eastern Florida, was set aside by President Theodore Roosevelt to protect the brown pelican. In 1909, when Roosevelt left office, the wildlife refuge system had 51 reservations in 21 States and 3 territories (Clark 1993). When the Salinas tract was added to the Cabo Rojo National Wildlife Refuge (NWR) in October 1999, wildlife refuges numbered more than 500 and occupied nearly 380 000 km^2 (Meretsky and others 2006 ; U.S. Fish and Wildlife Service 1999, see endnotes). Today, refuges are scattered in all States throughout the continental United States and in Alaska, Hawaii, Puerto Rico, the U.S. Virgin Islands (Ogburn 1979), and Navassa Island near Haiti's southwestern shores (U.S. Fish and Wildlife Service 2002).

Initially, the purpose of the refuge system was to protect wildlife, especially migratory waterfowl, from the devastating impacts of a growing society (Doyle 1979). Because migratory bird species move across State, provincial, and national borders, the Migratory Bird Treaty Act of 1918 recognized them as an international resource. Management of the wildlife and their habitats are the responsibility of the Secretary of the Interior. In 1924, a provision allowed for hunting and fishing. In 1934, during the Great Depression, an effort was made to purchase and restore habitats. Moreover, Congress passed the Migratory Bird Hunting and Conservation Stamp Act, which was, in essence, a tax on those who hunted migratory waterfowl. In 1956, the Fish and Wildlife Act expanded the role of refuges beyond waterfowl to all endangered wildlife. At the same time, the refuges faced pressure for greater public use, including recreation. In 1973, Congress passed the Endangered Species Act, subsequently amended, to protect endangered and threatened species. Today, refuge lands are mainly used for environmental education, fishing, wildlife observation, hiking, and photography rather than hunting.

The stated mission of the F&WS is "to administer a national network of lands and waters for the conservation, management, and where appropriate, restoration of the fish, wildlife and plant resources and their habitats within the United States for the benefit of present and future generations of Americans" (Meretsky and others 2006). Since many important migratory bird habitats in the eastern Caribbean have been lost through development, refuges in Puerto Rico and the Virgin Islands have become increasingly important in the conservation of migratory wildlife.

Objectives and Parameters

The purpose of this report is to compile information on the Cabo Rojo and Laguna Cartagena NWRs into a convenient summary to serve as a baseline for future research and management activities. This includes all known vascular plants and vertebrate animal species tallied within the refuges. The topics include administrative details; history; research, i.e., environmental data, flora, and fauna; management; and public use. This review of research topics highlights the importance of the refuges in the conservation of dry forest habitat and its wildlife, in particular the avifauna of Puerto Rico's southwest. Studies conducted within the refuges have been mentioned or briefly summarized along with relevant work carried out at nearby sites, including the Commonwealth forest reserve units at Boquerón and Guánica, the Boquerón Wildlife Refuge, the Parguera and Punta Guaniquilla Natural Reserves, and Los Morrillos de Cabo Rojo (Cabo Rojo Lighthouse area) (Departamento de Resursos Naturales 1979, Ventosa-Febles and others 2005). Inclusion of other sites, notably Guánica, is important because of the amount of relevant research that has been carried out there. Environmental issues and suggestions for future research and management activities have been outlined.

The Cartagena Lagoon, on the Laguna Cartagena NWR wildlife refuge, has a long record of human activity, and many observations have been summarized in unpublished reports over the years. This report does cite some gray literature, i.e., unpublished lists of plants and birds, trip reports, short-term field investigations, and student projects, mainly related to the refuge sites. Lists of nonvascular

plants and invertebrates, or details of water management for the Cartagena Lagoon, however, are topics beyond the scope of this review. Finally, the text relies heavily on the use of scientific names for the flora and fauna. To facilitate species identification, common names have been tabulated in English and Spanish. Also, English common names have been included when bird species are first mentioned in text or when they are discussed as separate research projects.

Administrative Details

The F&WS manages nine refuges in the Caribbean Basin that total about 10 230 ha of terrestrial habitat (table 1). Puerto Rico and its offshore islands contain five of the refuges; the U.S. Virgin Islands, three; and Navassa Island, about 60 km west of Haiti, is the remaining refuge. The refuges range in size from 6 ha on Green Cay to 7 566 ha on Vieques. The two most distant, Navassa and Sandy Point, are separated by 1100 km; all except Navassa, however, are within 250 km of the Headquarters tract at Cabo Rojo.

The Cabo Rojo and the Laguna Cartagena NWRs, situated in southwestern Puerto Rico, together occupy 1174 ha (Ventosa-Febles and others 2005) (fig. 1). The Headquarters and Salinas (salt flats) tracts are in the Cabo Rojo NWR, which also includes the current F&WS headquarters in the Caribbean. The Headquarters tract was transferred from the Foreign Broadcast Information Service, i.e., the Central Intelligence Agency, in June 1974 to help implement the national migratory bird program according to 16 U.S.C. 667b, an act authorizing the transfer of real property for wildlife or other purposes. The Salinas tract, numerically the most important area for shorebirds in Puerto Rico and the Caribbean region (Collazo and others 1995, see endnotes), was acquired in 1999 to protect important shore bird habitat.

The Laguna Cartagena NWR includes the Lagoon and Tinaja tracts. The six parcels in the Lagoon tract, previously owned by four individuals, were appraised in 1985 (Waight 1985, see endnotes). The Lagoon tract, established through a lease agreement with the Commonwealth of Puerto Rico in August of 1989, was for the conservation and management of fish and wildlife resources according to 16 U.S.C. 742f(a)(4), and for the benefit of the F&WS (Earsom and others 2004). The Tinaja tract was acquired in 1996 via a fee title from the U.S. Department of Agriculture Farm Service Agency. About one-half of the Lagoon tract is occupied by the Cartagena Lagoon and surrounding wetlands.

The major purpose for acquiring refuge lands in Puerto Rico was to assist the F&WS in carrying out its mission, which includes the conservation and protection of fish and wildlife resources, and carrying out the national migratory bird management program. Others have provided more specific details (Raffaele and others 1977; Schaffner 1995a and 1995b, see endnotes; Woodbury and others 1975):

- Increase, improve, and protect nesting and foraging habitat for native forest birds, shore birds, and wetland species, including threatened and endangered species.
- Provide wintering habitat for neotropical migratory forest bird species.
- Increase native plant diversity and protect threatened and endangered species.
- Restore fish, wildlife, plant resources, and their habitats.
- Reduce threats from exotic plant and animal species.
- Provide environmental education and interpretative opportunities for the public.

Historical Perspective

Puerto Rico's southwest, including the salt flats of Cabo Rojo and the Lajas Valley, has a long and rich history (Ibern Fleytas 1960). Before discovery, Cabo Rojo had numerous Indian inhabitants as evidenced by shell mounds and excavated sites. The Indians survived by collecting snails and other littoral fauna, fishing, hunting, and cultivating subsistence crops, including yuca. It is unlikely that their activities had a major impact on the island's vegetation although they used fire to clear land for their crops.

Some contend that in November 1493, Columbus and his crew first set foot on Puerto Rico in the vicinity of the town of Boquerón while looking for water (Ibern Fleytas 1960). Most, however, suggest it was most probably farther north near Añasco or Aguada (Brau 1969). As early as 1511, the Cabo Rojo Salt Flats were being exploited and San Germán was the first settlement dedicated to marketing salt (Gil-Bermejo García 1970, Sued Badillo 1985). In 1519,

Table 1—U.S. Fish and Wildlife Service refuges in the Caribbean Basin and Commonwealth protected areas in southwestern Puerto Rico [a]

Location and property name	Date(s) established	Area	Range in elevation	Number of species		Habitat description
				Plants [c]	Birds	
		ha [b]	*m*			
U.S. Fish and Wildlife Service refuges in the Caribbean						
Puerto Rico's southwest						
Cabo Rojo						
Headquarters tract [d]	1974	238	3–35	245	107	Scattered trees, shrubs, pasture
Salinas tract [e]	1999	513	0–3	~147	118	Salt flats, lagoons; mangrove, upland scrub
Laguna Cartagena						
Lagoon tract [f]	1989	317	11–40	189	146	Freshwater lagoon; grass, scattered trees
Tinaja tract [g]	1996	106	20–300	196	17+	Abandoned pasture and secondary forest
Subtotal	1974–99	1,174	0–300			
Elsewhere in Puerto Rico						
Desecheo [h]	1976	146	0–206	161	51	Secondry forest and scrub, heavily grazed
Culebra and cays [i]	1909–2004	607	0–107	410	120	Secondry forest and scrub; mangrove
Vieques [j]	2001–2003	7,566	0–301	781	107	Secondary subtropical moist and dry forest
U.S. Virgin Islands						
Buck Island, St. Thomas [k]	1969/81/04	18	0–33	43+	10	Secondary scrub
Green Cay, St. Croix [l]	1977	6	0–19	69	24	Secondary scrub
Sandy Point, St. Croix [m]	1984/03	170	0–3	225	99	Secondary scrub
Navassa Island [n]	1999	544	0–60	147	49	Secondary forest
Subtotal	1909–2004	9,057	0–301			
Total	1909–2004	10,231	0–301			
Reserves of the Commonwealth in southwestern Puerto Rico						
Boquerón Forest [o]	1918	1,876	0–5	?	>50	Mangrove wetlands, salinas, and scrub
Boquerón Wildlife Refuge [p]	1963	252	0–1	?	130	Mangrove wetlands, salinas, and scrub
Los Morrillos de Cabo Rojo [q]	1882	105	0–28	147	52	Secondary scrub
Punta Guanaquilla Natural Reserve [r]	1976	152	0–46	253	81	Coastal thicket, secondary scrub, wetlands
Guanica Forest [s]	1919	4,016	0–228	500	154	Late secondary subtropical dry forest
Parguera Natural Reserve [t]	1979	408	0–95	184	64	Mangrove wetlands, salinas, and scrub
Total	1882–1980	6,809	0–228			

continued

Table 1—U.S. Fish and Wildlife Service refuges in the Caribbean Basin and Commonwealth protected areas in southwestern Puerto Rico [a] (continued)

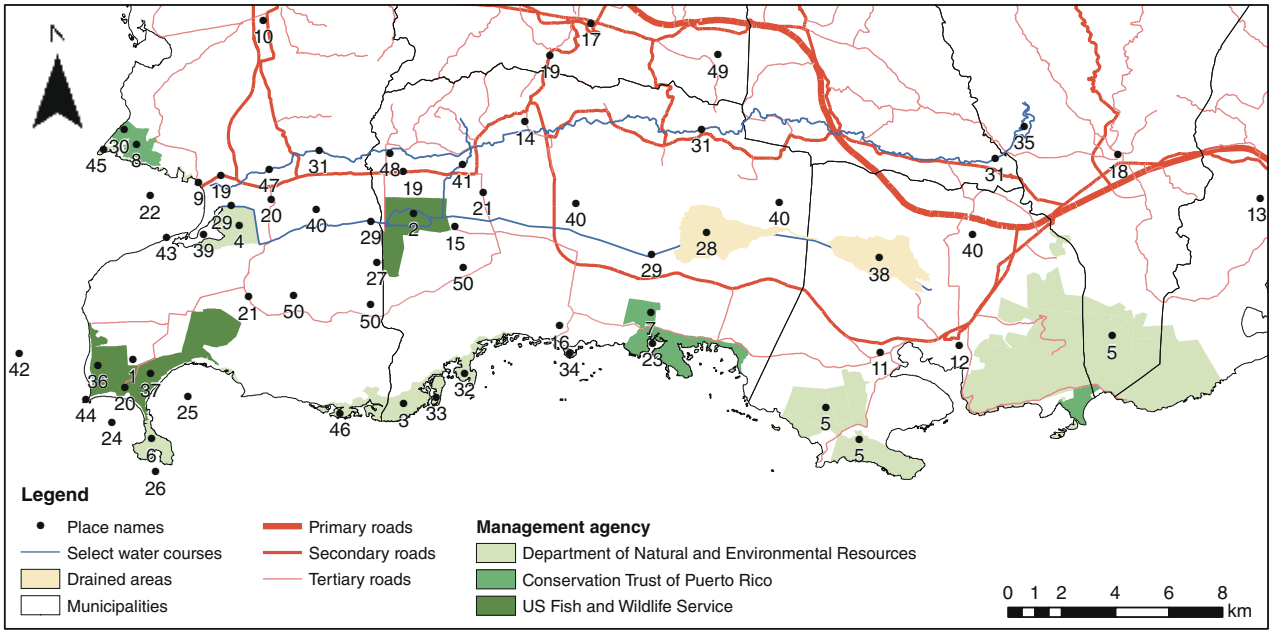
[a] Except for parts of Vieques, all areas are located in subtropical dry forest.
[b] Terrestrial areas (marine areas omitted) rounded to the nearest hectare.
[c] Flowering plants and ferns.
[d] Plants (McKenzie 1986, see endnotes); birds (Del Llano and others 1986, U.S. Fish and Wildlife Service 2002).
[e] Source: Ventosa-Febles and others (2005). Plants (no tally available; probably similar to Los Morillos de Cabo Rojo); birds (Collazo and others 1995, U.S. Fish and Wildllife Service 2004).
[f] Plants (Diaz-Soltero 1990); birds (U.S. Fish and Wildlife 2004).
[g] Plants (Proctor 1996, see endnotes; Weaver and Chinea 2003; Weaver and Schwagerl 2004, 2005); birds (U.S. Fish and Wildlife Service 2004).
[h] Plants (Breckon 2000, Woodbury and others 1971); birds (Anon. 1987, see endnotes; Struthers 1927; Wetmore 1918).
[i] Plants (Woodbury 1981, see endnotes); birds (U.S. Fish and Wildlife Service 1996); plants and birds (Metzen 1981, see endnotes).
[j] Plants (Proctor 1994); birds (Sorrie 1975).
[k] Plants and birds (Lombard 2004, see endnotes).
[l] Plants (Woodbury and Vivaldi 1982, see endnotes; Joe Schwagerl, personal observation.); birds (Wiley 2003, see endnotes).
[m] Plants (Anon., no date, see endnotes); birds (U.S. Fish and Wildlife Service 1993a).
[n] Plants (Zanoni and Buck 1999); birds (Earsom and others, in press).
[o] Source: Department of Natural Resources (1976); Ventosa-Febles and others (2005). Boquerón Forest is divided in 12 separate segments located in the municipalities of Lajas, Boquerón, and Mayaguez, as follows (from Bahia Montalva west to Cabo Rojo, then north toMayaguez): Bahía Montalva, Pitahaya, Los Molinos, lands near El Faro, Boquerón, Guaniquilla (mangroves at Villa Taína), Villa de la Mela mangroves, Puerto Real, Barrio Miradero (Punta Ostiones), Cayo Ratones, Joyuda Lagoon mangroves, and Guanajibo mangroves. Plants are mainly typical of mangroves and salinas.
[p] Source: Ventosa-Febles and others (2005).
[q] Sources: Cerame Vivas (1988); Municipio Autonomo de Cabo Rojo (1998).
[r] Sources: Fuentes Santiago and Quevedo Bonilla (2002); Vazquez and Kolterman (1998).
[s] Sources: Canals Mora (1990), Departamento de Recursos Naturales (1985), Quevedo and others (1990), Velez Rodriguez (no date).
[t] Sources: Departamento de Recursos Naturales (1981); Departamento de Recursos Naturales y Ambientales (2000a); Ventosa-Febles and others (2005).

the Spanish directed that sugar production be pursued in Puerto Rico. Other crops that were grown at one time or another around Cabo Rojo included sugar cane, cacao, coffee, cotton, and tobacco (Gil-Bermejo García 1970).

By 1559, the town of Cabo Rojo was settled. Apparently, the settlement was moved from an earlier site along the coast where a Spanish vessel was sunk by the French; later, the French also attacked San Germán. Cofresí (Roberto Couphersein y Ramírez de Arellano) was a Puerto Rican pirate born in Cabo Rojo in 1791. He attacked foreign, i.e., non-Spanish, ships and shared the booty with friends. Subsequently, he became a local legend and tales of his character and exploits were greatly enhanced.

In 1898, when Puerto Rico was occupied by the United States, the island's population was about 800,000 and the dominant industries were agriculture and lumbering (Morris 1901). The principal crop was coffee, followed by sugar, both accounting for more than 90 percent of the exports. Salt works situated along the south coast, including those at Cabo Rojo, constituted the principal mineral industry. At that time, the population of the town of Cabo Rojo was about 16,150; since the mid-1970s, the population of the municipality has climbed dramatically (Ramos y Ramírez de Arellano and others 1985, see endnotes) (fig. 2).

A socioeconomic study carried out during the early 1940s in the Lajas Valley region, i.e., from Boquerón to Guánica, showed the major "industrial" activities were salt production (13,600 tons per year), fishing (9.1 tons per week), charcoal production, and bark stripping of *Rhizorphora mangle* for tannin production in the Boquerón Forest (Hernández-Ramírez 1947). The principal farming activities (percentages of



Key	Map items	Key	Map items	Key	Map items	Key	Map items
	Protected areas:		**Towns and highways:**		**Geographic features:**		**Geographic features:**
1	Cabo Rojo Refuge	13	Guayanilla	25	Bahía Sucia	39	Laguna Rincón
2	Laguna Cartagena Refuge	14	Lajas	26	Cabo Rojo	40	Lajas Valley
3	Boquerón Forest	15	Maguayo	27	Cerro Mariquita	41	Magara Canal
4	Boquerón Wildlife Refuge	16	Parguera	28	Ciénaga El Anegado	42	Mona Passage
5	Guánica Forest	17	San Germán	29	Drainage Canal	43	Playa Combate
6	Los Morrillos de Cabo Rojo	18	Yauco	30	Hacienda La Romana	44	Punta Aguila
7	Parguera Natural Reserve	19	PR Route 101	31	Irrigation Canal	45	Punta Guaniquilla
8	Punta Guaniquilla Natural Reserve	20	PR Route 301	32	Isla Cueva	46	Punta Pitahaya
		21	PR Route 303	33	Isla Guayacán	47	Quebrada Boquerón
	Towns and highways:			34	Isla Magueyes	48	Quebrada Los Llanos
9	Boquerón		**Geographic features:**	35	Lago Loco	49	Río Guanajibo
10	Cabo Rojo	22	Bahía Boquerón	36	Laguna Candelaria	50	Sierra Bermeja
11	Ensenada	23	Bahía Fosforescente	37	Laguna Fraternidad		
12	Guánica	24	Bahía Salinas	38	Laguna Guánica		

Figure 1—Places mentioned within southwestern Puerto Rico in text.

farmland in parentheses) were: sugar cane production (57), corn (17), cotton and cowpeas (12), and several other crops (14). Pasturing of livestock included dairy cows, goats, sheep, and work animals.

Both refuge sites were essentially abandoned farms when acquired by the F&WS. The principal use of the Cabo Rojo Headquarters tract at the time of purchase was to graze cattle. Cattle grazing and the harvest of forage followed for several years. At Salinas, the major activity was salt production along with some wood harvest and grazing.

During the 1920s, the Cartagena Lagoon and adjacent lands were partitioned into estates for the production of sugar cane (Danforth 1926). At that time, owners considered draining the lagoon to

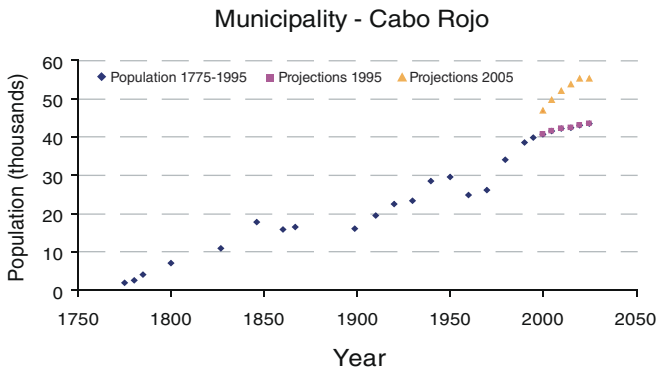


Figure 2—Population in the Cabo Rojo municipality: 1750–2025 (Junta de Planificación 1995, 2005; Ramos y Ramírez de Arellano and others 1985).

increase the planting area but needed the water to irrigate nearby fields during the summer months. Later, the lagoon and surrounding lands were acquired by the Puerto Rican Government.

Past use of the Tinaja tract included timber harvest for fuelwood and fence posts with recurrent fires used to clear the land for cattle grazing. Use of the steep upper slopes was abandoned first and reverted to scrub with scattered grass and barren patches. Grazing by goats, however, continued for a period. The midelevation slopes of Tinaja have had a mixture of secondary native and exotic tree species since the mid-1930s. On the lower slopes, where the last fire occurred in 1996, grazing by cattle and horses continued for a longer period. During the past decade, grazing and fire have been eliminated on the entire tract through improved fencing and regular F&WS patrol. A combination of factors—a dry climate, past sugar cane production, heavy grazing, recurrent fires, and later, a dense grass cover, have resulted in a slow recovery of woody vegetation on the refuge properties.

Both refuge properties are an integral part of public landholdings in southwestern Puerto Rico. Moreover, several other reserves contain about 6,800 ha of critical wildlife habitat managed for resident and migratory bird species (table 1). Land use changes in and around the Guánica Forest during the past 50 years showed that forest cover and urban areas had increased at the expense of agriculture, confirming a transition from an agrarian to urban society (Lugo and others 1996). Moreover, since 1990, the human population in the municipality of Cabo Rojo has grown in excess of projections because several coastal areas have been developed as summer homes (Junta de Planificación 1995, 2005) (fig. 2). These changes highlight the importance of protecting and managing critical wildlife habitat.

Growing population. The municipality of Cabo Rojo has experienced a substantial increase in population during the past 20 years adding to the pressures on the region's wildlife.
(Photo by Peter L. Weaver)

Environmental Conditions of the Refuges

The national wildlife refuge properties in southwestern Puerto Rico total 1174 ha and include four tracts of land ranging in size from 106 to 513 ha (table 1).

Geology

The southwestern part of Puerto Rico is characterized by long ridges such as the Sierra Bermeja separated by parallel valleys like Lajas that extend eastward for many kilometers from the Mona Passage (Meyerhoff 1933) (fig.1). The ridges contain rocks of marine Cretaceous sediments such as ashy shales, massive limestone, and agglomerates. The valleys, in contrast, are partly covered with alluvial deposits of recent origin underlain by consolidated carbonate and clastic strata (sedimentary rock) of Cretaceous and Tertiary age (Bonnet and Tirado Sulsona 1950, Graves 1991). These, in turn, are underlain by igneous rocks at depths of 165 to 265 m.

The 1500-ha Sierra Bermeja is the oldest and among the most interesting mountain ranges on the Caribbean plate. The Bermeja Complex of rocks is composed of basalt (volcanic origin), amphibolites and serpentinite (metamorphic rocks), and chert (formed by organisms in deep marine waters). The complex contains radiolarian (amoeboid protozoan) fossils in chert that date to 195 million years ago (Montgomery and others 1994a, 1994b; Pindell

and Barrett 1990). The Lower Jurassic radiolarian signature is older than the Caribbean Sea and establishes the Pacific origin of the Caribbean plate.

The Yauco-Boquerón anticlinal valley (Lajas Valley) is about 30 km long by 5 km at its widest point (Graves 1991). During the Tertiary period, the Lajas Valley was eroded by a large stream with its source in the mountains near the town of Yauco. Subsequently, the Río Guanajibo extended its headwaters and pirated streams flowing into the Lajas Valley (Mitchell 1922).

Nearly three-quarters the Cabo Rojo NWR consists of beach deposits and quartz sand deposits; also, Ponce limestone and alluvium cover nearly one-quarter of the tract (Bawiec 2001, Volckmann 1984a) (table 2, fig. 3). The remaining lands, in descending areal coverage, are occupied by pyroxene olivine basalt, Mariquita chert, mangrove swamp, and Parguera limestone. Brief descriptions of the geological features at Cabo Rojo NWR (Headquarters and Salinas tracts) are listed below with map designations (table 2, fig. 3):

Table 2—Geology and soils on the Headquarters and the Salinas tracts of the Cabo Rojo National Wildlife Refuge

Geology/soils Map designation and unit name [a]	Area	Refuge
	ha	*percent*
Geology [b]		
Kjm—Mariquita chert, Lower Cretaceous-Upper Jurassic	1.60	0.21
Kp—Parguera limestone, Upper Cretaceous	0.14	0.02
Kpob—Pyroxene Olivine basalt, Upper Cretaceous?	10.71	1.41
Qa—Alluvium, Holocene-Pleistocene	80.31	10.60
Qb—Beach deposits, Holocene	255.62	33.73
Qs—Mangrove swamp, Holocene	1.54	0.20
Qts—Quartz sand deposits, Tertiary	306.52	40.45
Tpo—Ponce limestone, Miocene-Oligocene	101.37	13.38
Total [c]	757.81	100.00
Soils [d]		
AcD—Aguilita clay, 5 to 20 percent slopes	11.34	1.50
AcE—Aguilita clay, 20 to 50 percent slopes	1.71	0.23
AmC2—Amelia-Magüayo gravelly clay loams, 5 to 12 percent slopes	17.86	2.36
AsB—Americus fine sand, 2 to 5 percent slopes	86.77	11.45
Ca—Cartagena clay	19.34	2.55
Co—Coastal beach	24.09	3.18
FrB—Fraternidad clay, 2 to 5 percent slopes	89.89	11.86
Gf—Guaynabo fine sand	28.20	3.72
JcB—Jacana clay, 2 to 5 percent slopes	0.58	0.08
Lr—Limestone rock land	24.46	3.23
PzB—Pozo blanco gravelly clay loam, 0 to 5 percent slopes	1.47	0.19
PzC—Pozo blanco gravelly clay loam, 5 to 12 percent slopes	14.20	1.87
SoA—Sosa loamy sand, 0 to 5 percent slopes	105.91	13.97
Tf—Tidal flats	107.43	14.17
Ts—Tidal swamp	1.25	0.16
W—Salt water lagoons	223.41	29.48
Total [c]	757.91	100.00

[a] Refer to geology map (fig. 3) and soils map (fig. 5).
[b] Sources: Bawiec (2001); Volckmann (1984a, 1984b).
[c] Totals slightly different due to map error.
[d] Sources: Bawiec (2001); Carter (1965).

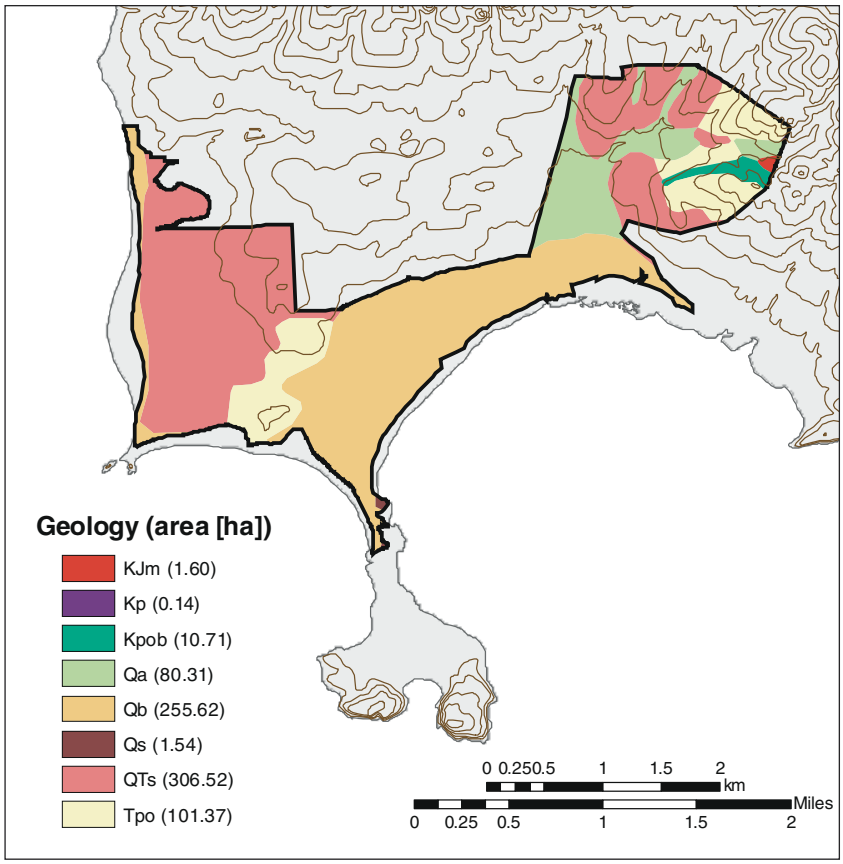


Figure 3—Geology and topography map of the Cabo Rojo National Wildlife Refuge (Bawiec 2001, Volckmann 1984a).

- KJm—Mariquita chert, laminated, fine grained, and dark gray in color containing radiolarian (amoeboid protozoa) and locally Foraminifera (amoeboid protists)
- Kp—Parguera limestone, basal conglomerate that grades upward into limestone composed of coarse skeletal clasts of fossils
- Kpob—Porphyritic, i.e., embedded crystals. augite hypersthenes, i.e., lustrous silicate of iron/ magnesium-olivine basalt
- Qa—Quaternary alluvium, unconsolidated sand and gravel with some silt and clay; locally includes fluvial terrace deposits
- Qb—Beach deposits or poorly consolidated beach sands; locally, sand dune deposits
- Qs—Swamp deposits, including sandy and silty clay, locally ranging to peat or peaty muck
- Qts—Friable quartz-rich sand deposits
- Tpo—Ponce limestone and Juana Diaz formation with poorly cemented, somewhat friable calcirudite (skeletal limestone) and calcarenite (dune limestone), including oyster shells, minor corals, and gastropods

More than 80 percent of the Laguna Cartagena NWR is covered by alluvium and nearly 20 percent by Mariquita chert; the remainder is Magüayo porphyry (Bawiec 2001, Volckmann 1984b) (table 3, fig. 4). Alluvium dominates in the valley, merging with colluvium at lowest levels along the valley walls. Mariquita chert covers the refuge from mid-to-high elevations. At highest elevations, Magüayo porphyry, the only geological feature not discussed above, covers a small area (table 3, fig. 4).

- TKh—Magüayo porphyry, a quartz-bearing inrusive rock occurring in isolated bodies

Table 3—Geology and soils on the Lagoon and Tinaja tracts of the Laguna Cartagena National Wildlife Refuge

Geology/soils Map designation—unit name [a]	Area	Refuge
	ha	*percent*
Geology [b]		
Kjm—Mariquita chert, Lower Cretaceous-Upper Jurassic	2.61	0.62
Qa—Alluvium, Holocene-Pleistocene	76.43	18.05
TKh—Magüayo porphyry, Lower Cretaceous	344.37	81.33
Total	423.41	100.00
Soils [c]		
Ag—Aguirre clay	19.73	4.66
AmB—Amelia-Magüayo gravelly clay loam, 2 to 5 percent slopes	37.85	8.94
AmC2—Amelia-Magüayo gravelly clay loams, 5 to 12 percent slopes	55.93	13.21
Ca—Cartagena clay	6.86	1.62
Cc—Cartagena silty clay loam, acid variant	23.50	5.55
Gc—Guánica clay	84.43	19.94
GuD—Guayama cherty clay loam, 5 to 20 percent slopes	0.70	0.16
GuF—Guayama cherty clay loam, 20 to 60 percent slopes	65.21	15.40
Sc—San Anton silty clay, moderately deep	0.92	0.22
Sn—Santa Isabel clay	20.54	4.85
Va—Vayas silty clay	7.77	1.84
Vo—Volcanic rock land	12.29	2.90
W—Fresh water lagoon	87.68	20.71
Total	423.41	100.00

[a] Refer to geology map (fig. 4) and soils map (fig. 6).
[b] Sources: Bawiec (2001); Volckmann (1984a, 1984b).
[c] Sources: Bawiec (2001); Carter (1965).

Soils

Soils in the Lajas Valley exhibit certain characteristics in common (Lugo-López and others 1959). They are very deep with high, nearly uniform clay content. The top soil is usually 30 cm, but in places approaches 60 cm deep. The small pores conduct water rather well in the top soil but show very slow hydraulic conductivity in the subsoil. The soils are low in organic matter and nitrogen and generally high in soluble salts and exchangeable sodium, notably below 60 cm. The taxonomy of Puerto Rican soils, including those of the Lajas Valley, was outlined according to the new soils classification system (7th approximation) (Lugo-López and Rivera 1976, 1977).

At the Cabo Rojo NWR, the soils of the Headquarters and Salinas tracts are distinct (table 2). For the most part, the Headquarters tract is an upland site and Salinas is a coastal one. The 15 soil types on the refuge are separated into 5 types of clay; 3 gravelly clay loams; 1 loamy sand; and 3 types of sand, limestone rock, tidal flats, and tidal swamps. Salt water lagoons cover about 40 percent of the Salinas tract, i.e., 30 percent of the entire refuge. Brief descriptions of the soils at Cabo Rojo NWR (Headquarters and Salinas) are listed below with map designations (Carter 1965) (table 2, fig. 5):

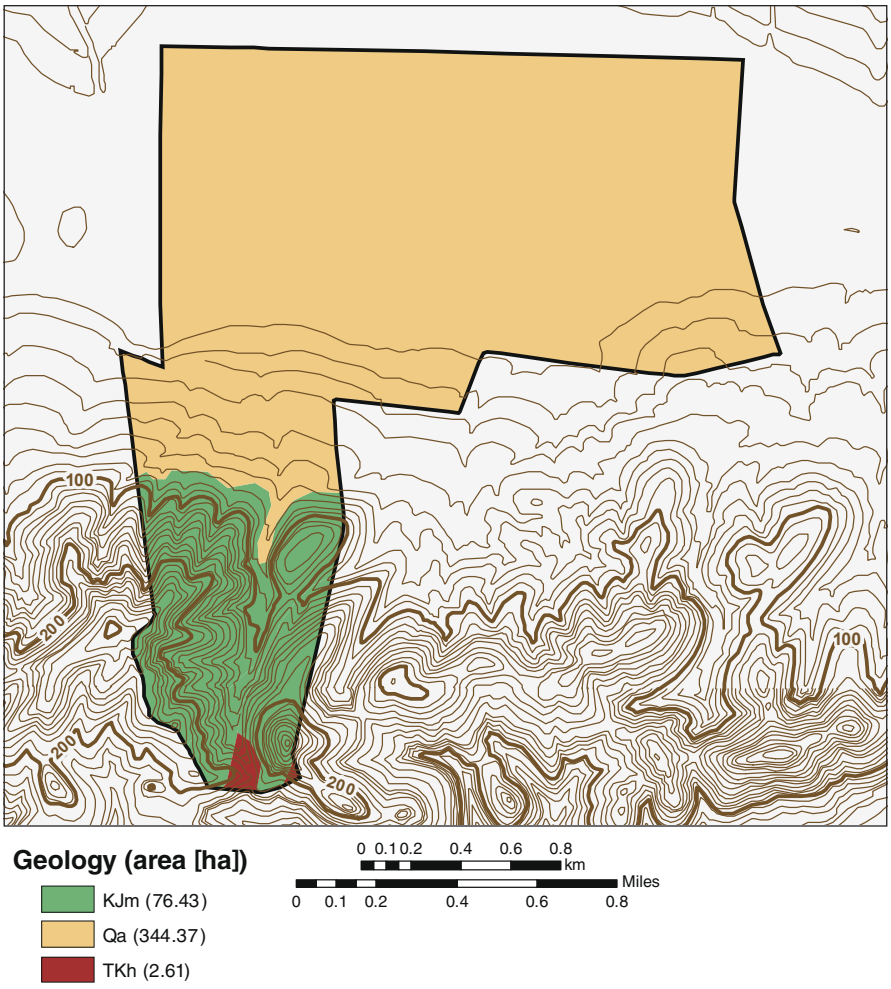


Figure 4—Geology and topography map of the Laguna Cartagena National Wildlife Refuge (Bawiec 2001, Volckmann 1984a).

- AcD—Aguilita clays are sloping; well drained-to-excessively drained, shallow soils on hills. They are highly calcareous and of medium natural fertility.
- AcE—Aguilita clays are a steeper variant of the above.
- AmC2—Amelia-Magüayo gravelly clay loams are a series that occur together. They are characterized by deep, well-drained acid soils in alluvium and colluvium, occurring on eroded, gentle foot slopes of hills. The mixture is about 60 to 70 percent Amelia, and 30 to 40 percent Magüayo.
- AsB—Americus fine sands are deep, gently sloping, excessively drained soils on the Coastal Plain. They are strongly acid and low in fertility.
- Ca—Cartagena clays are level to nearly level, somewhat poorly drained, and slightly saline-to-moderately saline soils on alluvial fans. When wet, they are slightly sticky and plastic throughout the profile. They have a perched water table at depths of 60 cm or greater.
- Co—Coastal beaches are made up of light-colored, gently rolling beach sands along the coast. They are an unconsolidated mixture of coral, shell, and quartz and are calcareous, excessively well drained, and low in natural fertility.
- FrB—Fraternidad clays are deep, nearly level or gently sloping and moderately well-drained soils. They are neutral to calcareous, heavy, sticky,

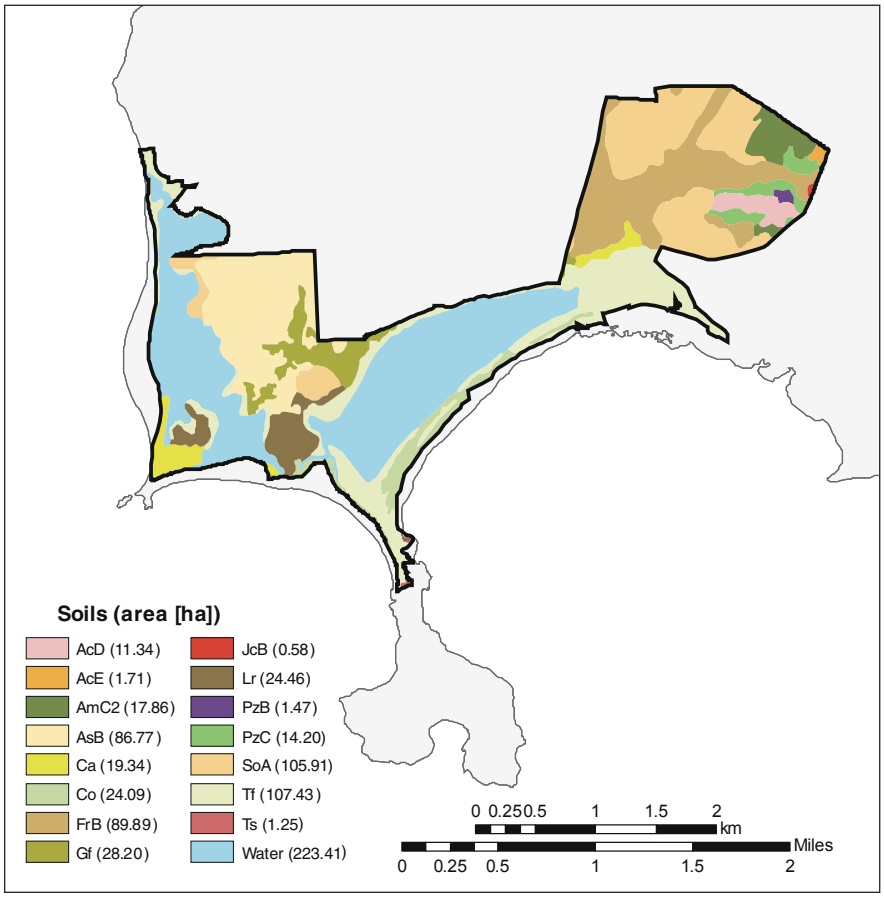


Figure 5—Soils map of the Cabo Rojo National Wildlife Refuge (Carter 1965).

shrink and swell with moisture changes, and are high in natural fertility.

- Gf—Guayabo fine sands are gently sloping, deep, excessively drained soils on the Coastal Plain. They are acid and low in natural fertility.
- JcB—Jácana clays are gently to strongly sloping, well-drained alluvial and colluvial soils in valleys. They are acid and medium in natural fertility.
- Lr—Limestone rocklands have steep slopes mostly covered with limestone cobbles and stones. These lands are shallow and low in moisture-holding capacity.
- PzB—Pozo blanco gravelly clay loams are nearly level to strongly sloping, moderately deep, well-drained soils on alluvial and colluvial foot slopes. They are highly calcareous and medium in natural fertility.
- PzC—Pozo blanco gravelly clay loams are a steeper variant of the above.
- SoA—Sosa loamy sands are moderately deep, excessively drained soils on nearly level to sloping Coastal Plains. They are underlain by stratified, dense, sandy clay and are low in available moisture and natural fertility.
- Tf—Tidal flats are nearly level lands along the coast. They are poorly drained and frequently flooded by salt water during high tides. They have a high water table, are saline, and when dry, are thinly crusted with salt.
- Ts—Tidal swamps are areas that are permanently flooded by shallow water along the coast.

At the Laguna Cartagena NWR, the soils situated in the Lajas Valley are distinct from those in the Sierra Bermeja. The fertile, alluvial soils of the Lajas

Valley are deep, heavy, difficult to drain, and often affected by salt, particularly in previously irrigated areas (Koenig 1953, Picó 1974, Willardson 1958). In contrast, the steep slopes of the Sierra Bermeja are shallow, stony, well drained, and dry.

Twelve soil types occupy the refuge, including three types of clay, two types of silty clay, two gravelly clay loams, two cherty clay loams, one silty clay loam, sand, and volcanic rock (table 3). Slightly more than one-quarter of the Lagoon tract is occupied by the Cartagena Lagoon, i.e., about 20 percent of the entire refuge (table 3). Soils not described above for Cabo Rojo follow with map designations (Carter 1965) (table 3, fig. 6):

- Ag—Aguirre clays are deep, level or nearly level, poorly drained soils on alluvial fans. They are sticky and plastic when wet, highly calcareous, and of medium natural fertility.
- AmB—Amelia-Magüayo gravelly clay loams are a series that occur together. They are characterized by deep, well-drained acid soils in alluvium and colluvium, occurring on the gentle foot slopes of hills. The mixture is about 60 to 70 percent Amelia, and 30 to 40 percent Magüayo.
- Cc—Cartagena silty clay loams, acid variant are level, somewhat poorly drained, and slightly saline soils on alluvial fans. They have a slightly coarser textured surface layer than Cartagena clays. They shrink and crack when dry, swell when wet, and are of medium natural fertility.
- Gc—Guánica clays are deep, nearly level, slowly permeable, calcareous, and with medium natural fertility. They have a high shrink-swell potential, and crack when dry.
- GuD—Guayama cherty clay loams are shallow, well-drained soils on the steep slopes of Sierra Bermeja. The soils are acid and medium in natural fertility.

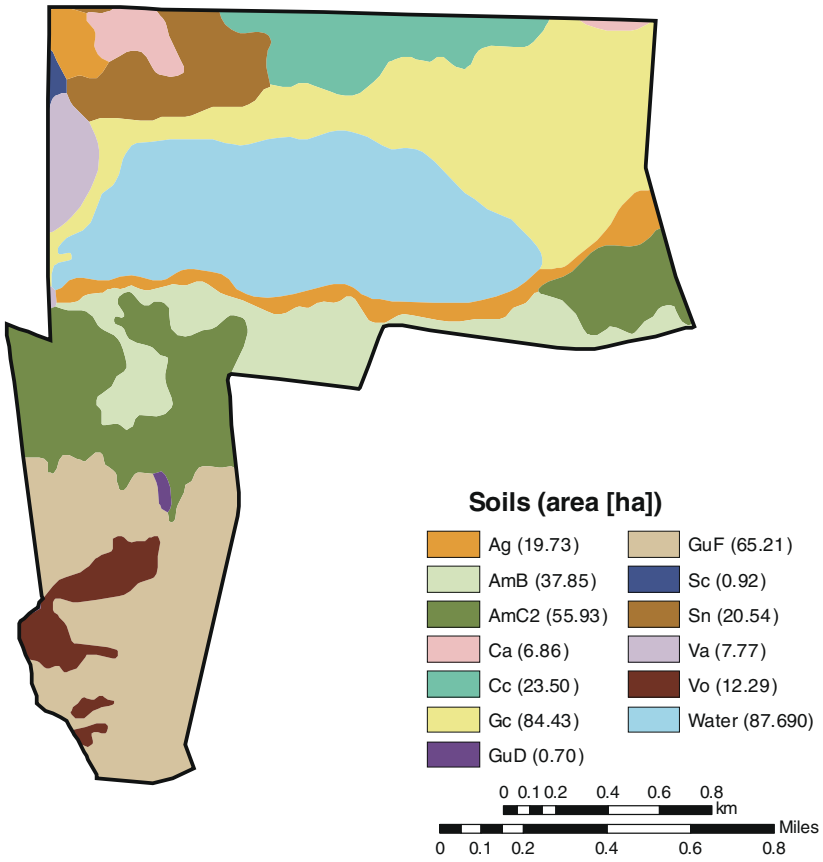


Figure 6—Soils map of the Laguna Cartagena National Wildlife Refuge (Carter 1965).

- GuF—Guayama cherty clay loams are a steeper variant of the former.
- Sc—San Anton silty clays (moderately deep) are moderately deep, well drained, nearly level alluvial soils on flood plains adjacent to streams. They are slightly acid to mildly calcareous, and moderately permeable, with a firm heavy clay substratum. They are high in natural fertility.
- Sn—Santa Isabel clays are deep, moderately well-drained soils on nearly level terrain in valleys. High in fertility, they shrink and swell with changes in moisture.
- Va—Vayas silty clays are nearly level, poorly drained soils on flood plains. They have a high water table, and are neutral to mildly alkaline above and saline at lower levels.
- Vo—Volcanic rocklands are characterized by acid volcanic rock outcrops that cover more than one-half of the mapping area. Areas not covered by outcrops are covered by stony or gravelly clay loams or clays.

Physiography and Hydrology

The western part of the Lajas Valley rises from sea level at Bahía Boquerón to about 13 m in elevation at PR Route 303 (fig. 1). The highway runs along the drainage divide that separates the eastern and western parts of the valley (Graves 1991). The principal aquifer of the Lajas Valley consists of alluvial deposits. Consolidated sedimentary rocks with different hydraulic characteristics underly the deposits and could be considered as a distinct aquifer (Graves 1991). The principal aquifer is recharged by rainfall and streamflow, most of which occurs through coarse grain alluvial fans along the valley's edges. Seasonal changes of 0.6 m are apparent in the altitude of the potentiometric surface, which averages about 15 m at the northern and southern boundaries of the valley, and 4 m in the middle. Discharge of ground water occurs through pumping, evapotranspiration, and subsurface seepage.

The Headquarters tract, characterized by gentle slopes, ranges from <5 m in the southwest corner to about 35 m in elevation in the northwest corner (fig. 3). The entire Salinas tract is virtually at sea level. The large, shallow Laguna Candelaria and Laguna Fraternidad salt water lagoons, which fluctuate in size according to rainfall, runoff from upland areas, and tidal levels are the most striking features of the tract (Tripp and Collazo 2003). Evaporation from the lagoons is high, and salinity tends to increase with distance from the water control structures. Water movement in the lagoons is influenced by wind and flow is generally from east to west, particularly in Laguna Fraternidad.

The Lagoon tract ranges in elevation from 40 m on the south side bordering the slopes of Sierra Bermeja to 11 m at the shoreline of the Cartagena Lagoon (Schaffner 1995b, see endnotes) (fig. 4). To the north, the property is flat, rising to 12 m at the border with private holdings. At the time of discovery, Cartagena Lagoon was once part of a system of 50 freshwater lagoons throughout Puerto Rico (Colón 1982a). Within the Lajas Valley, it was part of a series of wetlands that extended from Laguna Guánica westward for about 30 km through Ciénaga El Anegado and the Cartagena Lagoon to Laguna Rincón on the west coast (Ramírez Toro and Minnigh 1997, see endnotes). Cartagena Lagoon was a landlocked water body maintained by runoff from the surrounding mountains; heavy rainfall, however, caused ephemeral streams to raise the water level in the lagoon, which then overflowed, draining westward 7 km through the Río Boquerón, i.e., today the Drainage Canal, to a mangrove swamp along Bahía Boquerón (Danforth 1926). The water level of the lagoon varied seasonally, rising during the fall with heavy rainfalls and declining during the warm summer months. The size of the lagoon could fluctuate from 0 to 140 ha and its depth from 0 to 1.5 m. The lagoon's dynamic nature provided a variety of habitats—open water for the foraging of resident and migratory waterfowl, emergent vegetation with nesting areas for resident aquatic birds, and foraging habitat for wading birds during the seasonal change in depth.

Agricultural development subsequently wrought dramatic changes to the lagoon's water regimen. Cartagena Lagoon remains today, but by the early 1980s, it had lost 95 percent of its open water and some of its wildlife. This was due to a host of activities such as deforestation around the lagoon, pumping water for irrigation, eutrophication and pollution, canal construction, the growth of weedy plants, cattle grazing, and the concentration of hunters at the only remaining lagoon in the Lajas Valley. Today, water enters the Lajas Valley from the east via the Irrigation Canal and flows to the Cartagena Lagoon through the Margara Canal. This gravity-fed

aqueduct extends 37 km from Lago Loco, passing north of the town of Magüayo, through the Cartagena Lagoon, and west to Bahía Boquerón. The aqueduct supplies about 5 670 000 m^3 (4,600 acre-feet) of water per month (Graves 1991).

The Tinaja tract, contiguous with the lagoon property, lies about 0.5 km south of Cartagena Lagoon. The tract measures approximately 0.8 by 1.6 km (upslope), and ranges from 20 to 290 m in elevation (fig. 4). The highpoint of the Sierra Bermeja is Cerro Mariquita at 301 m. It lies about 50 m upslope to the west. Tinaja is dissected by two major arroyos that carry water towards the Cartagena Lagoon during heavy downpours.

Tinaja. Rising to 300 m at Cerro Mariquita, the 110-ha Tinaja tract has a long history of fires and grazing. Today, with protection, secondary forest is rapidly replacing the grass cover. (Photo by Peter L. Weaver)

Climate

Puerto Rico, lying in the path of the easterly trade winds, has a climate tempered by proximity to the ocean (Calvesbert 1970). The island's weather is influenced by major systems, including easterly waves and cold fronts, and occasionally by tropical storms and hurricanes. The southwestern part of the island, in the shadow of the Central Mountains, is drier than the north coast and mountain summits.

Precipitation—During the 15-year period between 1991 and 2005, mean annual rainfall at the Cabo Rojo Headquarters tract, 13 km southwest of the town of Lajas, averaged about 930 mm/year (table 4). During the same period, mean annual rainfall at the Cartagena Lagoon tract, 5 km southwest of Lajas, averaged about 1058 mm/year. At Cabo Rojo, rainfall in particular years varied from 49 to 162 percent of the 15-year mean (table 4). At Cartagena Lagoon, the range was from 57 to 159 percent. The driest years during the period were 1997 at Cabo Rojo and 2002 at Cartagena Lagoon; the wettest years were 2003 at Cabo Rojo and 1998 at Cartagena Lagoon. These values agree with previous estimates (Calvesbert 1970, Ravalo and others 1986).

Table 4—Mean annual rainfall at the U.S. Fish and Wildlife Service refuges, 1991–2005

Year	Cabo Rojo		Laguna Cartagena		Comparison [a]
	mm/year	*percent* [b]	*mm/year*	*percent* [b]	*percent*
1991	575	62	707	67	81
1992	1032	111	1149	109	90
1993	870	94	1135	107	77
1994	715	77	870	82	82
1995	668	72	918	87	73
1996	877	94	978	92	90
1997	459	49	709	67	65
1998	1464	157	1687	159	87
1999	740	80	1140	108	65
2000	980	105	1094	103	90
2001	945	102	1199	113	79
2002	794	85	602	57	131
2003	1509	162	1119	106	135
2004	996	107	1110	105	90
2005	1327	143	1461	138	91
Mean	930	100	1058	100	88

[a] Comparison: annual rainfall Cabo Rojo/Laguna Cartagena.

[b] Percent = rainfall for particular year divided by 15-year mean for each site.

Heavy rains. A heavy downpour converts the normally dry arroyo traversing the Tinaja tract into an instant stream with a small waterfall. (Photo by Peter L. Weaver)

When comparisons are made by refuge site, rainfall at Cabo Rojo averaged 88 percent of that at Cartagena Lagoon for the entire measurement period. During particular years, rainfall at Cabo Rojo varied from 65 to 135 percent of that at Cartagena Lagoon. Rainfall at Cartagena Lagoon exceeded that at Cabo Rojo except for 2002 and 2003.

Rainfall in Puerto Rico for the period from 1990 to 1997 was only 87 percent of the normal (30 years of record) for the 12 stations with the longest records (Larsen 2000). Between 1991 and 1997, mean annual rainfalls were 742 mm at Cabo Rojo and 924 mm at Cartagena Lagoon (table 4). Comparable rainfall values for 1998 through 2005 were greater, averaging 1094 mm at Cabo Rojo and 1176 mm at Cartagena Lagoon. In this instance, the earlier 7-year records represent only 68 and 78 percent, respectively, of the later 8-year records, and 80 and 87 percent, respectively, of the entire 15-year record (table 4).

Rainfall averages between 1971 and 2000 are available for two sites nearby—the town of Lajas, and Isla Magueyes on the coast 8 km south of Lajas (figs. 7A and 7B). Mean annual rainfall at Lajas is 1143 mm, ranging from 50 mm in January to 173 mm in October. At Magueyes, the mean annual rainfall is only 768 mm, ranging from 29 mm in February to 131 mm in October. At both sites, most rainfall occurs from the beginning of August through the end of November, averaging 54 percent of the total at Lajas and 59 percent at Magueyes. A second, but lower rainfall peak, is evident during May.

Temperature—Temperature averages are also available for Lajas and Magueyes (figs. 7A and 7B). The mean annual temperature at Lajas is 25.3 °C, ranging from 23.2 °C in January to 26.8 °C in July. At Magueyes, it is 27.1 °C, ranging from 25.2 °C in January to 28.5 °C in June and August. These values

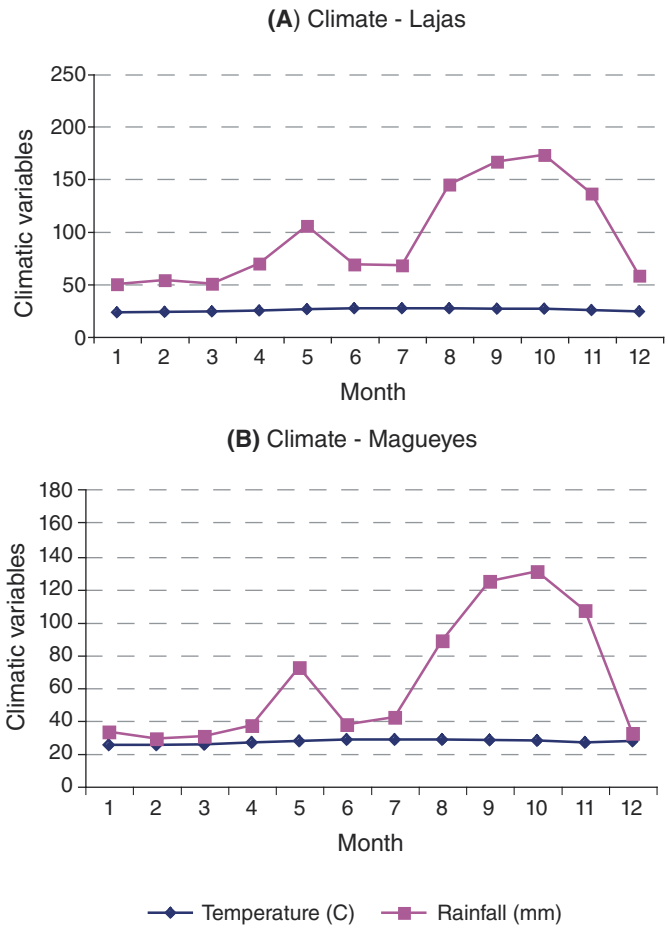


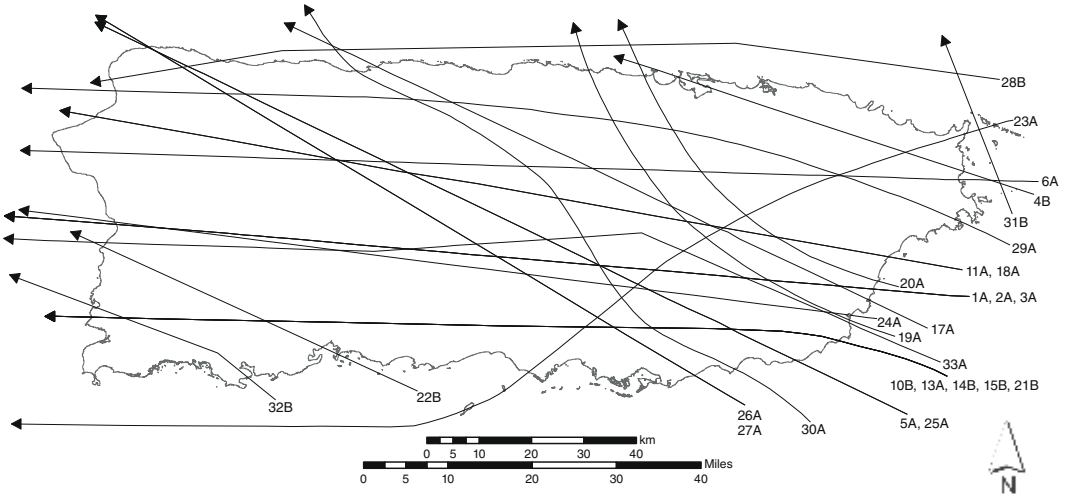
Figure 7—Rainfall and temperature diagram (1971–2000): (A) Lajas, (B) Magueyes.

agree closely with the previous mean estimate of 26 °C, with monthly means varying by only 3 °C or so during the year (Calvesbert 1970, Daly and others 2003).

Relative humidity and evaporation—Two estimates of pan evaporation in the Lajas Valley are available: 1930 mm/year (Anderson 1977) and 1525 mm/year (Graves 1991). Potential evapotranspiration at Cabo Rojo, estimated by the Hargreaves-Samani model, averaged 1660 mm/year (Goyal 1991). Another estimate of potential evapotranspiration for the Lajas Valley was 1250 mm/year (Anderson 1977).

Hurricanes—Since 1700, Puerto Rico has apparently experienced hurricane force winds at least 33 times. Twenty hurricanes had trajectories over much of the island (type A hurricane) and 13 had trajectories over a portion of the island, or immediately offshore (type B hurricane) (Neumann and others 1988, Quiñones 1992, Salivia 1972) (fig. 8). Local effects from more distant storms or hurricanes (type C storms) were also experienced more than 50 times. Since hurricane size, duration, and wind speed vary considerably, estimating trajectories and classifying storm types before the 20th century is a matter of conjecture. Several of the earlier hurricanes could have impacted the forests in southwestern Puerto Rico to some degree (fig. 8).

Four hurricanes damaged Puerto Rico's southwest since the end of the 19th century (fig. 8). San Ciríaco of 1899 and San Felipe II of 1928 passed to the northeast, and Georges of 1998 to the north. San Ciríaco with sustained winds around 180 km/hour, and San Felipe II with winds at 250 km/hour, were major storms, the latter perhaps being the most powerful on record for Puerto Rico. Hortense in 1996, a category 1 hurricane on the Saffir-Simpson Hurricane Scale, passed directly over the refuges (Monzón 1996). With sustained winds of 135 km/hour and rainfall averaging between 75 and 125 mm in the southwest, Hortense caused flooding, uprooted trees, and damaged buildings and electrical lines. Its short residence time over Puerto Rico, poorly defined center, and generally low winds prevented more damage. Georges in 1998,



Legend for major hurricanes in Puerto Rico since 1700[1, 2]

Key	Year	Name	Key	Year	Name	Key	Year	Name	Key	Year	Name
1-A	1738	Santa Rosa II	10-B	1805	San Vicente II	18-A	1827	San Jacinto II	26-A	1899	San Ciriaco
2-A	1738	San Leoncio III	11-A	1807	San Jacinto	19-A	1835	San Hipólito	27-A	1928	San Felipe II
3-A	1751	San Agapito	12-B/?	1809	San Esteban III	20-A	1837	N.S. de los Angeles	28-B	1931	San Nicolás
4-B	1766	San Jenaro	13-A	1813	San Liborio II	21-B	1851	San Agapito II	29-A	1932	San Cipriano II
5-A	1766	San Marcus	14-B	1814	San Liborio III	22-B	1852	San Llorenzo	30-A	1956	Santa Clara
6-A	1772	San Agustín	15-B	1816	San José de Cupertino	23-A	1867	San Narciso	31-B	1989	Hugo
7-B/?	1772	San Ramón II	16-A/?	1819	San Mateo III	24-A	1876	San Felipe I	32-B	1996	Hortense
8-B/?	1780	San Antonio	17-A	1825	Santa Ana	25-A	1893	San Roque III	33-A	1998	Georges
9-B/?	1785	San Lupo									

[1]Key: A = hurricane vortex passed over island with hurricane force winds; B = hurricane vortex passed over part of the island or offshore, with hurricane force winds on part of the island; A/? and B/? = uncertain trajectory (i.e., San Ramón II in 1772 passed northeast of the island). Trajectories in 1899 and later are known; pre-1899 trajectories were sketched from descriptions except those classed as A/? or B/?.
[2]Sources: Monzón 1996, Neumann and others 1988, Quiñones 1992, Salivia 1972.

Figure 8—Hurricane trajectories over Puerto Rico since 1700.

a category 3 hurricane with sustained winds of 180 km/hour, flooded the Lajas Valley and damaged both refuges.

Flora

"Puerto Rico was originally mantled by forests from the level of the sea to the summit of its mountains" (Hill 1899, p. 7), and the dominant vegetation in southwestern Puerto Rico at the time of Columbus' arrival was forest (Murphy 1916). Mangroves probably covered about 12 000 ha of Puerto Rico's shorelines, declining to nearly one-half by 1938 (Carrera and Lugo 1978). The dry, rocky slopes along the south coast were covered by woodland and cactus (Wadsworth 1950, 1962). Prominent tree species included *Amyris elemifera*, *Bucida buceras*, *Bursera simaruba*, *Ceiba pentandra*, *Colubrina arborescens*, *Exostema caribaeum*, *Guaiacum officinale*, *Pictetia aculeata*, and *Tabebuia hetrophylla* (Wadsworth 1962) (see appendix A for authorities, and common English and Spanish names of plant species mentioned in text).

The flora of Puerto Rico, ranging from coastal areas through the mountainous interior, was studied in detail during the 1920s (Britton and Wilson 1923–1930, Cook and Gleason 1928, Gleason and Cook 1927). Britton, the founder and first director of the New York Botanical Garden, helped carry out the first systematic inventory of natural history in the Caribbean (Sastre-D.J. and Santiago-Valentín 1996). Many of his expeditions included sites in southwestern Puerto Rico. Major environmental concerns at that time included the island's loss of forest cover, and the need for forest policy and reforestation.

Mangroves grew along the coast. *Bucida buceras*, often draped with the epiphyte *Tillandsia recurvata*, and its associates were common in the stream deltas and alluvial valleys of the original forest (Gleason and Cook 1927). *Capparis cyanophallophora*, *Citharexylum fruiticosum*, *Coccoloba diversifolia*, *Guaiacum officinale*, *Guapira fragrans*, *Pisonia albida*, and *Tabebuia hetreophylla* were common along the coastal strip (Gleason and Cook 1927). *Pterocarpus officinalis*, associated with the landward side of mangroves and swamps, probably grew around Cartagena Lagoon at the time of the island's discovery. Subsequently, during colonization and settlement, trees were cut for construction, fuel, and agriculture. At the beginning of the 20th century, the deciduous forests, ranging from Patillas in southeastern Puerto Rico along the south coast to Hormigueros near Mayagüez, were recurrently burned and grazed (Murphy 1916).

In the early 1900s, aside from locally grown fruit trees, the most conspicuous trees of the southwestern coastal areas were the natives *Cassine xylocarpa*, *Ceiba pentandra*, *Hippomane mancinella*, *Hymenaea courbaril*, *Manilkara bidentata*, and the exotics *Delonix regia* and *Tamarindus indica* (Hill 1899). Other native trees observed during the early 1900s were *Acacia farnesiana*, *Andira inermis*, *Bucida buceras*, *Guazuma ulmifolia*, *Inga laurina*, *Inga vera*, *Pictetia aculeata*, *Randia aculeata*, *Stahlia monosperma*, and the exotic *Haematoxylum campechianum* (Gleason and Cook 1927, Murphy 1916). Pastureland, if unattended, would soon revert to a thorn thicket characterized by *Capparis flexuosa*, *Parkinsonia aculeata*, *Pilosocereus royenii*, and *Pithecellobium unguis-cati* among other species (Gleason and Cook 1927).

The Great Depression and World War II forced most islanders to utilize available land for pasture and crops. During the late 1940s, only 6 percent of Puerto Rico was in natural forest. After the mid-1980s, however, much of the agricultural land had been abandoned and secondary forests occupied about one-third of the island, including much of the southwest (Birdsey and Weaver 1982, Franco and others 1997). Occasional remnants of past forest cover, for example, the large *Hymenaea courbaril* along the jeep road in Tinaja, show that the largest trees in the original dry forest attained diameters of at least 1 m and heights approaching 20 to 25 m.

All of Puerto Rico's native tree species and many introduced exotics have been described and illustrated in local publications (Francis and Liogier 1991, Francis and Lowe 2000, Little and Wadsworth 1964, Little and others 1974). Moreover, taxonomic descriptions of the flora (grasses, trees, and vines) are available for Puerto Rico and other islands in the Caribbean (Acevedo-Rodríguez and Woodbury 1985; Hitchcock 1936; Howard 1979, 1988–1989; Liogier 1985–1997; Liogier and Martorell 1982, 2000). Eight common species of grasses have also been illustrated in a field guide (Más and García 1990). Plant nomenclature in this report has followed Liogier.

Recently, all of Puerto Rico's forest type and land cover types were mapped (Helmer and others 2002). Mapping zones encompassing the refuges and protected areas of the southwest were designated as dry-alluvial and dry-volcanic/sedimentary/limestone areas. The vegetation formations included lowland dry semideciduous forest or woodland/shrubland, tidal and semipermanently flooded evergreen sclerophyllous forest, and lowland dry mixed evergreen drought-deciduous shrubland with succulents. The major land use of much of the southwest is pasture.

Major Forest Types in the Southwest

Southwestern Puerto Rico, including all of the refuge properties, is situated in the Subtropical Dry Forest according to the ecological life zone system (Ewel and Whitmore 1973, Holdridge 1967). Within the life zones, associations are referred to as zonal (that is, with a typical climate and a typical soil type), or azonal if strongly influenced by edaphic, atmospheric, or hydric conditions. Another classification system used throughout the Caribbean also recognizes environmental effects on vegetation (Beard 1949, 1955).

The major types of vegetation cover in the southwest are: mangroves; salt flats; littoral woodland (beach thickets); mesquite and semievergreen woodland; coastal shrub or thorn woodland; deciduous woodland; agricultural lands, including pastures; and residential areas and roadside trees (McKenzie and Noble 1990). Mangroves and salt flats are the vegetation types that most closely approach the original cover. Moreover, the littoral woodland still contains numerous tree species that were part of the original vegetation. In contrast, pastures, agricultural lands, and residential areas are the most modified landscapes. The remaining vegetation types contain exotic and native species in compositions that differ from the original vegetation. Currently, the refuge sites are highly disturbed by human activity and occupied by secondary vegetation, including numerous exotics. The following vegetation descriptions, mainly overstory trees, are derived from previous work on forest cover in southwestern Puerto Rico (McKenzie and Noble 1990).

Mangrove forest—Mangroves are dominated by four tree species: (1) *Avicennia germinans*, (2) *Conocarpus erecta*, (3) *Laguncularia racemosa*, and (4) *Rhizophora mangle*. *Rhizophora mangle* frequently forms a fringe along the coast and occasionally isolated islands of vegetation in shallow water. *Avicennia germinans* and *Laguncularia racemosa* are common in estuaries and around salt flats. *Conocarpus erecta* is commonly found at the landward edge of tidal mangrove swamps.

Salt flats—Often adjacent to mangrove swamps, the salt flats contain a ground cover with *Batis maritima*, *Heliotropium curassavicum*, *Sesuvium portulacastrum*, and other salt-tolerant plants. Trees are usually limited to scattered patches of *Avicennia germinans* and *Laguncularia racemosa*.

Littoral woodland (beach thickets)—The littoral woodland, stretching in a fringe along the coast behind beaches, contains several native canopy species like *Canella winterana*, *Clerodendron aculeatum*, *Coccoloba diversifolia*, *Coccoloba uvifera*, *Colubrina arborescens*, *Erithalis fruticosa*, *Erythroxylum aerolatum*, *Jacquinia arborea*, *Krugiodendron ferreum*, *Piscidia carthagenesis*, *Pisonia albida*, *Randia aculeata*, and *Rochefortia acanthophora*. The exotic *Thespesia populnea* reproduces abundantly in some areas.

Mesquite and semi-evergreen woodland—Land clearing for pasture and agriculture in the lowlands between the salt flats and nearby mountains has modified the original forest dominated by *Bucida buceras* (Cook and Gleason 1928), into an association with grass and scattered *Prosopis juliflora*, resembling a savanna (Garcia-Molinari 1952). Other common trees include the natives *Bucida buceras*, *Guaicum officinale*, and *Pisonia albida* along with numerous understory species. Common exotics are *Leucaena leucocephala*, *Pithcellobium dulce*, and *Tamarindus indica*. Trees common to arroyos in the mesquite and semievergreen woodland include natives such as *Acacia farnesiana*, *Crecentia cujete*, *Piscidia carthagenesis*, and *Tabebuia heterophylla* and exotics like *Albizia lebbeck*, *Bauhinia monandra*, and *Swietenia mahagoni.*

Coastal shrub or thorn woodland—Some areas are dominated by a coastal scrub previously called cactus scrub or thorn woodland (Beard 1949). The dominant canopy trees in this vegetation type are almacigo *Bursera simaruba*, *Guaicum offincinale*, *Pisonia albida*, *Plumeria alba*, *Prosopis juliflora*, and scattered *Bucida buceras*. Near Bahia Sucia, the

composition varies somewhat in small areas of limestone. *Bucida buceras*, *Crescentia cujete*, *Guapira discolor*, *Pisonia albida*, *Prosopis juliflora*, and *Tabebuia heterophylla* are the principal canopy species.

Deciduous woodland—The major tree species in the deciduous woodland are *Bourreria succulenta*, *Bucida buceras*, *Bursera simaruba*, *Clusia rosea*, *Coccolobia diversifolia*, *Colubrina arborescens*, *Colubrina elliptica*, *Erothroxylum aerolatum*, *Guazuma ulmifolia*, *Pisonia albida*, *Rauvolfia nitida*, *Thouinia striata* var. *portoricensis*, *Zanthoxylum martincense*, *Zanthoxylum monophyllum*, and *Ziziphus reticulata*. Occasionally *Guaicum offincinale* is found.

Other Vegetation Types

Other vegetation types are solely the result of human activities and are maintained in a highly modified state by regular tending, at least for a period of time.

Agricultural lands and pastures—Agricultural lands often contain *Carica papaya*, *Persea americana*, and ground crops such as melons, peppers, pineapples, pumpkin, and yucca. Pastures are occupied by about 15 species of native and introduced grasses. Secondary regeneration of native tree species and planted *Prosopis juliflora* and *Swietenia mahagoni* are seen in the vicinity of the refuges.

Residential and roadside trees—Selected for shade, ornament, and fruit, or regenerated naturally, several species of trees survive around private homes, along fence lines, and scattered in fields. The most common trees planted for shade or as ornamental are *Delonix regia*, *Swietenia mahagon*i, *Tabebuia heterophylla*, *Tecoma stans*, and *Tectona grandis*. Among the most common fruit trees are *Tamarindus indica*.

Forest tree plantings (plantations)—Forest trees are planted for a variety of purposes, usually timber production. In Puerto Rico's dry southwest, however, timber production was not a priority (Birdsey and Weaver 1982), although experimental work with timber species was attempted more than 60 years ago (Marrero 1950; Wadsworth 1943, 1990). During the past 25 years, at least 80 tree species have been planted on the refuge lands to stimulate native forest regeneration and to restore wildlife habitat.

Vegetation Types at the Refuges

Frequent fires, heavy grazing, and continuous cropping, mainly in sugar cane, characterized the past use of the refuges. Soil erosion and sedimentation were rampant. During this period, native plants were severely reduced in numbers and several exotics increased in areal extent. Today, the refuges are covered with pasture interspersed with native and exotic trees, patches of secondary forest, and tree plantings of various species.

Cabo Rojo NWR—The Cabo Rojo NWR is divided into two tracts: Headquarters and Salinas. Intensive farming and grazing were the main uses of the Headquarters tract. In 1978, livestock were removed when the first refuge manager arrived. In 1980, the planting of *Bucida buceras* trees began in several areas. The planting continued irregularly through 1995 and annually thereafter when several new tree species were introduced (Weaver and Schwagerl 2004).

The existing forest cover in the wooded portion of the Headquarters tract contains *Prosopis juliflora* along with a few other exotic tree species such as

Large native tree. One of the largest native trees in Puerto Rico's dry southwest, Hymenaea courbaril *L. (West Indian locust) grows on the refuge sites.* (Photo by Peter L. Weaver)

Albizia lebbeck, *Leucaena leucocephala*, *Melicoccus bujugatus*, *Parkinsonia aculeata*, *Pithecellobium dulce*, and *Tamarindus indica* (Stacier 1992; Zuill 1985, see endnotes). Maturing *Bucida buceras* trees also grow along with occasional *Hymenaea courbaril* and other native species scattered in secondary patches. Regeneration of native tree species is apparent under existing tree cover. In general, drainages contain the greatest concentration of large trees.

In the grass-dominated areas, *Panicum maximum* and *Cenchrus ciliaris* grow along with widely scattered trees of *Prosopis juliflora* or clumps of cactus. The grasses cause serious problems. They are aggressive competitors for light and water and retard the regeneration of native tree species. Moreover, the grasses facilitate the spread of wildfires that sometimes enter from surrounding farmlands.

The Salinas tract of the refuge contains three principal vegetation types: (1) scattered patches of mangrove, (2) stretches of littoral woodland, and (3) the salt flats with salt-tolerant plants. The mangroves and the littoral woodland have been affected by the harvest of fenceposts and fuelwood in the past. The tract also contains shallow lagoons, not exceeding 0.5 m in depth, and occupying about 225 ha (Negrón González 1986).

Laguna Cartagena NWR—The Laguna Cartagena NWR is partitioned into two major tracts: Lagoon and Tinaja. The Lagoon tract has three distinct areas: (1) the lagoon, centrally located, with its aquatic vegetation; (2) a recently abandoned sugar cane plantation, now largely planted with trees lying to

Fires. The exotic Prosopis juliflora *(Sw.) DC. (mesquite) was planted long ago on the Cabo Rojo National Wildlife Refuge (at left in photo). Many mesquite trees have survived recurrent fires which are a constant threat to wildlife and undermine efforts to restore the natural habitat.* (Photo by Peter L. Weaver)

Grass and cactus. Grass and cactus, a vegetation type maintained by fires, glistens in the early morning sun. (Photo by Peter L. Weaver)

Salt flats. The salt flats and ponds on the Salinas tract at Cabo Rojo provide wildlilfe habitat for numerous species of migratory and resident birds. (Photo by Peter L. Weaver)

the north; and (3) an abandoned pasture with naturally occurring trees and several patches of planted trees, lying to the south (Weaver and Schwagerl 2005). The lagoon itself consists of open water and areas with cattails (Díaz-Soltero 1990).

The Tinaja tract also has three distinct areas. The lower, gentler slopes were grazed and recurrently burned through 1996 when the F&WS acquired the property. At that time, the lower slopes had the appearance of savanna-like grassland with scattered native and exotic trees. Today, in the absence of grazing and fire, numerous trees have regenerated, principally the exotic *Leucaena leucocephala* (Weaver and Schwagerl 2004). The midslopes are covered with secondary vegetation, some dating back at least to the mid-1930s when it was visible in aerial photographs (Weaver and Chinea 2003). The upper slopes around Cerro Mariquita are very steep, rocky, and heavily eroded by past grazing. Much of the vegetative cover is short, yet of considerable ecological value due to the presence of rare and endangered plant species. The partially forested Tinaja tract is important to Cartagena Lagoon as a source of unpolluted water.

Vegetative surveys have been carried out at both the Cabo Rojo Refuge (McKenzie 1986, see endnotes) and the Laguna Cartagena Refuge (Díaz-Soltero 1990; Proctor 1996, see endnotes). The identified plants include: 10 ferns, 1 gymnosperm, 103 monocotyledons, and 533 dicotyledons (appendix B). Among the monocots are 3 Alismataceae, 3 Araceae, 5 Arecaceae, 2 Commelinaceae, 22 Cyperaceae, 55 Graminae, 3 Liliaceae, 1 Najadaceae, 5 Orchidadceae, 1 Pontederiaceae, 1 Smilaceae, and 1 Typhaceae. The dicots include 88 families. Twelve families had 53 percent of the species: (1) 20 Boraginaceae, (2) 23 Compositae, (3) 20 Convolvulaceae, (4) 34 Euphorbiaceae, (5) 71 Leguminosae, (6) 31 Malvaceae, (7) 14 Myrtaceae, (8) 11 Polygonaceae, (9) 19 Rubiaceae, (10) 11 Sapindaceae, (11) 12 Solanaceae, and (12) 16 Verbenaceae.

Fauna on the Refuges

Several studies of fauna, some dating back to the early 20th century, have been carried out on the refuges. Although mainly interested in birds, Danforth (1926, 1931) also observed other animal groups, particularly those associated with the avifauna.

Mammals

Eight species of mammals, other than domestic livestock and household pets, have been reported at Laguna Cartagena: *Herpestes auropunctatus* (mongoose), two bats, two rats, one mouse, and two monkeys (table 5). The most easily seen is the mongoose, which is widespread. Originally introduced from Asia between 1877 and 1879 to control rats in sugar cane fields, the mongoose is now Puerto Rico's most detrimental predator on ground-nesting birds and lizards (Raffaele 1983). At Cartagena Lagoon during the 1920s, mongooses were seen eating eggs from nests and attacking waterfowl (Danforth 1926). They also consume frogs, blind snakes, lizards, and several species of invertebrates, including ants (Nellis 1999, Wolcott 1953).

Mongoose populations are greatest in coastal grassy areas near small streams and low in forested areas even when water is available (Pimentel 1955). A study in Guánica Forest concluded that the mongoose and *Caprimulgus noctitherus* (Puerto Rican nightjar) were separated by habitat requirements—the mongoose was more prevalent in coastal scrub below 75 m elevation and the nightjar at higher elevations (Vilella and Zwank 1993a) (Pine 1980).

In the past, rats fed mainly on sugar cane but also ate bird eggs in and around the refuges. Elimination of cane production from surrounding areas has probably reduced rat populations, and possibly mongoose numbers. Mice, in contrast, feed mainly on seeds and fruits. Of the 14 species of bats endemic to Puerto Rico (Pine 1980), only 2 species have been observed on the Cabo Rojo Headquarters tract (table 5).

In 1960, the small islands of Isla Cueva and Isla Guayacán near Parguera were acquired from the government of Puerto Rico for research on monkeys

Table 5—Animal species other than birds at the Cabo Rojo and Laguna Cartagena National Wildlife Refuges and Commonwealth protected areas in southwestern Puerto Rico [a] [b]

Group and species	Common name		Refuges [c]				Other Reserves [d]				
			Cabo Rojo		Laguna Cartagena						
	English	Spanish	H	S	L	T	A	B	C	D	E
Mammals											
Native—bats											
Artibeus jamaicensis	Jamaican fruit-eating bat	Murciélago frutero de Jamaica								D	
Brachyhylla cavernarum	Antillian fruit-eating bat	Hocico de cerdo								D	
Erophylla sezekoini	Brown flower bat	Murciélago de las flores								D	
Molossus molossus fortis	Velvety free-tailed bat	Murciélago de techos			X						
Monophyllus redmani	Greatre Antillian long-tailed bat	Murciélago lenguilargo								D	
Mormoops blainvilli	Antillian ghost-faced bat	Barbicacho								D	
Noctilio leporinus	Greater bulldog bat	Murciélego pescador					A				E
Nyctinomus murinus [e]	Brazilian free-tailed bat	Murciélago de viejo			X						
Introduced—various											
Erythrocebus patas	Patas monkey	Mono patas	X		X						
Macaca mulatta	Rhesus monkey	Mono macaca				X					E
Herpestes auropunctatus	Mongoose	Mangosta	X	X	X	X	A		C	D	
Mus musculus	House mouse	Ratón			X						
Rattus norvegicus	House rat	Rata común			X						
R. rattus	Roof rat	Rata negra			X		A				
Reptiles											
Lizards											
Ameiva exsul	Puerto Rican ground lizard	Siguana común			X		A	B		D	E
A. wetmorei	Blue tailed ground lizard	Siguana de rabo azul				X		B		D	E
Anolis cooki	Dry land anole	Legartijo del seco		X			A	B		D	E
A. cristatellus	Puerto Rican crested anole	Lagartijo común			X		A	B		D	E
A. ponsensis	Ponce's garden lizard	Lagartijo jardinero				X		B		D	
A. pulchellus	Grass anole	Lagartijo rayon			X		A	B		D	
A. stratulus	Spotted lizard	Lagartijo manchado			X			B		D	
Geckos											
Phyllodactylus wirshingi	NA [f]									D	
Sphaerodactylus macrolepsis	Common gecko	Salamanguita común			X						
S. roosevelti	Roosevelt's dwarf gecko									D	
S. nicholsi nicholsi	Nichol's dwarf gecko	Salamanguita pigmea			X					D	E

continued

Table 5—Animal species other than birds at the Cabo Rojo and Laguna Cartagena National Wildlife Refuges and Commonwealth protected areas in southwestern Puerto Rico [a b] (continued)

Group and species	Common name		Refuges[c]				Other Reserves [d]				
			Cabo Rojo		Laguna Cartagena						
	English	Spanish	H	S	L	T	A	B	C	D	E
Reptiles (continued)											
Turtles											
Dermochelys coriacea	Leatherback turtle	El tinglar		X							
Eretmochelys imbricata	Hawksbill turtle	El carey		X							
Trachemys stejnegeri	West Indian slider	La jicotea			X		A				
Snakes											
Epicrates inoratus	Puerto Rican boa	Culebron								D	
Typhlops richardi	Blind snake	Vibora toro			X						
Amphibians											
Bufo marinus	Marine toad	Churi	X		X		A				
Eleutherodactylus antillensis	Puerto Rican red-eyed frog	Coqui churi			X		A			D	
E. coqui	Coqui	Coqui común			X		A				
Leptodactylus albilabris	White-lipped frog	Ranita de labio blanco			X	X	A				
Pelthophryne lemur	Puerto Rican crested toad	Sapo concho								D	
Rana catesbiana	Bull frog	Sapo toro			X						
Fish											
Anguilla rostrata	Eel	Anguilla			X						
Awaous taiasica	Striated river goby	Saga			X						
Bathygobius soporator	Frillfin goby	Gobio mapo			X						
Caranx latus	Horse eye jack	Jurel, Ojon			X		A				
Centropomidae	Snook family	Familia de Robalos		X							
Centropomus parallelus	Fat snook	Robalo blanco			X						
Centropomus undecimales	Common snook	Robalo					A				
Dormitator maculatus	Fat sleeper	Mapiro			X						
Eleotris pisonis	Spiny cheek sleeper	Moron			X						
Gerres cinereus	Yellow fin mojarra	Mojarra							C		
Gobiomorus dormirtor	Bigmouth sleeper	Guavina			X						
Hypostomus plecostamus	Plecostomus	Pez gato			X						
Ictalurus nebulosus	Brown bullhead	Barbudo			X						
Lepomis gibbosus	Pumpkin seed	Chopa			X						
L. macrochirus	Bluegill	Chopa			X						
Liposarcus multiradiatus [g]	Armored sailfin catfish	Pleco?			X						

continued

Table 5—Animal species other than birds at the Cabo Rojo and Laguna Cartagena National Wildlife Refuges and Commonwealth protected areas in southwestern Puerto Rico [a] [b] (continued)

Group and species	Common name		Refuges [c]				Other Reserves [d]				
			Cabo Rojo		Laguna Cartagena						
	English	Spanish	H	S	L	T	A	B	C	D	E
FIsh (continued)											
Megalops atlanticus	Tarpon	Sabalo			X		A				
Mugilidae	Mullet family	Familia de Jareas o Lizas		X			A				
Mugil curema	Mullet	Jarea					A		C		
Poecilia reticulata	Guppy	Gupi			X						
P. vivipara	Top minnow	Cisi			X						
Tilapia aurea	Tilapia	Tilapia			X						
T. mossambica	Tilapia	Tilapia mozambica			X		A		C		

[a] Sources: Danforth (1926), Diaz-Soltero (1990), Joglar (1998), Negrón González (1986), Rivero (1978). Domestic animals are omitted.

[b] Sources (fish names): Erdman (1972), Erdman and others (1985).

[c] Cabo Rojo Refuge, with tracts; H = Cabo Rojo Headquarters; S = Salinas. Laguna Cartagena Refuge, with tracts; L = Lagoon; T = Tinaja.

[d] Other reserves and information sources: A = Boqueron Wildlife Refuge (Chabert and others 1982, Negrón González 1986). Fifteen species of fish were mentioned for the lagoon but only six were identified to species. B = Los Morrillos de Cabo Rojo (Municipio Autonomo de Cabo Rojo 1998); C = Punta Guaniquilla Natural Reserve (Fuentes Santiago and Quevedo Bonilla 2002); D = Guánica Forest (Canals Mora 1990, Conde Costas y González 1990, Genet 2002, Rivero 1978); E = Parguera Natural Reserve (Departamento de Recursos Naturales 1981; Departamento de Recursos Naturales y Ambientales 2000a: Ventosa-Febles and others 2005).

[e] Now called *Tadarida brasiliensis*.

[f] NA = not known.

[g] Cartagena Lagoon (identified by Carlos Santos, University of Puerto Rico).

(Vandenbergh 1989). Before its closure in 1982, some *Erythrocebus patas* and *Macaca mulatta* (patas and rhesus monkeys) kept at the La Paguera Primate Facility escaped into the surrounding area (González-Martínez 1990). The rhesus monkeys, excellent swimmers, migrated into the Sierra Bermeja range where during the 1980s observers Phoebus and others (1989, page 157) noted "the escapees and their offspring are now doing quite well, living on several large adjoining cattle ranches" (Phoebus and others (1989, p. 157). Rhesus monkeys have been recorded at Laguna Cartegena and favor the fruits of *Clusia rosea* and *Hymenacea coubaril*. In 1966, rhesus monkeys were also released on the Isla Desecheo NWR (Evans 1989). By 1970, they were recognized as a serious threat to native fauna and flora, feeding on sea bird eggs and native vegetation. The largest known colony of *Sula leucogaster* (brown booby) was decimated and the *Sula sula* (red-footed booby) colony also declined in numbers, as a result of monkey predation. In addition, the monkeys consumed *Bursera simaruba* wood pulp for water and used local cactus plants as a secondary source of moisture and nutrition. Not easily seen by visitors, they disperse into small groups to optimize foraging.

In the late 1990s, about 120 patas monkeys ranged freely throughout 125 km^2 of southwestern Puerto Rico where they were recorded on both refuges (González-Martínez 1998). At that time, the patas roamed in four heterosexual groups and several all-male bands, traveling a minimum daily distance of 0.8 to 2.0 km. They depend heavily on five introduced tree species: (1) *Leucaena leucocephala*, (2) *Mangifera indica*, (3) *Melicoccus bijugatus*, (4) *Prosopis juliflora*, and (5) *Tamarindus indica* along with the native *Bourreria succulenta*. They also eat the fruits of *Stenocereus hystrix* and *Bromelia penguin* as well as grasshoppers and dung beetles (González-Martínez 1990). Fruits of *Bursera simaruba* and *Spondias mombin* are eaten by both rhesus and patas monkeys. All monkeys are a threat to public health, damage crops, prey on bird eggs, and have spread in the southwest. If they reach other parts of the island they could become virtually impossible to control.

Birds

Birds include resident, migrant, vagrant, and introduced species. West Indian bird communities have higher proportions of frugivores than mainland communities; the arrival of migrant parulids during winter months, however, reverses the pattern (Faaborg and Terborgh 1980). Moreover, small gleaning insectivores that spend the winter on the islands are overrepresented whereas hawks and large, gleaning insectivores, frugivores, and granivores are either absent or underrepresented (Faaborg and Terborgh 1980).

Of the 212 species sighted on the refuges, 12 are endemic, 25 are listed as game or protected game species, and 14 have been introduced as game or for other purposes. Moreover, seven species are listed as threatened or endangered or as candidates for listing by the F&WS, five are listed as threatened by the Commonwealth of Puerto Rico, and two species are listed by both. Finally, 13 are target species for management at Cartagena Lagoon (table 6, top). Raffaele's (1983, 1989) compendia of Puerto Rican bird species, based on nearly 7 years of observations, disclosed that about one-half of the island's 269 recorded species, including exotics, had been recorded at one site—Cartagena Lagoon. Another 22 bird

Troupial. Icterus icterus *(troupial) is a permanent resident introduced from South America, commonly seen in southwestern Puerto Rico between Ponce and Boquerón.* (U.S. Fish and Wildlife Service photo)

Table 6—Bird species at the Cabo Rojo and Laguna Cartagena National Wildlife Refuges and Commonwealth protected areas in southwestern Puerto Rico [a]

Genus and species	Common name		Refuges [b]				Status [c]						Other Reserves [d]				
			Cabo Rojo		Laguna Cartagena												
	English	Spanish	H	S	L	T	E	N	M/R	GIP	C/F	C/T	A	B	C	D	E
Species reported for Cabo Rojo and Laguna Cartegena Wildlife Refuges, as well as other reserves in southwestern Puerto Rico																	
Actitus macularius	Spotted sandpiper	Playero coleador	X	X	X			C	M				A	B	C	D	E
Agelaius xanthomas	Yellow-shouldered blackbird	Mariquita	X	X	X		E	U	R		F	T	A	B		D	E
Amandava amandava	Strawberry finch	Chamorro fresa	X		X			C	R				A				
Ammodramus savannarum	Grasshopper sparrow	Gorrión chicharra	X		X			C	R			CT	A				
Anas acuta	Northern pintail	Pato pescuecilargo			X			U	M	G			A			D	
Anas americana	American wigeon	Pato cabeciblanco			X			C	M	G			A		C		
Anas bahamensis	White-cheeked pintail	Pato quijada colorada		X	X			C	R	P	F	CT	A		C	D	
Anas clypeata	Northern shoveler	Pato cuchareta			X			U	M	G			A				
Anas crecca	Green-winged teal	Pato aliverde			X			R	M	G			A				
Anas discors	Blue-winged teal	Pato zarcel		X	X			C	M	G		T	A		C	D	
Anas penelope	Eurasian wigeon	Silbón Europeo			X			R	M								
Anas platyrhynchos	Mallard	Pato cabeciverde			X			R	M	G							
Anas rubripes	American black duck	Pato oscuro			X			A	M	G							
Anous stolidus	Brown noddy	Cervera parda		X				C	R								
Anthracothorax dominicus	Antillean mango	Zumbador dorado	X	X	X			C	R			C	A		C	D	
Anthracothorax viridis	Green mango	Zumbador verde			X		E	U	R				A	B		D	
Ardea alba	Great egret	Garza real			X			C	R				A	B	C	D	E
Ardea herodias	Great blue heron	Garzón cenizo	X	X	X			C	MR				A	B	C	D	E
Arenaria interpres	Ruddy turnstone	Playero turco		X				C	M				A		C	D	E
Asio flammeus	Short-eared owl	Múcaro real	X		X			U	R			C	A			D	
Aythya affinis	Lesser scaup	Pato pechiblanco			X			U	M	G			A				
Aythya collaris	Ring-necked duck	Pato acollarado			X			U	M	G			A				
Bartramia longicauda	Upland sandpiper	Playero pradero		X				R	M								
Botaurus lentiginosus	American bittern	Yaboa americana			X			R	M			C	A				
Bubulcus ibis	Cattle egret	Garza ganadera	X	X	X	X		C	R				A	B	C	D	E
Buteo jamaicensis	Red-tailed hawk	Guaragua colirrojo	X	X	X	X		C	R				A		C	D	E
Butorides virescens	Green heron	Martinete	X	X	X			C	R				A	B	C	D	E
Calidris alba	Sanderling	Playero arenero		X				C	M							D	
Calidris alpina	Dunlin	Playero espaldicolorado		X				R	M								
Calidris canutus	Red knot	Playero gordo		X	X			U	M			C					
Calidris fuscicollis	White-rumped sandpiper	Playero de rabadilla blanca	X	X	X			U	M								
Calidris himantopus	Stilt sandpiper	Playero patilargo		X	X			C	M			C	A		C	D	E
Calidris mauri	Western sandpiper	Playero occidental	X	X	X			C	M			C	A			D	E
Calidris melanotos	Pectoral sandpiper	Playero pectoral	X	X	X			C	M				A			D	
Calidris minutilla	Least sandpiper	Playero menudillo	X	X	X			C	M				A		C		E

continued

Table 6—Bird species at the Cabo Rojo and Laguna Cartagena National Wildlife Refuges and Commonwealth protected areas in southwestern Puerto Rico [a] (continued)

Genus and species	Common name		Refuges [b]				Status [c]						Other Reserves [d]				
			Cabo Rojo		Laguna Cartagena												
	English	Spanish	H	S	L	T	E	N	M/R	GIP	C/F	C/T	A	B	C	D	E
Calidris pusilla	Semipalmated sandpiper	Playero gracioso	X	X	X			C	M			C	A			D	E
Caprimulgus carolinensis	Chuck-wills-widow	Guabairo de las Carolinas	X					U	M							D	
Caprimulgus noctitherus	Puerto Rican nightjar	Guabairo de Puerto Rico				X	E	R	R		F					D	E
Cathartes aura	Turkey vulture	Aura tiñosa	X	X	X			C	R	I			A	B	C	D	E
Catharus fuscesens	Veery	Zorzalito rojizo		X				A	T								
Catharus ustulatus	Swainson's thrush	Zorzal de Swainson		X				A	T							D	
Charadrius alexandrinus	Snowy plover	Chorlito blanco		X				U	R			C		B			
Charadrius melodus	Piping plover	Chorlito melódico		X				R	M		F						
Charadrius semipalmatus	Semipalmated plover	Chorlito acollarado		X	X			C	M				A		C	D	E
Charadrius vociferus	Killdeer	Chorlito sabanero	X	X	X			C	R				A	B		D	
Charadrius wilsonia	Wilson's plover	Chorlito marítimo		X	X			C	R			C	A	B	C	D	E
Chlidonias niger	Black tern	Fumarel común		X	X			C	M								
Chlorostilbon maugaeus	Puerto Rican emerald	Zumbadorcito de Puerto Rico	X	X	X		E	C	R						C	D	
Chordeiles gundlachii	West Indian nighthawk	Querequequé antillano	X	X	X			U	MR				A			D	
Chordeiles minor	Common nighthawk	Querequequé migratorio	X					R	M					B		D	
Circus aeruginosus	Western marsh harrier	Aguilucho lagunero occidental			X			A	M								
Circus cyaneus	Northern harrier	Gavilán de ciénaga	X	X	X			U	M				A				
Coccyzus americanus	Yellow-billed cuckoo	Pájaro bobo piquiamarillo	X	X	X			U	MR				A			D	
Coccyzus minor	Mangrove cuckoo	Pájaro bobo menor	X	X	X			C	R				A	B	C	D	E
Coccyzus vieilloti	Puerto Rican lizard cuckoo	Pájaro bobo mayor			X		E	C	R						C	D	
Coereba flaveola	Bananaquit	Reinita común	X	X	X			C	R				A	B	C	D	E
Columba livia	Rock pigeon	Paloma domestíca	X	X				C	R						C	D	
Columbina passerina	Common ground dove	Rolita	X	X	X			C	R	P			A	B	C	D	E
Contopus latirostris	Lesser Antillean pewee	Bobito antillano menor	X	X	X			C	R			C	A	B		D	E
Contopus virens	Eastern wood peewee	Pibi oriental		X				R	MT								
Crotophaga ani	Smooth-billed ani	Judio	X	X	X			C	R				A	B	C	D	E
Cypseloides niger	Black swift	Vencejo negro			X			U	R			C				D	
Dendrocygna arborea	West Indian whistling-duck	Chiriría caribeña			X			R	R	P	C	CT	A		C		
Dendrocygna autumnalis	Black-bellied whistling-duck	Chiriría pinta			X			A	M								
Dendrocygna bicolor	Fulvous whistling-duck	Pato bicolor			X			U	MR	P			A				
Dendroica adelaidae	Adelaide's warbler	Reinita mariposera	X		X	X	E	C	R			C		B	C	D	E
Dendroica caerulescens	Black-throated blue warbler	Reinita azul	X					C	M			C			C	D	
Dendroica coronata	Yellow-rumped (myrtle)warbler	Reinita coronada	X	X	X			C	M				A			D	
Dendroica discolor	Prairie warbler	Reinita galana	X	X	X			C	M			C	A		C	D	
Dendroica dominica	Yellow-throated warbler	Reinita gargantiamarilla	X					U	M				A			D	
Dendroica magnolia	Magnolia warbler	Reinita manchada	X		X			R	M				A		C	D	
Dendroica palmarum	Palm warbler	Reinita palmera	X					U	M				A		C	D	

continued

Table 6—Bird species at the Cabo Rojo and Laguna Cartagena National Wildlife Refuges and Commonwealth protected areas in southwestern Puerto Rico [a] (continued)

Genus and species	Common name		Refuges [b]				Status [c]						Other Reserves [d]				
	English	Spanish	Cabo Rojo		Laguna Cartagena												
			H	S	L	T	E	N	M/R	GIP	C/F	C/T	A	B	C	D	E
Dendroica pensylvania	Chestnut-sided warbler	Reinita flaquicastaña	X	X				R	M							D	
Dendroica petechia	Yellow warbler	Canario de mangle	X	X	X			C	R			C	A	B	C	D	E
Dendroica striata	Blackpoll warbler	Reinita rayada	X		X			CU	MT				A			D	
Dendroica tigrina	Cape May warbler	Reinita tigre	X	X	X			C	M				A			D	
Dendroica virens	Black-throated green warbler	Reinita verdosa	X					R	M							D	
Dolichonyx oryzivorus	Bobolink	Chambergo			X			U	M								
Egretta caerulea	Little blue heron	Garza azul	X	X	X			C	R				A		C	D	E
Egretta rufescens	Reddish egret	Garza rojiza		X	X			R	M								
Egretta thula	Snowy egret	Garza blanca	X	X	X			C	R				A		C	D	E
Egretta tricolor	Tricolored heron	Garza pechiblanca		X	X			C	R				A	B	C	D	E
Elaenia martinica	Caribbean elaenia	Juí blanco	X	X	X			C	R						C	D	
Empidonax virescens	Acadian flycatcher	Mosquiro verdoso		X				A	T								
Estrilda melpoda	Orange-cheeked waxbill	Veterano	X	X	X			C	R	I			A	B	C	D	E
Estrilda troglodytes	Black-rumped waxbill	Veterano orejicolorado			X			R	R	I						D	
Eudocimus albus	White ibis	Ibis blanco			X			R	T								
Euphonia musica	Antillian euphonia	Jilguero	X		X			R	R							D	
Euplectes afer	Yellow crowned bishop	Napoleón tejedor			X			U	R	I							
Euplectes francicanus	Orange bishop	Osbispo anaranjado			X			U	R	I						D	
Falco columbarius	Merlin	Falcón migratorio	X	X	X			U	M	I			A		C	D	E
Falco peregrinus	Peregrine falcon	Halcón peregrino	X	X	X			U	M		F	C			C	D	
Falco sparverius	American kestrel	Fálcon común	X	X	X			C	R				A	B	C	D	E
Fregata magnificens	Magnificent frigatebird	Tijereta		X	X			C	R			C	A	B	C	D	E
Fulica caribaea	Caribbean coot	Gallinazo Caribeño			X			U	R	P	CF	CT	A				
Fulica americana	American coot	Gallinazo americano			X			C	MR	P			A			D	
Gallinago delicata	Wilson's snipe	Becasina	X	X	X			C	M	G		T	A				
Gallinula chloropus	Common gallinule	Gallareta común	X	X	X			C	R	G		T	A	B	C	D	
Gallus gallus	Red junglefowl	Gallo/Gallina silvestre	X		X			C	R	I						D	
Geothlypis trichas	Common yellowthroat	Reinita picatierra	X	X	X			C	M				A				
Geotrygon montana	Ruddy quail-dove	Paloma perdiz rojiza			X			U	R	P		C				D	
Haematopus palliatus	American oystercatcher	Ostrero caracolero		X				U	R			C				D	
Himantopus mexicanus	Black-necked stilt	Viuda	X	X	X			C	R				A	B	C	D	E
Hirundo rustica	Barn swallow	Golondrina horquillada	X	X	X			C	M				A			D	
Icterus dominicensis	Greater Antillean oriole	Calandria		X	X			C	R			C	A		C		
Icterus galbula	Baltimore oriole	Bolsero de Baltimore	X		X			U	M							D	
Icterus icterus	Troupial	Turpial	X	X	X			C	R	I			A	B	C	D	E
Iridoprocne bicolor	Tree swallow	Golondrina biclor		X				R	M								
Ixobrychus exilis	Least bittern	Martinetito		X	X			C	R			C	A		C	D	E

continued

Table 6—Bird species at the Cabo Rojo and Laguna Cartagena National Wildlife Refuges and Commonwealth protected areas in southwestern Puerto Rico [a] (continued)

Genus and species	Common name		Refuges [b]				Status [c]						Other Reserves [d]				
			Cabo Rojo		Laguna Cartagena												
	English	Spanish	H	S	L	T	E	N	M/R	GIP	C/F	C/T	A	B	C	D	E
Jacana spinosa	Northern jacana	Jacana Centroamericana			X			A	T								
Larus argentatus	Herring gull	Gaviota argéntea	X		X			R	M								
Larus atricilla	Laughing gull	Gaviota gallega	X	X	X			C	R					B		D	
Laterallus jamaicensis	Black rail	Gallito negro			X			R	M			C					
Limnodromus griseus	Short-billed dowitcher	Agujeta piquicorta	X	X	X			C	M				A		C	D	E
Limosa fedoa	Marbled godwit	Barga canela		X				A	M								
Limosa haemastica	Hudsonian godwit	Barga albiblanca		X	X			R	M								
Lonchura cucullata	Bronze mannikin	Diablito	X	X	X	X		C	R	I			A		C	D	
Lonchura malabarica	Indian silverbill	Gorrión picoplata	X	X	X			C	R	I			A	B		D	
Lonchura malacca	Troicolored munia	Monjita tricolor	X	X	X			C	R	I						D	
Lonchura punctulata	Nutmeg mannikin	Gorrión canela	X	X	X	X		C	R	I				B	C	D	
Lophodytes cucullatus	Hooded merganser	Mergansa encapuchada			X			A	M								
Loxigilla portoricensis	Puerto Rican bullfinch	Come ñame	X	X	X	X	E	C	R				A	B	C	D	E
Margarops fuscatus	Pearly-eyed thrasher	Zorzal pardo	X	X	X	X		C	R				A		C	D	E
Megaceryle alcyon	Belted kingfisher	Martín pescador norteño	X	X	X			C	M				A		C	D	
Megascops nupides	Puerto Rican screech-owl	Múcaro común	X		X			U	R			C	A			D	
Melanerpes portoricensis	Puerto Rican woodpecker	Carpintero de Puerto Rico	X	X	X	X	E	C	R				A	B	C	D	
Mergus serrator	Red-breasted merganser	Mergansa piquilarga			X			A	M								
Mimus gundlachii	Bahama mockingbird	Ruiseñor de las Bahamas	X					A	T								
Mimus polyglottos	Northern mockingbird	Ruiseñor	X	X	X	X		C	R				A	B	C	D	E
Mniotilta varia	Black-and-white warbler	Reinita trepadora	X	X	X			C	M				A		C	D	
Molothrus bonariensis	Shiny cowbird	Tordo lustroso	X	X	X	X		C	R				A	B	C	D	E
Myiarchus antillarum	Puerto Rican flycatcher	Juí de Puerto Rico	X	X	X	X		C	R			C	A	B	C	D	E
Nesospingus speculiferus	Puerto Rican tanager	Llorosa			X		E	C	R							D	
Numida meleagris	Helmeted guineafowl	Guinea torcaz	X		X			U	R	G						D	
Nyctanassa violacea	Yellow-crowned night-heron	Yaboa común	X	X	X			C	MR			C	A	B	C	D	E
Nycticorax nycticorax	Black-crowned night-heron	Yaboa real	X	X	X			U	MR				A			D	
Olor columbianus	Whistling swan	Cisne silbador			X			A	M								
Oporonis agilis	Connecticut warbler	Reinita de Connecticut	X	X				R	M								
Oporonis formosus	Kentucky warbler	Reinita de Kentucky	X					R	M							D	
Oporonis philadelphia	Mourning warbler	Reinita enlutada	X		X			R	M								
Oxyura dominica	Masked duck	Pato enmascarado			X			R	R	P	C	CT	A				
Oxyura jamaicensis	Ruddy duck	Pato chorizo			X			C	R	P	CF	CT	A		C	D	
Pandion haliaetus	Osprey	Águila pescadora	X	X	X			C	M				A	B	C	D	E
Parula americana	Northern parula	Reinita pechidorada	X	X	X	X		C	M				A		C	D	
Passerina caerulea	Blue grosbeak	Azulejo	X					R	M							D	
Passerina cyanea	Indigo bunting	Gorrión azul	X		X			U	M				A			D	

continued

Table 6—Bird species at the Cabo Rojo and Laguna Cartagena National Wildlife Refuges and Commonwealth protected areas in southwestern Puerto Rico [a] (continued)

Genus and species	Common name		Refuges [b]				Status [c]						Other Reserves [d]				
	English	Spanish	Cabo Rojo		Laguna Cartagena												
			H	S	L	T	E	N	M/R	GIP	C/F	C/T	A	B	C	D	E
Patagioenas leucocephala	White-crowned pigeon	Paloma cabeciblanca		X	X			R	R			C	A			D	
Patagioenas squamosa	Scaly-naped pigeon	Paloma turca			X			R	R	G						D	
Pelicanus occidentalis	Brown pelican	Pelícano pardo		X	X			C	R		F		A	B	C	D	E
Petrochelidon fulva	Cave swallow	Golondrina de cueva	X	X	X			C	R				A		C	D	
Petrochelidon pyrrhonata	Cliff swallow	Golondrina de penasco		X	X			R	M								
Phaethon lepturus	White-tailed tropicbird	Rabijunco		X				C	R			C				D	
Phalacrocorax olivaceus	Olivaceous cormorant	Cormorán oliváceo			X			A	M								
Pheucticus ludovicianus	Rose-breasted grosbeak	Piquigrueso	X					R	M							D	
Phoenicopterus ruber	American flamingo	Flamenco		X				R	T			C					E
Piranga olivacea	Scarlet tanager	Piranga escarleta		X				R	MT								
Piranga rubra	Summer tanager	Piranga roja		X				R	T								
Plegadis falcinellus	Glossy ibis	Ibis lustroso			X			R	RT				A			D	
Pluvialis dominica	American golden plover	Playero dorado		X	X			R	M								
Pluvialis squatarola	Black-bellied plover	Playero cabezón		X	X			C	M				A		C	D	E
Podiceps dominicus	Least grebe	Tigua	X		X			R	R		C	CT	A		C		
Podilymbus podiceps	Pied-billed grebe	Zaramago			X			C	R	P		C	A		C		
Porphyrula martinica	Purple gallinule	Gallareta azul			X			R	R			CT	A				
Porzana carolina	Sora	Gallito			X			R	M				A				
Porzana flaviventer	Yellow-breasted crake	Gallito amarillo			X			U	R		C	CT					
Progne cryptoleuca	Cuban martin	Golodrina Cubana		X				R	T								
Progne subis	Purple martin	Golondrina púrpura	X					R	M								
Progne dominicensis	Caribbean martin	Golondrina de iglesias	X	X	X			C	R				A	B	C	D	
Protonotaria citrea	Prothonotary warbler	Reinita anaranjada	X	X				U	M			C	A			D	E
Quiscalus niger	Greater Antillean grackle	Chango	X	X	X			C	R				A	B	C	D	E
Rallus longirostris	Clapper rail	Pollo de mangle		X	X			C	R				A	B		D	E
Riparia riparia	Bank swallow	Golondrina parda	X	X	X			C	R				A			D	
Seiurus aurocapilla	Ovenbird	Pizpita dorada	X	X	X			C	M							D	
Seiurus motacilla	Lousiana waterthrush	Pizpita del río	X		X			C	M			C	A			D	
Seiurus noveboracensis	Northern waterthrush	Pizpita de mangle	X	X	X			C	M			C	A	B	C	D	E
Setophaga ruticilla	American redstart	Candelita	X	X	X			C	M				A	B		D	E
Sphyrapicus varius	Yellow-bellied sapsucker	Carpintero pechiamarillo			X			R	M							D	
Spindalis portoricensis	Puerto Rican spindalis	Reina mora	X	X	X	X	E	C	R				A			D	E
Sterna anaethetus	Bridled tern	Gaviota monja		X				C	R			C					
Sterna antillarum	Least tern	Gaviota pequeña		X	X			U	R		C	C	A			D	E
Sterna dougalli	Roseate tern	Palometa		X				C	R		F					D	
Sterna fuscata	Sooty tern	Gaviota oscura		X	X			C	R							D	
Sterna hirundo	Common tern	Gaviota común		X				C	MR				A	B		D	

continued

Table 6—Bird species at the Cabo Rojo and Laguna Cartagena National Wildlife Refuges and Commonwealth protected areas in southwestern Puerto Rico [a] (continued)

Genus and species	Common name		Refuges [b]				Status [c]						Other Reserves [d]				
			Cabo Rojo		Laguna Cartagena												
	English	Spanish	H	S	L	T	E	N	M/R	GIP	C/F	C/T	A	B	C	D	E
Sterna maxima	Royal tern	Gaviota real		X				C	R				A	B	C	D	
Sterna nilotica	Gull-billed tern	Gaviota piquigorda		X	X			U	M				A				
Sterna sandvicensis	Sandwich tern	Gaviota piquiaguda		X	X			U	R				A	B	C		
Streptopelia roseogrisea	African collared-dove	Tórtola collarina	X		X			U	R	I						D	
Sula leucogaster	Brown booby	Boba prieta		X				C	R							D	
Sula sula	Red-footed booby	Boba patiroja		X				C	R			C					
Tiaris bicolor	Black-faced grassquit	Gorrión negro	X	X	X	X		C	R				A		C	D	E
Tiaris olivaceus	Yellow-faced grassquit	Gorrión barba amarilla	X		X	X		C	R				A	B	C	D	
Todus mexicanus	Puerto Rican tody	San Pedrito	X	X	X	X	E	C	R				A	B	C	D	E
Tringa flavipes	Lesser yellowlegs	Playero guineilla menor	X	X	X			C	M				A	B	C	D	E
Tringa melanoleuca	Greater yellowlegs	Playero guineilla mayor	X	X	X			C	M				A	B	C	D	E
Tringa semipalmatus	Willet	Playero albiblanco		X	X			CU	M				A		C	D	E
Tringa solitaria	Solitary sandpiper	Playero solitario		X	X			C	M			C	A			D	
Turdus plumbeus	Red-legged thrush	Zorzal de patas coloradas	X		X			C	R				A		C	D	E
Tyrannus caudifasciatus	Loggerhead kingbird	Clérigo	X	X	X			C	R			C				D	
Tyrannus dominicensis	Gray kingbird	Pitirre	X	X	X			C	R				A	B	C	D	E
Vermivora chrysoptera	Golden-winged warbler	Reinita alidorada	X	X				R	M							D	
Vermivora pinus	Blue-winged warbler	Reinita aliazul		X				R	T								
Vidua macroura	Pin-tailed whydah	Viuda colicinta	X		X			U	R	I							
Vireo altiloquus	Black-whiskered vireo	Julián chiví	X	X	X			C	R						C	D	
Vireo griseus	White-eyed vireo	Julián chiví ojiblanco	X	X	X			U	M								
Vireo latimeri	Puerto Rican vireo	Bien-te-veo	X		X	X	E	C	R			C				D	E
Vireo olivaceus	Red-eyed vireo	Julián chiví ojirrojo		X	X			R	T							D	
Wilsonia canadensis	Canada warbler	Reinita de Canadá			X			A	M								
Wilsonia citrina	Hooded warbler	Reinata de capucha	X		X			U	M				A			D	
Zenaida asiatica	White-winged dove	Tórtola aliblanca	X	X				U	R	G			A	B	C	D	E
Zenaida aurita	Zenaida dove	Tórtola cardosantera	X	X	X			C	R	G			A	B	C	D	E
Zenaida macroura	Mourning dove	Tórtola rabilarga	X		X			U	R	G						D	E
Zonotrichia albicollis	White-throated sparrow	Chingolo			X			A	M								

continued

Table 6—Bird species at the Cabo Rojo and Laguna Cartagena National Wildlife Refuges and Commonwealth protected areas in southwestern Puerto Rico [a] (continued)

Genus and species	Common name		Refuges [b]				Status [c]						Other Reserves [d]				
			Cabo Rojo		Laguna Cartagena												
	English	Spanish	H	S	L	T	E	N	M/R	GIP	C/F	C/T	A	B	C	D	E
Species reported for other reserves in southwestern Puerto Rico but not recorded at Cabo Rojo or Laguna Cartegena Wildlife Refuges																	
Archilochus colubris	Ruby-throated hummingbird	Zumbadorcito de garganta roja						R	M							D	
Brotogeris versicolurus	White-winged parakeet	Perquito aliblanco						C	R	I						D	
Catharus bicknelli	Bicknell's thrush	Zorzal de Bicknell						R	M			C				D	
Catharus minimus	Gray-cheeked thrush	Zordal de mejilla gris						R	M							D	
Colinus virginianus	Northern bobwhite	Codorniz						R	R	I			A				
Dendroica castanea	Bay-breasted warbler	Reinita castana						R	M							D	
Dendroica fusca	Blackburnian warbler	Reinita de fuego						R	T							D	
Eulampis holosericeus	Green-throated carib	Zumbador pechiazul						R	R							D	
Geotrogon chrysia	Key West quail-dove	Paloma perdiz áurea						U	R			C				D	
Geotrygon mystacea	Bridled quail-dove	Paloma perdiz de Martinica						R	R			C				D	
Helmitheros vermivorum	Worm-eating warbler	Reinita gusanera						U	M			C				D	
Larus delawarensis	Ring-billed gull	Gaviota piquianillada						C	M				A				
Lomnothlypis swainsonii	Swainson's warbler	Reinita de Swainson						R	M							D	
Myopsitta monachus	Monk parakeet	Perico monje						U	R	I			A	B			
Numenius phaeopus	Hudsonian curlew	Playero pico corvo						R	M				A				E
Orthohyncus cristatus	Antillean crested hummingbird	Zumbadorcito crestado						C	R							D	
Passer domesticus	House sparrow	Gorrion ingles						U	R	I						D	
Phalaropus lobatus	Red-necked phalarope	Faloropo picofino						A	M						C		
Stercorarius pomarinus	Pomarine jaeger	Pagalo pomarino						R	M								E
Streptopelia decaocto	Eurasian collared-dove	Tórtola turca								I						D	
Tachornis phoenicobia	Antillean palm swift	Vencejito						A								D	
Wilsonia pusilla	Wilson's warbler	Reinita de Wilson						A	M							D	

[a] Sources: Species list and information derived from several sources (Chabert Llompart and others 1986; Danforth 1926, 1929, 1931, 1936; Diaz-Soltero 1990; Hernández Prieto 1990; Kepler 1971, 1972; McCandless 1961, 1962; Moreno 1997; Ortiz Rosas 1981; Raffaele 1983; Toro McCown and Chabert 1986; U.S. Fish and Wildlife Service 2002, 2004; Wetmore 1927; Wiley 1974, see endnotes). Some species listings are from historical records.

[b] Cabo Rojo Refuge, with tracts; H = Cabo Rojo headquarters; S = Salinas. Laguna Cartagena Refuge, with tracts; L = Lagoon; T = Tinaja. Species present are indicated with an X.

[c] Status: E = endemic; N = numbers in Puerto Rico (C = very common or common; U = uncommon; R = rare to extremely rare; A = accidental) (Raffaele 1983); M/R: M = migrant, transient (T), or visitor and R = resident or resident breeder; GIP: G = game species, I = introduced as game or other purpose, P = protected game species; C/F (listed species): (C = threatened or endangered by Puerto Rico; F = listed or candidate for listing by U.S. Fish and Wildlife Service); C/T (species of concern): C= conservation concern, local or regional; T = target species for managment at the Cartagena Lagoon; blank space = no detail.

[d] Reserves and information sources: A = Boqueron Wildlife Refuge (Chabert and others 1982); B = Los Morrillos de Cabo Rojo (Municipio Autonomo de Cabo Rojo (1998); C = Reserva Natural Punta Guaniquilla (Fuentes Santiago and Quevedo Bonilla 2002); D = Guánica Forest (Arendt and others 2007; Hernández Prieto 1990); E = Parguera Natural Reserve (Departamento de Recursos Naturales 1981, Departamento de Recursos Naturales y Ambientales 2000a; Ventosa-Febles and others 2005).

Ducks. Anas discors *(blue-winged teal) is a common wintering duck in Puerto Rico that is found on several types of water bodies, including freshwater lagoons and hypersaline salt ponds. The species may be observed throughout the year but is most common from October through April.* (U.S. Fish and Wildlife Service photo)

species not yet recorded at the refuges have been reported on five nearby reserves in southwestern Puerto Rico (table 6, bottom; fig. 1).

The salt flats at Cabo Rojo are among the best sites to attract birds migrating from North and South America through the eastern Caribbean. The fall bird migration may be divided into three events with some overlap: (1) shorebirds dominate from July to mid-September, (2) warblers from September to mid-October, and (3) migrant waterfowl in late October and November (Collazo and others 1995, McCandless 1961). Data recorded at the salt flats showed:

- More than 25 species of shorebirds
- As many as 40,000 shorebirds migrating through the salt flats during the fall months
- Daily counts in the fall sometimes exceeding 7,000 birds, with historic daily counts as high as 10,000 birds
- A small breeding population of *Charadrius alexandrinus* (snowy plover) not found elsewhere in Puerto Rico

In 1900, "Christmas counts" began in the United States as a means to protect bird species from traditional holiday hunts. In 1921, Stuart Danforth began Christmas bird counts in Mayagüez, PR, when *Aeglaius xanthomus* (yellow-shouldered blackbird) comprised 62 percent of the 720 birds sampled. In 1925 and 1927, the count was done at Cartagena Lagoon, and the 1926 and 1928 counts were between Guánica and Boquerón (McCandless 1962). Results were published in the local Journal of Agriculture. Counts between 1955 and 1960 were carried out by McCandless and colleagues (Burden 1961) and included the Cartagena Lagoon and Cabo Rojo Lighthouse, as have all subsequent counts from 1972

Falcon. Falco sparverius *(American kestrel) is a locally common permanent resident in Puerto Rico that prefers coastal areas with large trees for nesting. It is often seen on exposed perches in open areas from which it hunts.* (U.S. Fish and Wildlife Service photo)

to the present (figs. 9A, 9B, and 9C). In 1955 and 1956, about one-quarter of the birds tallied were *Bubulcus ibis* (cattle egrets).

The earliest counts were undertaken by Danforth alone, or in 1928, with the help of the well-known ornithologist James Bond (McCandless 1962). The 1955 to 1959 counts were carried out by McCandless with fewer than 10 assistants. The Danforth counts are not comparable with later work because of the lack of field assistance and travel difficulties.

The 31-year record between 1972 and 2002 showed a mean of 9,203.5 ± 795.0 (range = 996 to 20,475) individuals of 97.8 ± 2.2 species (range = 65 to 112) tallied by an average of 21.3 ± 2.0 (range = 3 to 44) observers (Puerto Rican Ornithological Society 2006, see endnotes).The greatest number of species tallied was in 1972 and 1974 and the fewest in 1978. It is noteworthy that the lowest number of species tallied was between 1976 and 1979, a period when drought may have negatively impacted bird species at nearby Guánica Forest (Faaborg and Arendt 1989a, 1989b, 1990). This same period also coincides with the fewest observers participating in the count.

Early in the 20th century, sugar cane fields on the south coast were largely devoid of tree cover (Wetmore 1916). At that time, Cartagena Lagoon was considered to be Puerto Rico's most important breeding ground for resident and migrant waterfowl (Danforth 1926). During nearly 2 years of observations, Danforth identified 105 resident and migratory bird species and described 8 vegetation types. He feared that the lagoon would be drained and that some species would be lost or decline in numbers. He suggested protective measures to increase bird numbers and diversity and pointed out the need for public education. His interest in government control

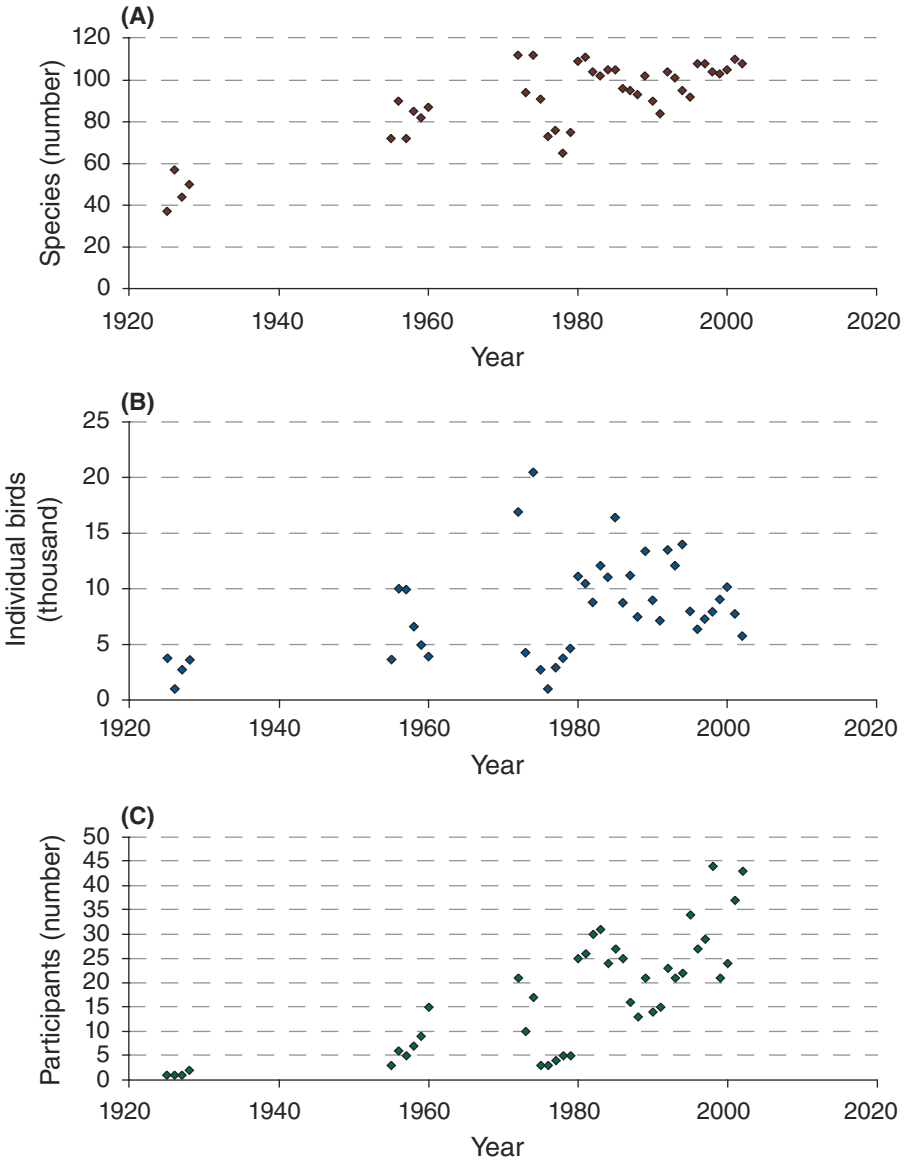


Figure 9—Christmas bird counts: (A) number of species, (B) number of individual birds, and (C) number of participants.

of the lagoon was realized many years later. Only recently, sugar cane production discontinued north of the Cartagena Lagoon. Today, the land is used as pasture for livestock.

Reptiles and Amphibians

Eleven reptiles and five amphibians have been reported as terrestrial residents on the refuges: seven lizards, one land turtle, two geckos, one blind snake, one toad, and four frogs. In addition, two sea turtles, *Eretmochelys imbricata* and *Dermochelys coriacea*, briefly use the beaches at Cabo Rojo for laying eggs (table 5).

Ameivas, commonly called iguanas (or preferably siguanas), actively forage on the ground, rarely ascending trees. *Ameiva exsul*, the most common and widely distributed siguana in Puerto Rico, is found in coastal areas to about 350 m in elevation, and on offshore islands (Rivero 1978). *Ameiva wetmorei*, a very attractive siguana that is rarely

seen, is confined to the open, deciduous forest and scrub of southwestern Puerto Rico. During 1920, *Ameiva exsul*, *Anolis cristatellus*, *Anolis pulchellus*, and *Anolis stratulus* were all reported for the Lagoon tract (Danforth 1926). On the Tinaja tract, *Ameiva wetmorei* is found at higher elevations and *Anolis poncensis* on the lower slopes. The only amphibian reported then was the frog, *Leptodactylus albilabris*, from the Cartagena Lagoon. *Leptodactylus albilabris* is seldom found distant from wetlands, including streams. Tadpoles and small frogs are eaten by the lagoon waterfowl, particularly the herons (Danforth 1926).

Of the eight species of anoles found in Puerto Rico, five have been recorded in grass and bushes on the refuges (Rand 1964, Rivero 1978). *Anolis cooki* occurs in disjunct populations between Cabo Rojo and Guayanilla on the south coast. Currently, it is endangered due to habitat changes and possibly competition from other lizards. *Anolis cristatellus* occurs all over Puerto Rico up to 550 m in elevation. It commonly enters houses. *Anolis poncensis* is found along the dry south coast, mainly from Cabo Rojo to the town of Salinas east of Ponce. It is often seen in low bushes and cactus. *Anolis pulchellus*, also common, prefers grasses in open areas. Sometimes it climbs low bushes but is never found in trees. *Anolis stratulus* is widely distributed in the lowlands, and common at intermediate elevations in the mountains.

Ground lizard. Ameiva wetmorei *(blue-tailed ground lizard) is uncommon at higher elevations on the Tinaja tract of the Laguna Cartagena National Wildlife Refuge. (U.S. Fish and Wildlife Service photo)*

Two geckos of the genus *Sphareodactylus* are found in the refuges. *Sphareodactylus macrolepsis* is the most common and widely distributed species of the genus, with subspecies occurring from the coast to 850 m in elevation (Rivero 1978). *Sphareodactylus nicholsi* prefers dry habitat, extending along the north coast from the town of Manati west to Mayagüez and south and east to Ponce and Juana Díaz (Rivero 1978). It frequents open deciduous forest where it forages among the leaves.

Trachemys stejnergeri (previously *Pseudemys terrapen*) is Puerto Rico's only native turtle. It occupies lagoons and streams in the lowlands where it feeds on plants and animals. Typhlopids are blind snakes, also called worm snakes, which live underground. *Typhlops richardi* feed on invertebrates including ants and termites.

To most islanders, the amphibian fauna of Puerto Rico includes the group commonly known as "coquis" in the genus *Eleutherodactylus*, and *Bufo marinus*, the common toad (Rivero 1978). The toad was imported from Jamaica and Barbados during the 1920s to control a grub on sugar cane. A few years later, it was abundant. *Rana catesbiana*, the bullfrog, was introduced for similar purposes in 1935 and since has spread in coastal areas to 150 m in elevation. It prefers wetlands including lagoons and streams.

Two species of *Eleutherodactylus*, both widely distributed on the island, have been identified on the refuges (table 5). *Eleutherodactylus coqui*, the best known, climbs into tree branches at night whereas *Eleutherodactylus antillensis* calls from low branches and bushes. Insectivorous birds are common predators of frogs; moreover, ameivas, anoles, and several invertebrates may also eat young amphibians (Rivero 1978).

Fish

Four species of fish were reported for Cartagena Lagoon during the 1920s (Danforth 1926) (table 5). At that time, when the lagoon waters evaporated during June and July, local fishermen speared *Anguilla rostrata*. Some of the eels were in excess of 1 m in length. Smaller eels served as food for the *Ardea herodias* (great blue heron) (Danforth 1926) and probably other wading bird species as well. Among the fish species, *Centropomus parallelus* were reported by local farmers. Individuals of *Dormitator*

maculates, rather scarce, were usually observed among the cattails where they would bury themselves in the mud when water levels were low. *Poecilia vivipara* were most abundant, often seen in great numbers swarming in shallow water. The latter fish species was the only one used to any extent as food by the birds.

Additional fish surveys were carried out in 1957, 1980, and 1985 (Díaz-Soltero 1990). At least 17 species were recorded one or more times (table 5). Moreover, unknown individuals called "pez grande" (big fish) by local folks were reported to have lived in the mud and attained a weight of 9 kg (Danforth 1926). The population was apparently exterminated when the lagoon dried up in 1923.

Other Flora and Fauna

A compendium of plant, animal, and fungi species was listed in the plan for the development and management of Cartagena Lagoon (Díaz-Soltero 1990). The tables derived from several unpublished reports included 26 species of algae, 8 species of fungi, 23 species of protozoans, 11 species of metazoans, and 96 species grouped as "microbiota." Also tallied were 2 species of Platyhelminthes, 6 species of Mollusca, 5 species of Annelida, 5 species of Arthropoda (Crustacea), and 27 species of Arthropoda (Insecta). In a study of the lagoon's water quality, 67 insect species belonging to five orders—Hemiptera, Diptera, Coleoptera, Odontata, and Ephemeroptera—were collected (Deliz Quiñones 2005). Six families and twenty-four species of butterflies were tentatively identified on both refuges (Asencio López and Rentas Soto 2006, see endnotes; Haselmayer 2000, see endnotes; Hernández 2004; Ramos 1982; Smith and others 1994) (table 7).

At the Salinas tract, the water boatmen and brine shrimp found in Candeleria and Fraternidad lagoons serve as prey for numerous shorebirds (Bonilla Soto 1984, Tripp and Collazo 2003). The lagoons are also the habitat for two new, extremely halophilic species of bacteria—*Halogeometricum borinquense* (Montalvo-Rodríguez and others 1998); and *Haloterrigena thermotolerans*, a highly thermo-tolerant Archaeon belonging to the order Halobacterias (Montalvo-Rodríguez and others 2000). Also, three strains of halophilic Archaebacteria were reported (Montalvo-Rodríguez and others 1997).

Butterflies. Sunning themselves in the early morning hours, these Heliconius charitonia *(zebra butterflies) are occasionally seen along the dirt road and in the arroyos of the Tinaja tract.*
(Photo by Peter L. Weaver)

Finally, about 100 species of parasites found on 63 species of freshwater sport fishes were identified (Bunkley-Williams and Williams 1994). The fish are commonly caught in the island's reservoirs, streams, and lagoons, including those in and around the refuges and other protected areas.

Environmental Issues

The need to increase, improve, and protect nesting and foraging habitat for native forest birds, shorebirds, and wetland species, including threatened and endangered species, was indicated in the mid-1970s (Raffaele and others 1977, Woodbury and others 1975). In 1979, after 6 years of investigation, several of Puerto Rico's critical wildlife areas were identified including the Boquerón Commonwealth Forest, the Boquerón Wildlife Refuge, the Cabo Rojo Salt Flats and cliffs, the Cartagena Lagoon, Punta Guaniquilla Natural Reserve, and the Guánica Forest (Department of Natural Resources 1979). At the beginning of the new millennium, the importance of species and habitat protection remain as critical issues (Núñez-García and Hunter 2000, U.S. Fish and Wildlife Service 2002, Ventosa-Febles 2005). A number of factors indicate the need for additional habitat in the Caribbean Islands NWR Complex, including the refuges in southwestern Puerto Rico:

Table 7—Butterfly species found on the Cabo Rojo and Laguna Cartagena National Wildlife Refuges [a]

Names		
Scientific—family species	English	Occurrence [b]
Danaidae		
Danaus plexippus	Monarch	Common in open areas
Heliconidae		
Agraulis vanillae	Gulf fritillary	Fairly common in open areas
Heliconius charitonia	Zebra	Uncommon in arroyos
Hesperidae		
Cymaenes tripunctus	Three-spotted skipper	Abundant in open areas
Pyrgus oileus oileus	Tropical checkered skipper	Fairly common in open areas
Ubanus proteus	Long-tailed skipper	Very common everywhere in September uncommon after mid-October
Lycaenidae		
Hemiargus hanno watsoni	Hanno blue	
Strymon columella	Hairstreak	Common in open areas
Nymphalidae		
Anartia jatrophae	Peacock	Fairly common everywhere
Biblis hyperia	Red rim	Fairly common near arroyos
Ephyriades arcas	Skipper	Uncommon in wooded area
Euptoieta hegesia watsoni	Mexican fritillary	Seen once in open area
Hamadryas amphichloe	Pale cracker	Fairly common in wooded area
Junonia evarete	Mangrove buckeye	Common closest to salinas
Junonia genoveva	Tropical buckeye	Very common everywhere
Pieridae		
Anaea borinquenalis	Leafwing	Seen once in wooded area
Aphrissa sp.	Sulphurs	
Appias drusilla monomorpha	Amarilla white	
Ascia monuste eubotea	Great southern white	Very common in open areas
Eurema elathea	False-barred sulphur	Common in open areas
Eurema lisa euterpe	Little yellow	
Kricoginia sp.	Suphurs	
Phoebis agarithe/sennae	Large orange sulphur/ cloudless sulphur	Uncommon in open areas
Phoebis philea	Orange-barred sulphur	

[a] Sources: Haselmayer (2000), see endnotes; Asencio Lopez and Rentas Soto (2006), see endnotes. Lists compiled during visits to Cabo Rojo Refuge.
[b] Occurrence: Uncommon, fairly common, common, very common; abundant; sightings are a function of site and season.

- The past cutting of Puerto Rico's forests for agriculture and selective harvest of commercial timber, i.e., habitat destruction, which occurred on 99 percent of the island (Wadsworth 1950)
- The devastation of dry forest in Puerto Rico, the Neotropics, and worldwide, so much so that some consider it as the most endangered tropical ecosystem (Janzen 1988a)
- Habitat destruction resulted in 22 percent of Puerto Rico's native bird species being considered as either endangered or threatened (Raffaele 1983)
- The considerable number of threatened and endangered species that use the current refuges in southwestern Puerto Rico; including resident, migratory, and endemic birds; and those with special habitat requirements such as mangroves and salt flats (U.S. Fish and Wildlife Service 2002)
- The relatively limited size of the refuges in comparison to the island, and the need to secure sufficient habitat to assure recovery of listed species in recovery plans (fig. 1)

- The actual and projected sharp increase in human population and economic activity in the southwest, notably the municipality of Cabo Rojo (Núñez-García and Hunter 2000) (fig. 2)
- The devastating impacts of recent hurricanes which may portend a gloomy future given current concerns over global warming and more active and destructive hurricane periods (Van Bloom and others 2005) (fig. 8)
- The threat of recurrent droughts and associated wildfires that could destroy portions of the existing habitat and their wildlife, or negatively influence the breeding of some bird species
- The increase of Erythrocebus patas and Macaca mulatta monkeys and their potential impact on native wildlife along with the persistent, negative impact of the mongoose
- The undetermined impact of exotic species on native flora both in dry forest and wetland habitats
- The relatively small size of the Lagoon tract, the condition of farmlands immediately surrounding it, and the need for good land management to secure quality water for wildlife protection

In addition, 14 of the 21 species considered as Caribbean sea bird fauna (Schreiber and Lee 2000) have been recorded on the refuges and protected areas of southwestern Puerto Rico. The species include: *Anous stolidus* (brown noddy), *Fregata magnificans* (magnificent frigatebird), *Larus atricilla* (laughing gull), *Phaethon lepturus* (white-tailed tropicbird), and *Pelecanus occidentalis* (brown pelican), two boobies, *Sula leucogaster* (brown booby) and *Sula sula* (red-footed booby), and seven terns, *Sterna anaethetus* (bridled tern), *Sterna antillarum* (least tern), *Sterna dougallii* (roseate tern), *Sterna fuscata* (sooty tern), *Sterna hirundo* (common tern), *Sterna maxima* (royal tern), and *Sterna sandvicensis* (sandwich tern) (table 6). Most of these species exist in low densities and normally feed at considerable distances from breeding sites. Typically they produce a single, slow-growing offspring and populations are slow to recover after disturbances (Schreiber and Lee 2000). Primary threats to these sea birds are loss of nesting habitat due to development, human disturbance of colonies, introduced predators, and limited biological information for management purposes (Halewyn and Norton 1984, Schreiber 2000). Other problems include egg predation, pollution of oceanic waters due to various sources, excessive fishing, and recurrent hurricanes that can negatively impact small populations.

Sea birds. Sterna sandvicensis *(sandwich terns), a species widely distributed throughout the world including southwestern Puerto Rico, breeds in dense colonies along the seacoast and on islands.*
(Photo by Jorge Saliva)

Endangered Species

The Endangered Species Act of 1973, as amended through 1988, directs Federal Agencies to promote the recovery of all listed species (U.S. Fish and Wildlife Service 1988). Species' names are published in the Federal Register and recovery plans are developed to enhance their survival. Recovery plans include a description of the current status of endangered species, their ecology (life history, distribution, and population trends), habitat description and requirements, factors that influence their survival, (e.g., fires, hurricanes), and reasons for listing the species. Also provided are recovery goals, recovery criteria, and the required actions to assure species recovery.

Recovery criteria deal with sustainability of the species. Among the concerns are adequate reproduction, genetic robustness to avoid inbreeding and to allow for adaptation, sufficient habitat, and control of threats to survival. Between 1970 and 1996, the F&WS developed recovery plans for 123 species that are found on either the Cabo Rojo orand Laguna Cartagena NWR, as well as for one sea turtle and one

plant species still not recorded but known from nearby sites (table 8).

The endangered plant species include two endemic grasses in the genus *Aristida* (McKenzie and others 1989). *Aristida chaseae* is found on exposed rocky outcrops at 150 to 200 m in elevation near Cerro Mariquita on the Tinaja tract. *Aristida portoricensis* grows in exposed rock crevices in association with the former. Both have also been recorded at the western end of Sierra Bermeja. Three other listed plant species are endemic to the Sierra Bermeja and grow on the Tinaja tract. *Eugenia woodburyana* is a small, evergreen tree that grows on the slopes of Cerro Mariquita. *Lyonia truncata* var. *proctorii*, an evergreen shrub, grows on steep slopes in the open. *Veronia proctorii*, a small, erect shrub, grows on upper slopes near Cerro Mariquita. *Ottoschulzia rhodoxylon*, a small evergreen tree found in western Puerto Rico and Hispaniola (Little and others 1974), grows on the Tinaja tract. *Stahlia monosperma*, is a medium-sized tree that survives as scattered populations in dry

Table 8—U.S. Fish and Wildlife Service species recovery plans applicable to species at the Cabo Rojo and Laguna Cartagena National Wildlife Refuges [a]

Group and species	Common name	Federal Register	Dates	
			Federal Register	Recovery plan
			- - - - mo/day/yr - - - -	
Flora				
Aristida chaseae A.S. Hitchc.	NA [b] (Poaceae)	58 FR 25755-25758	04/27/1993	07/31/1995
A. portoricensis Pilger [c]	NA (Poaceae)	55 FR 32257	08/08/1990	05/16/1994
Catesbaea melanocarpa Krug & Urban [d]	Tropical lilythorn	64 FR 13116-13120	03/17/1999	07/15/2005
Eugenia woodburyana Alain [e]	NA (Myrtaceae)	59 FR 46715	09/09/1994	10/06/1998
Lyonia truncata Urban var. proctorii [f]	NA (Ericaceae)	58 FR 25755-25758	04/27/1993	05/16/1994
Ottoschulzia rhodoxylon (Urban) Urban [g]	NA (Icacinaceae)	55 FR 13488-13491	04/10/1990	09/20/1994
Stahlia monosperma (Tul.) Urban [h]	*Cobana negra*	55 FR 12790-12792	04/05/1990	11/01/1996
Vernonia proctorii L.E. Urbatsch [i]	NA (Asteraceae)	58 FR 25755-25758	04/27/1993	05/16/1994
Fauna				
Agelaius xanthomus [j]	Yellow-shouldered blackbird	41 FR 51019-510122	11/19/1976	11/12/1996
Caprilumgas noctitherus [k]	Puerto Rican whip-poor-will	38 FR 14678	06/04/1973	04/19/1984
Chelonias mydas [l]	Green turtle	43 FR 32808	07/28/1978	10/29/1991
Dermochelys coriacea [l]	Leatherback turtle	35 FR 8495	06/02/1970	04/06/1992
Eretmochelys imbricata [l]	Hawksbill turtle	35 FR 8495	06/02/1970	12/15/1993
Pelecanus occidentalis occidentalis	Brown pelican	35 FR 16047	10/13/1970	08/??/1985

[a] Source: Code of Federal Regulations 1970–1999.
[b] NA = not applicable (i.e., no common names or no existing recovery plans).
[c] Source: Silander (1994).
[d] Source: Rivera and Foote (2004). Reported on private property near the refuges.
[e] Sources: Breckon and Kolterman (1994); U.S. Fish and Wildlife Service (1993b, 1998).
[f] Source: Breckon and Kolterman (1994).
[g] Sources: Breckon and Kolterman (1994); Silander (1994), see endnotes; U.S. Fish and Wildlife Service (1990). Recorded for Sierra Bermeja and possibly present on the Tinaja tract.
[h] Source: Saliva (1996).
[i] Source: Breckon and Kolterman (1994).
[j] Sources: U.S. Fish and Wildlife Service (1976), see endnotes; Rivera (1996).
[k] Source: Diaz Diaz (1984), see endnotes.
[l] Of the sea turtles, Chelonias mydas has not yet been recorded on the Salinas tract.

coastal areas near mangroves (Little and Wadsworth 1964). It has also been planted on both refuges. The remaining plant species, *Catesbaena melanocarpa*, has not yet been found on the refuges but is reported on private property nearby. It is also reported on St. Croix and in the Lesser Antilles. Six of the refuge plants, (i.e., all except *Lyonia truncata* var. *proctorii* and *Ottoschulzia rhodoxylon*,), are also listed as priority species that purportedly could be extirpated within 5 to 10 years (Missouri Botanical Garden 1992).

Endangered animal species (table 8) include *Agelaius xanthomus*, formerly reported on the Headquarters tract (Wiley 1974, see endnotes) and still occasionally seen; and *Falco peregrinus* (peregrine falcon), a recent winter migrant that has been delisted. The Puerto Rican whip-poor-will, *Caprimulgus noctitherus*, was recently reported on the Tinaja tract and sea turtles, *Dermochelys coriacea* and *Eretmochelys imbricata*, nest on the beaches at Cabo Rojo.

Rare and endangered. A recently discovered rare and endangered plant without a common name, Vernonia proctorii L.E. Urbatsch*, grows on the slopes of the Tinaja tract near Cerro Mariquita.* (U.S. Fish and Wildlife Service photo)

Management Activities

Management of the refuges involves routine surveillance as well as activities aimed at the protection, maintenance, and improvement of the habitat for wildlife, and education of the public. The major activities have included: fire prevention and control on both refuges, restoration of native habitat on both refuges, management of the Cartagena Lagoon, development of structures and improvements, and collaborative activities (table 9).

Fire and Habitat Restoration

Fires at both refuges like those during February of 2002 have caused considerable damage in the past. Fire continues to be used to clear pastures by farmers surrounding the refuges, particularly during the January through April dry season. Occasionally, these fires escape onto refuge lands. Fire prevention involves public education, training for fire fighting, and the construction and maintenance of fire breaks, especially during the dry season. In 2006, all fire breaks were widened.

During the 1990s, a grassland management plan and a reforestation plan were developed for both refuges (Schaffner 1995a, 1995b, see endnotes). The long-term objectives of the grassland plan were to alter the composition favoring native grasses and change the overstory to benefit the bird species. Mowing grass for forage, prescribed burning, and the provision of firebreaks were incorporated into the plan. The reforestation plan was aimed at increasing the variety of native tree species. The planting list contained about 50 tree and shrub species, among them *Roystonea borinquena,* which is used for nesting by at least 15 resident bird species (Perez Rivera 1977), 12 of which are recorded on the refuges. Both management plans were implemented to some extent although the vegetation conversion goals and proposed annual planting goals were not met.

From 1980 to 2001, more than 9,000 trees representing 78 species were planted on the refuges for habitat restoration (Weaver and Schwagerl 2004) (table 10). By 2006, the number had increased to

Table 9—Chronology of activities that influenced the Cabo Rojo National Wildlife Refuge (Headquarters and Las Salinas National Wildlife tracts) [a]

Date	Events and activities
700 BC	Indians harvest salt; Indians throughout Puerto Rico engage in the commerce of salt from Cabo Rojo
1500s +	Las Salinas and Cerro Mariquita in Sierra Bermeja become reference points for travelers around southwestern Puerto Rico
1508	Juan Ponce de Leon is the first Spanish explorer to set foot on the Salinas de Cabo Rojo; in 1511, he begins procedures for salt extraction
1528	Spain's first confrontation with another European power (France) takes place in Bahía Sucia at Las Salinas
1585	British construct a bunker at Las Salinas as part of a military strategy to control Puerto Rico
Early 1600s	Las Salinas become communal property when the Spanish crown announces the collapse of the salt extraction
1799	Last attack of the British in Puerto Rico takes place at Puerto Real, north of Punta Guanaquilla, in Cabo Rojo municipality
1815	Spain proclaims La Real Cédula (Royal Document) allowing greater freedom in economic development and trade including the importation of equipment to facilitate salt extraction at Las Salinas
Mid-1800s	Ramón Baldorioty de Castro works as administrator of Las Salinas
1883	Town of Lajas founded with 6,238 persons [b]
Early 1900	Forests in Lajas Valley are cut to increase land for sugar cane production [b]
1972	Department of Natural Resources is created with jurisdiction over the island's natural resources [b]
1973	Passage of the Endangered Species Act [b]
1974	U.S. Fish and Wildlife Service acquires the Headquarters tract from the Foreign Broadcast Information Service; first avifauna survey on the Headquarters tract records 24 species
1976	Water Law (Ley de Aguas) is approved and Department of Natural Resources has authority to regulate the development and use of the island's water resources [b]
1978	Full time manager arrives at the Headquarters site
1980	Reforestation begins by planting *Bucida buceras* at Headquarters tract
1986	McKenzie prepares the first critical plant list for the Headquarters site
1997	Major restoration begins with planting trials of numerous tree species
1999	Las Salinas is the second tract acquired as part of the Cabo Rojo Refuge
2003	Visitor information and interpretative center is completed on Salinas tract
2004	Observation tower of salt flats is completed; visitor's house at Headquarters tract is refurbished
2008	New Headquarters building is constructed

[a] Sources: Toro McCown and Chabert (1986); McKenzie (1986), see endnotes; Ramírez Padilla (1985).
[b] These five events are also important with regard to the Cartagena Lagoon Refuge but are not repeated in table 11.

Table 10—Tree species planted at the Cabo Rojo and Laguna Cartagena National Wildlife Refuges, 1980–2003

Species	Trees planted by Refuge [a]			Assessment [b]	
	CR	LC	Total	Survival	Growth
	- - - - - - - - -	*no.*	- - - - - - - - -		
Acrocomia media O.F. Cook	10	5	15	P	MR
Amyris elemifera L. [c]	14	0	14	MR	MR
Andira inermis (W. Wright) DC.	15	146	161	G	G
Annona glabra L.	2	30	32	G	F
Annona muricata L.	2	2	4	MR	MR
Annona squamulosa L.	35	0	35	G	F
Avicennia germinans (L.) L.	40	0	40	P	P
Bourreria succulenta Jacq.	57	31	88	G	G
Bucida buceras L.	1,429	1,204	2,633	G	G
Bunchosia glandulosa (Cav.) L.C. Rich.	32	0	32	MR	MR
Bursera simaruba (L.) Sarg.	710	488	1,198	G	G
Calophyllum calaba Jacq.	4	0	4	P	MR
Capparis cyanophallophora L. [c]	6	0	6	MR	MR
Capparis hastata Jacq.	4	0	4	MR	MR
Capparis indica (L.) Fawe. & Rendle	20	2	22	F	P
Cedrela odorata L.	32	6	38	F	F
Ceiba pentandra (L.) Gaertn.	20	164	184	G	G
Chamaesyce articulata (Aubl.) Britton	1	0	1	MR	MR
Citharexylum fruticosum L.	72	107	179	G	F
Clusia rosea Urban	2	1	3	MR	MR
Cnidoscolus aconitifolius (Mill.) I.M. Johnst.	6	0	6	MR	MR
Coccoloba diversifolia Jacq. [c]	12	0	12	MR	MR
Coccoloba uvifera (L.) L.	190	5	195	P	F
Cocos nucifera L.	13	69	82	P	MR
Colubrina arborescens (Mill.) Sarg.	57	18	75	G	G
Comocladia dodonaea (L.) Urban	2	0	2	MR	MR
Conocarpus erectus L.	190	0	190	F	F
Cordia alliodora (Ruiz & Pav.) Oken	12	0	12	MR	MR
Cordia collococca L.	9	67	76	G	F
Cordia sulcata DC.	62	92	154	G	G
Cresentia cujete L.	25	39	64	G	F
Cresentia portoricensis Britton	5	15	20	F	F
Crossopetallum rhacoma Crantz [c]	12	0	12	MR	MR
Erythoxylum areolatum L.	91	7	98	G	G
Erythroxylum rotundifolium Lunan [c]	10	0	10	MR	MR
Eugenia ligustrina (Sw.) Willd.	3	0	3	MR	MR
Eugenia woodburyana Alain	2	0	2	P	P
Ficus benjamina L.	4	0	4	MR	MR
Ficus citrifolia Mill.	57	107	164	P	P
Guaiacum officinale L.	312	159	471	G	P
Guaiacum sanctum L. [c]	14	0	14	MR	MR
Guazuma ulmifolia Lam.	25	63	88	G	G
Gymnanthes lucida Sw. [c]	14	0	14	MR	MR
Helicteres jamaicensis Jacq.	8	0	8	G	F
Hymenea courbaril L.	10	8	18	P	P
Inga fagifolia (L.) Willd.	2	0	2	MR	MR
Jaquina arborea Vahl	41	20	61	P	P
Mangifera indica L.	2	0	2	MR	MR

continued

Table 10—Tree species planted at the Cabo Rojo and Laguna Cartagena National Wildlife Refuges, 1980–2003 (continued)

Species	Trees planted by Refuge [a]			Assessment [b]	
	CR	LC	Total	Survival	Growth
	- - - - - - - - -	*no.*	- - - - - - - - -		
Manilkara bidentata (A. DC.) Chev.	0	13	13	MR	MR
Masticodendron foetidissimum (Jacq. Crong.	6	39	45	F	F
Melococcus bijugatus Jacq.	11	5	16	MR	MR
Metopium toxiferum (L.) Krug & Urban	3	0	3	MR	MR
Petitia domingensis Jacq.	5	0	5	MR	MR
Pimenta racemosa (Mill.) J.W. Moore	2	0	2	MR	MR
Piscidia carthagenesis Jacq.	4	0	4	MR	MR
Pisonia albida (Heimer) Britton	24	1	25	MR	MR
Pisonia subcordata Sw.	5	36	41	MR	MR
Samanea saman (Willd.) Merrill	21	23	44	G	G
Polygala cowellii (Britton) Blake	78	14	92	P	F
Pterocarpus officinalis Jacq.	0	13	13	MR	MR
Randia aculeata L.	3	1	4	MR	MR
Reynosia uncinata Urban [c]	4	0	4	MR	MR
Roystonea borinquena O.F. Cook	2	9	11	P	P
Sabal casuarium (O.F. Cook) Beccari	4	0	4	MR	MR
Sapindus saponaria L.	0	21	21	F	F
Senna polyphylla (Jacq.) Irwin & Barneby	24	0	24	G	F
Spondias mombin L.	28	48	76	G	F
Stahlia monosperma (Tul.) Urban	330	368	698	G	F
Sterculia apetala (Jacq.) Karst.	11	0	11	MR	MR
Swietenia mahogani Jacq.	716	0	716	G	G
Tabebuia heterophylla (DC.) Britton	128	147	275	G	F
Tamarindus indica L.	10	9	19	G	F
Terminalia catappa L.	4	0	4	MR	MR
Thespesia populea (L.) Soland	150	25	175	P	MR
Trichilia hirta L.	47	37	84	G	G
Trichilia tricantha Urban	4	0	4	P	MR
Zanthoxylum flavum Vahl	73	36	109	P	MR
Ziziphus reticulata (Vahl.) DC.	3	0	3	MR	MR
Total	3,700	5,397	9,097		

[a] Refuges: CR = Cabo Rojo; LC = Laguna Cartagena.

[b] Tentative assessment—Survival and growth: G = good; F = fair; P = poor; MR = more research is needed.

[c] Tree species planted in research plot near airstrip by Sandra Molina.

about 17,500 trees, 88 percent of which were on the Headquarters and Lagoon tracts (Weaver and Schwagerl 2008) (fig. 10). At an average spacing of 5 by 5 m, i.e., 400 trees/ha, the original plantings were designed to cover about 44 ha.

Five species—*Bucida buceras*, *Bursera simaruba*, *Guaiacum officinale*, *Stahlia monosperma*, and *Swietenia mahagoni*—represented 63 percent of the plantings. Survival and growth rates for all of the species were assessed recently (table 10). Growth in diameter and height showed that *Bucida buceras*, *Ceiba pentandra*, and *Guazuma ulmifolia* performed best among native species, and *Swietenia mahagoni* among the exotics. Survival was rated as good for 25 species, 12 of which also had good growth rates. Another six species had fair survival rates. The plantings showed that a concerted effort using available resources can be successful if fire protection is provided. The plantings also proved that several tree species perform satisfactorily and may be used in habitat restoration.

Puerto Rico's dry forest refuges are critical nesting and foraging habitat for native and migratory birds. In the past, dry forests were widespread, not only on the island but throughout the neotropics. Today, major efforts are being made in some countries like

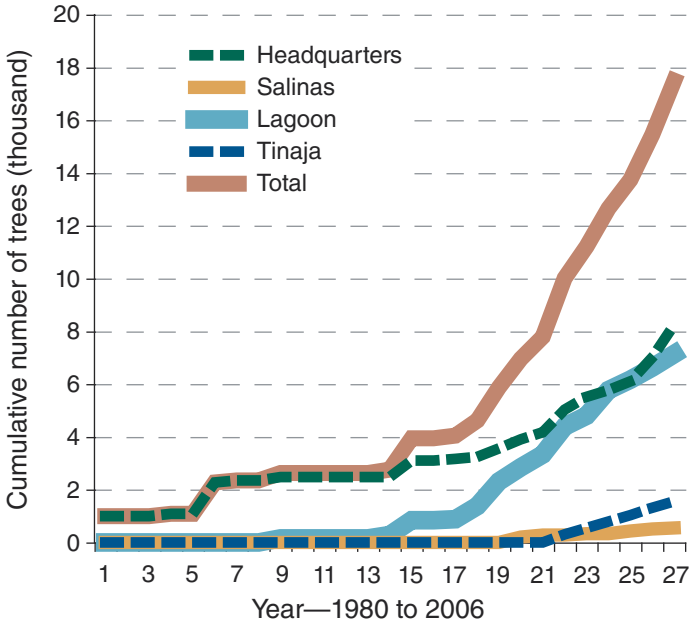


Figure 10—Tree plantings by refuge tract and year since 1980.

Habitat restoration. Several tree species were tested in the continuing effort to reforest abandoned agricultural land surrounding the Cartagena Lagoon. (U.S. Fish & Wildlife Service photo)

Research on survival and growth. A sapling of Andira inermis *(W. Wright) HBK (moca) is measured for growth at the Laguna Cartagena National Wildlife Refuge. The early survival and growth of most planted species were assessed recently.* (Photo by Peter L. Weaver)

Costa Rica to restore wildlife habitat (Janzen 1988b). Research has shown that some species of woody plants regenerate satisfactorily under tree plantings. By comparison, recruitment of woody plants into pasture lands is slow because grasses compete for water and nutrients, or because recurrent fires inhibit woody growth (Guariguata and others 1995). Patterns of understory regeneration vary with overstory tree species, their densities, and their management.

Complete recovery of dry forest from past disturbance takes considerable time and involves biomass accumulation, the development of a mature forest structure, and regrowth of a typical species composition. In southwestern Puerto Rico, the recovery of plant biomass, regardless of species, may take 50 years or more. Recovery of mature structure, i.e., a mixture of small and large diameters of native and exotic species, could take 200 years or more. Finally, recovery of biomass and structure along with a species composition similar to that at the time of the island's discovery, i.e., typical species-site relationships, could easily take one-half of a millennium or more (Weaver and Schwagerl 2005). At that time, shade-tolerant exotic trees are likely to persist. Moreover, unknowns such as climatic change could impose other ecosystem changes. A sustained reforestation effort using native tree species should accelerate natural succession through its effects on vegetative structure, microclimate, and soils (Parrotta 1993).

Cartagena Lagoon

The Cartagena Lagoon was originally an open, freshwater wetland with a short hydroperiod, and without a permanent inlet or outlet (Schaffner 1994, see endnotes). The bottom of the lagoon, consisting of dense alluvial clay, trapped local rainfall, sheet flow, and ephemeral streamflow to accumulate water during the wet season. Shallow, open water, occupying most of the lagoon, provided foraging habitat for resident and migrant waterfowl and the surrounding emergent vegetation was used for nesting by resident aquatic birds. The gradual decline in water levels associated with the dry season extended foraging opportunities for wading species.

Agricultural development during the late 19th century and throughout most of the 20th century negatively impacted the Cartagena Lagoon (table 11). In the late 1800s, farming intensified in and around the Lajas Valley when forest cover was gradually replaced by sugar cane plantations. Both infiltration of rainwater into the soil and runoff were influenced. About 1920, the farmers began pumping the lagoon to irrigate surrounding lands, reducing the lagoon's dry season water levels. Early ornithologists expressed concern over the potential impacts of water removal on the lagoon's avifauna (Danforth 1926). In the 1950s, the completion of the Lajas Valley irrigation project (Koenig 1953) left Cartagena Lagoon as the only body of fresh water in the valley. In 1955, a proposal for draining the lagoon was opposed by government officials in Puerto Rico and the United States. In the late 1950s, widespread recognition of wildlife values associated with the lagoon resulted in a recommendation that it be expropriated. At that time, landowners and renters had constructed dikes and drainage canals to further lower water levels.

In 1961, the Margara Canal was completed to conduct unused irrigation water from the north and to maintain lagoon water levels. Drainage water from sugar cane fields, however, aggravated eutrophication; and the relatively static water levels promoted the encroachment of water lettuce, water hyacinths, and cattails into open water. Moreover, the stable water levels and fertilized runoff from cane fields caused the gradual formation of a thick, floating peat mat (Ramírez Toro and Minnigh 1997, see endnotes). In the early 1980s, avifauna abundance and diversity were notably less than in earlier years. In 1982, the lagoon dried out completely.

In 1989, the lagoon was finally established as a wildlife refuge; however, maintenance of the Margara Canal and drainage canals was discontinued by the local government, causing aquatic vegetation to proliferate. In the early 1990s, the water control structure was repaired and the floating peat mat was discovered. The peat mat, along with the lack of canal maintenance, contributed to greater flooding in Magüayo. The mat, by virtue of its volume, increased the margin of the lagoon during rainfall

Table 11—Chronology of activities that influenced the Laguna Cartagena National Wildlife Refuge (Lagoon and Tinaja tracts) [a]

Date	Events and activities
1493	Columbus lands in southwestern Puerto Rico; lagoon functions naturally, receiving water by overland flow and from small, intermittent streams (arroyos) during heavy rains; avifuna abounds in diversity and numbers
Late 1800s – early 1900s	Farming begins in Lajas Valley; trees are cut for housing, agriculture, and fuel; water regimen changes, possibly at first by accentuating wet season runoff and gradually diminishing water levels during the dry season; the Lajas Valley becomes privately owned farms
1920s	Local farmers begin pumping Cartagena Lagoon to irrigate sugar cane; dry season water levels diminish; Danforth investigates bird species at Cartagena Lagoon and initiates a Christmas bird count; Gleason and Cook describe the vegetation in the Lajas Valley and around the lagoons at Cartagena and Guánica
1945	Quebrada Los Llanos diverts water toward Cartagena Lagoon
1950s	Lajas Valley irrigation system is built (Lago Loco at Río Loco dam is constructed to supply water to the Lajas Valley; the Laguna Anegada and Laguna Guánica are drained to reclaim land for cultivation); a drainage canal runs through the Cartagena Lagoon to the Bahía de Boquerón; Cartagena remains as only fresh water lagoon in the Lajas Valley, resulting in additional hunting pressures on its wildlife
Mid–1955	Proposed drainage of Cartagena Lagoon is opposed by the governor of Puerto Rico and the U.S. Secretary of the Department of the Interior
1956	McCandless revives the Audubon Christmas count between Cartagena Lagoon and Los Morrillos de Cabo Rojo; a new water control structure is built at Cartagena Lagoon and continuous pumping drastically reduces lagoon area; water levels remain relatively constant except for major rainfall events
1958-59	Importance of Cartagena Lagoon's wildlife, scientific, economic, sport (hunting), tourism, and recreation values is recognized and expropriation is recommended; land owners and renters construct dikes and drainage canals lowering the water levels in the lagoon
Late 1950s	Federal aid project establishes aquatic vegetation (water lettuce, water hyacinth, and cattails); water extraction continues to reduce the lagoon size creating more land to irrigate for sugar cane production
1960s	Drainage water from sugar cane fields aggravates eutrophication (i.e. fertilizers, pesticides, and sediment); untreated sewage enters from town of Magüayo along the refuge's eastern border; plant associations change; relatively static water levels promote the growth of water lettuce, water hyacinths, and cattails into open water areas; bird species decline in the lagoon
1961	Magara Canal is completed to conduct unused irrigation water from the north to maintain lagoon water levels; vandalism of the water control structure prevents filling the lagoon to the proposed target level of 11 m
1979	Department of Natural Resources recognizes the Cartagena Lagoon as a critical wildlife habitat
Early 1980s	Avifauna diversity and abundance is significantly less than in earlier years; Magüayo expands northward to the Magara Canal
1982+	Lagoon dries up and the pumping of irrigation water stops; growth and annual burning of cattails results in accumulation of cattail biomass into a floating mat
1983	The Department of Natural Resources requests the U.S. Congress to acquire Cartagena Lagoon; the Puerto Rico Land Administration receives Cartagena Lagoon and surrounding properties
1989	Cartagena Lagoon is established as a wildlife refuge through lease agreement with the Land Administration; maintenance of Margara and drainage canals terminates, inhibiting the drainage of canal waters; aquatic vegetation develops in the canals; heavy rainfalls cause the overflow of canals, saturating adjacent soils and increasing flood events in Magüayo

continued

Table 11—Chronology of activities that influenced the Laguna Cartagena National Wildlife Refuge (Lagoon and Tinaja tracts)[a] (continued)

Date	Events and activities
1990	The Puerto Rico Planning Board designates the Cartagena Lagoon National Wildlife Refuge as a Natural Reserve
Early 1990s	Water control structure is repaired and the floating peat mat is discovered
1993	Water quality studies are initiated by Interamerican University, San German; observations show that nutrients leaving the lagoon are greater than the amounts entering; sugar cane harvest terminates around Cartagena Lagoon
1994	Worst drought in several decades causes the lagoon to dry up
1996	The Tinaja tract is acquired as part of the Laguna Cartagena Refuge with fee title from the U.S. Department of Agriculture Farm Service; Proctor prepares the first plant list for the Tinaja tract
1997+	Grazing and fire are eliminated from the Tinaja tract; reforestation begins on the Lagoon and Tinaja tracts
2005	The observation tower is built at Cartagena Lagoon

[a] Sources: Danforth (1926); Díaz-Soltero (1990); Gleason and Cook (1927); Proctor (1996), see endnotes; Ramírez Padilla (1985); Schaffner (1994), see endnotes; Toro McCown and Chabert (1986).

Cartagena Lagoon. The lagoon, with ample water, supports an uncommon burst of flowering Eichornea crassipes *(Mart.) Solms.-Laub. (water hyacinths).* (Photo by Peter L. Weaver)

events, and hampered water flow through the lagoon. The intent of the water control structure was to gain control over water levels and reestablish the lagoon's historic hydroperiod. Fluctuations in water level would purportedly result in the characteristic species changes along the margin of the lagoon and benefit the wildlife.

In 1990, a comprehensive management plan was prepared for the Cartagena Lagoon with information on its flora and fauna as well as suggested monitoring and research activities (Díaz-Soltero 1990). In 1994, the lagoon dried out again during the island's worst drought in decades.

In 1996, the Tinaja tract was added to the Laguna Cartagena NWR. For several years, the lower part of the tract had been managed for livestock grazing, which included recurrent burning. Fencing around the tract was repaired and grazing eliminated. In 2000, the lagoon entered the new millennium in a degraded condition, suffering from a century of problems, and replete with a legacy of efforts to successfully mitigate them. However, surveys conducted in 1998 and 2003 showed that woody vegetation had increased in the absence of fire and grazing (Weaver and Chinea 2003; Weaver and Schwagerl 2004, 2005). Finally, an unpolluted source of fresh water was again available to the lagoon.

Structures and Improvements

The major human improvements at the Cabo Rojo and Laguna Cartagena NWRs consist of the development of various types of buildings, roads, trails, towers, water control structures, security measures, and commercial salt ponds (table 12),

Table 12—Structures and improvements at the Cabo Rojo and Laguna Cartagena National Wildlife Refuges [a]

	Cabo Rojo		Laguna Cartagena	
Structures or improvements	Headquarters	Salinas	Lagoon	Tinaja
Buidlings and related facilities				
Office and visitors center (m^2)	1935			
Shop building (m^2)	595			
Guard house (m^2)	9			
Microwave building and pole (m^2)	21			
Oil building (m^2)	6			
Refuge workshop (m^2)	186			
Tree shade houses–nursery (m^2)	160			
Museum complex (m^2)		209		
Museum parking (m^2)		17		
Other [b]	NA			
Improvements—visitors				
Observation towers (no.)		1	1	
Information kiosk (no.)	1			
Signs (information) (no.)	5		1	
Interpretative trail (km)	2.3			
Cactus garden (ha)	0.1			
Farmhouse (no.)	1			
Silo (no.)	1			
Ruins (no.)	5			
Structures—water				
Canals or drainages (km)	5.6		3.5	
Water level controls (no.)		2	3	
Wells (no.) [c]	4		5	
Watering troughs (no.)	2			1
Impoundments (no.)	4			1
Access roads				
Paved roads—entrance (km)	1.2			
Dirt roads (km) [d]	24.6	3.2	3.1	2.4
Security				
Boundary fencing (km)	17.7	11.5	7.1	4.5
Gates (no.)	2	2	2	1
Firebreaks (km)	6.5	1.9	14.8	
Commercial activities				
Salt ponds (no.)		2		

[a] Cabo Rojo (Headquarters and Salinas tracts); Laguna Cartagena (Lagoon and Tinaja tracts).
[b] Septic tank, water lines, sewer lines, transformers, electrical lines, and telephone lines at Cabo Rojo headquarters site.
[c] At Cabo Rojo, one for irrigation and three out of service; at Laguna Cartagena, one for observation, one for irrigation, and three out of service.
[d] Only 1 km of dirt road is being maintained at Tinaja.

along with the planting of trees. The Headquarters tract includes an office building with a visitor's reception area and interpretative displays, a workshop, a tree nursery, four wells, an old farm house and silo used today for volunteers, and cattle watering troughs scattered throughout the property. Improvements include a 0.1-ha cactus garden, 1.2 km of paved roads, 25 km of dirt roads, and 6.5 km of firebreaks. The property also has a security gate and is surrounded by 17.7 km of fencing.

Nursery production. The small headquarters nursery regularly produces seedlings for planting. Between 1980 and 2001, more than 9,000 trees representing 78 species were planted on the Cabo Rojo and Laguna Cartagena National Wildlife Refuges. (Photo by Peter L. Weaver)

The Salinas tract has a small visitor information center, salt ponds, an 8-m high observation tower overlooking the salt operations, the foundation of an old windmill, a short birdwatchers trail, culverts, and an unimproved road on top of a dike leading to the fishermen's facility. This facility is a 2.5 -ha enclosure with a building that contains equipment for the storage of fish and fish products by the municipality's fishermen (Departamento de Agricultura 1995, see endnotes). Since 1981, the Commonwealth Department of Agriculture has rented the property and structure to the Municipality of Cabo Rojo for a nominal sum. In addition, there are at least 3.2 km of dirt roads and 1.9 km of firebreaks. A portion of the property along PR Route 301 is fenced.

The major structures at the Lagoon tract are the lagoon water control structures, 3.5 km of canals, five wells, scattered cattle watering troughs, and a 7-m observation tower overlooking the lagoon. In addition, there are 3.1 km of dirt roads and 14.8 km of firebreaks. About 7.1 km of fencing surround the property. The only structure on the Tinaja tract is a watering trough. In addition, there are 2.4 km of dirt roads and 4.5 km of fencing surrounding the property. Descriptive information regarding all wells in the Lajas Valley, including those found on the refuges, was compiled and published by the U.S. Geological Survey (Graves 1991).

Collaborative Activities

The Coastal Zone Management Program (PMZCPR in Spanish) was established in Puerto Rico by virtue of the 1978 Federal Coastal Zone Management Law (Departamento de Recursos Naturales y Ambientales 1997, 2000b). Special planning areas were designated by the Puerto Rican Government to protect the island's natural, historic, cultural, and archaeological resources. These special areas include Boquerón, Parguera, and Guánica along Puerto Rico's southwest coast. The Boquerón sector of the Southwest Special Planning Area (SBAPES in Spanish) covers the area from Punta Pitahaya to PR Route 101, north of Punta Guaniquilla, and encompasses the Cabo Rojo NWR and borders the Laguna Cartagena NWR. In carrying out its mission, the F&WS cooperates with the Puerto Rico Planning Board, the Puerto Rico Department of Natural and Environmental Resources, and the Puerto Rico Department of Public Works.

In 1993, an interagency committee was formed among Federal and Puerto Rican Agencies with responsibility or authority for the Cartagena Lagoon. Since the F&WS was responsible for land management and leasing the lagoon from the Puerto Rico Land Authority, both were represented. Other entities included were:

- Federal—the Army Corps of Engineers, the U.S. Department of Agriculture, the Natural Resources Conservation Service, and the U.S. Environmental Protection Agency
- Puerto Rico—the Department of Natural and Environmental Resources and the Energy Authority

- Center for Education, Conservation and Environmental Interpretation (Centro para Educación y Interpretación Ambiental, or CECIA in Spanish) of Interamerican University at San German

A work plan was devised with short- and long-term goals including habitat restoration, the installation of a water control structure, and the mitigation of floods in the town of Magüayo. The Puerto Rico Conservation Foundation (Fundación Puertorriqueña de Conservación in Spanish), the Department of Natural Resources and the Environment, and the Autoridad de Carreteras assisted in generating public support for the acquisition of the Salinas tract.

In addition to the aforementioned groups, the F&WS cooperates with several other Commonwealth and Federal Government Agencies, and with numerous universities in Puerto Rico and elsewhere, including:

- U.S. Department of Agriculture Forest Service, International Institute of Tropical Forestry
- U.S. Department of Agriculture Natural Resources Conservation Service
- U.S. Geological Service, Biological Resources Division
- Conservation Trust of Puerto Rico
- Puerto Rico Department of Agriculture
- Puerto Rican Rural Development Corporation
- Puerto Rican Ornithological Society
- Pontifical Catholic University of Puerto Rico in Ponce
- Metropolitan University
- University of Puerto Rico
- McMaster University in Hamilton, Ontario, Canada
- Plymouth State University in New Hampshire
- University of Missouri in Columbia

The F&WS also works closely with the local nongovernmental organization called the Cabo Rojo Residents for Environmental Health (Cabo Rojeños Pro Salud Ambiente in Spanish), which is a refuge friend's group. Another important aspect of collaborative activities concerns the residents of the nearby community of Magüayo, since fires originating in that vicinity have burned refuge lands on several occasions. A recent survey showed that residents had little appreciation of the environmental values associated with the refuge and that the majority had not participated in environmental programs or restoration efforts (Ruiz and Huertas 2005, see endnotes). Linking benefits to the community with conservation efforts might stimulate local interest and participation.

Public Use of Refuges

Visitors

During 2005, the Cabo Rojo NWR received 135,400 visitors, mainly at beach sites, and 11,200 visitors at the Headquarters Visitors Center. Another 8,000 persons in 90 groups visited the Cabo Rojo Interpretative Center on the Salinas tract. About 1,000 people visited Cartagena Lagoon. (U.S. Fish and Wildlife Service 2005, see endnotes). Fishing, but not hunting, is allowed on the refuges. However, fishing is considered poor and no records are kept. Other activities at both refuges included:

- 1,050 visitors for wildlife observations, including 920 that used foot trails
- 200 visitors for photography, including 45 that used photo blinds

Visitors to refuges. The refuges receive nearly 150,000 visitors each year, about 90 percent for a day on the beach. The remainder, like these Boy Scouts, visit for a hike and birdwatching at either the Headquarters tract or Laguna Cartagena. (Photo by Ken Foote)

- 2,370 participants in environmental education programs, including 38 teachers in programs held onsite and offsite, and 2,264 students in programs held onsite and offsite
- 4,890 participants in interpretative programs, including 2,330 held onsite and 1,560 held offsite

Residents and tourists are encouraged to visit the refuges through available brochures and books (Nellis 1999, Raffaele 1983, U.S. Fish and Wildlife Service 2004).

Special Use Permits

A total of 174 special use permits have been granted for activities at the Cabo Rojo and Laguna Cartagena NWRs since 1979–97 at the Cabo Rojo Headquarters tract, 11 at the Salinas tract, 64 at the Lagoon tract, and 2 at the Tinaja tract (table 13). Two permits were issued during the 1970s, 15 in the 1980s, 116 in the 1990s, and 41 since 2000. Of the total, 2 involved structures, i.e., removal of antennae cables and anchors, and building culverts and water diversion devices; and 70 were administrative in nature dealing with various topics, i.e., release of floodwaters on refuge property, tick eradication, testing broadcast signals from South American stations, cutting forage for animals (silage), salt extraction operations, grazing to reduce grass cover or sugar cane, and maintenance of vegetation along the roadsides and in irrigation canals or drainages. The remaining 100 use permits dealt with 42 studies on various topics, some renewed at later dates, i.e., climate, botany and botanical collections, vegetation monitoring, native and exotic vertebrate wildlife species, invertebrates, wildlife monitoring, photography, and water sampling.

The F&WS has sponsored studies, research projects, and educational programs with universities and government agencies through grants and cooperative agreements for several years. Most of the cooperating students and professors are from universities in Puerto Rico, Canada, and the United States. The topics of many studies are summarized in the list of special use permits (table 13). Study plans or proposals and final reports or publications are required for F&WS records.

Among the formal activities of the F&WS are those related to planning for bird conservation (Núñez-García and Hunter 2000) and biological reviews (U.S. Fish and Wildlife Service 2002) where various research and monitoring needs are indicated. Christmas counts have also been carried out for several years. Among the less formal research activities are recurrent bird surveys, which include tallies of bird species and estimates of their numbers.

Other Major Protected Areas in the Southwest

Six other major protected areas are situated in southwestern Puerto Rico, in addition to the F&WS refuges of Cabo Rojo and Laguna Cartagena. They are (Department of Natural Resources 1979, Ventosas-Febles and others 2005) (fig. 1):

- Boquerón Commonwealth Forest
- Boquerón Wildlife Refuge
- Guánica Commonwealth Forest
- Los Morrillos de Cabo Rojo
- Parguera Natural Reserve
- Punta Guaniquilla Natural Reserve

Boquerón Commonwealth Forest

The Boquerón Commonwealth Forest is partitioned into three major areas: (1) an area along the west coast near Punta Guaniquilla extending southeast to Laguna Rincón, (2) a patch along the eastern edge of Bahía Sucia, and (3) an extensive area ranging from Punta Pitahaya east to Parguera (Department of Natural Resources 1976). The forest occupies 1876 ha between sea level and 5 m in elevation (table 1). Most of the area is classified as tidal swamp and tidal flats (Carter 1965). The major types of wildlife habitat in the Boquerón Forest are islets, mangroves and mudflats, salinas, and coastal lowlands. The main cover types are basin and fringe mangroves, beach thicket, salt flat vegetation, and scrub woodland (Cintrón and others 1978).

Mangrove roots provide habitat for invertebrates and algae, and offer protection for numerous species of juvenile fish (Austin 1971). Also, regardless of salinity or temperature, several species of fish, including *Centropomus* spp., *Mugil* spp., *Tylosurus crocodilus*, *Gerres ciriereus*, and *Diapterus plumieri* frequent mangrove systems. During the 1970s, the social and foraging behavior of 18 species of warblers (Parulidae) was studied on 2 offshore islands—

Table 13—Special use permits for the Cabo Rojo and Laguna Cartagena National Wildlife Refuges

Permit topics	Decades [a]			
	1970s	1980s	1990s	2000+
	number of permits			
Cabo Rojo—Headquarters tract				
Flood waters: release on refuge lands	1			
Solar radiation: measurement	1	2		
Climate: study before installation of areostat radar system		1		
Botanical specimens: collect and examine		1		
Broadcast antenna: remove cables and anchors		1		
Ticks: administer U.S. Department of Agriculture eradiction program		1		
Cattle ticks: study basic ecology and longevity under field conditions		1		
Broadcast signals: investigate levels from South American stations		3		
Herpestes auropunctatus (mongoose): field test oral vaccine for rabies; determine age and sex		1		
Herpestes auropunctatus (mongoose): live trap and implant microchips for tracking		1	2	
Hay: cut and remove for livestock feed and silage		2	22	3
Panicum maximum (Guinea grass): determine the impact of cattle grazing			1	
Vegetation: conduct surveys and collect specimens except endangered species			1	
Feral primates: collect data on ecology, distribution, and behavior			3	
Grass: cut by hand and remove as feed for domestic animals			3	
Dendroica discolor (prairie warbler) and *Parula americana* (northern parula): investigate the use of several habitats			4	
Bird nesting: study reproductive success of nesting birds, notably exotic finches			2	
Vegetation: collect samples for analysis of habitat and nest site selection by birds			2	
Dry forest: study floristic composition of forest fragments			1	
Bird species: survey distribution, abundance, and habitats using point counts			2	
Molothrus bonariensis (shiny cowbirds): use radio transmitter to determine longevity			2	
Shaerodactylus nicholsi (Nichol's dwarf gecko): study			3	
Bats: use mist nets to determine species composition and abundance			1	
Polygala cowellii (violet-tree): study pollination and population ecology			2	
Myiarchus antillarum (Puerto Rican flycatcher): study breeding biology and foraging ecology			1	
Myiarchus antillarum (Puerto Rican flycatcher) and *Icterus dominicensis* (Greater Antillian oriole): nesting and breeding season observations			1	
Monitor: Neotropical migrant and resident landbirds			1	
Prosopis juliflora (mesquite) and *Bucida buceras* (oxhorn bucida) trees: cut mesquite to release planted oxhorn bucida			2	
Seiurus motacilla (Louisiana water thrush) and *S. noveboracensis* (northern water thrush): determine if species are limited by available habitat in Puerto Rico			4	
Bursera simaruba (gumbo-limbo) and *Hymanea courbaril* (West-Indian-locust) trees: collect leaf and seed samples for study of gene flow among forest fragments			1	2
Crotophaga ani (smooth-billed ani): tracking, banding, blood samples			3	1
Aristida chaseae (endemic grass): life history and competition with other grasses			2	1
Native tree species: develop protocol for seed germination for use at refuges			2	1
Falco sparverius (American kestrel): capture for genetic analyses				1
Refuge: site sampling to determine bacterial mats, diatoms, and cilates				1
Aristida chaseae (endemic grass): collect samples				1
Seeds: collect in traps under crowns of native and exotic trees and identify				2
Subtotal	2	14	68	13

continued

Table 13—Special use permits for the Cabo Rojo and Laguna Cartagena National Wildlife Refuges (continued)

Permit topics	Decades[a] 1970s	1980s	1990s	2000+
		number of permits		
Cabo Rojo—Salinas tract				
Structures: install culverts and water diversion devices		1		
Artemia franciscana (brine shrimp): ultraviolet B radiation as factor in reproduction				1
Birds: blood samples and banding				1
Photography: series of photos of habitat and species				1
Migratory shorebirds: identify factors that affect their distribution and density				1
Salt extraction: operations				3
Vegetation: maintain roadside plants				3
Subtotal		1		10
Laguna Cartagena—Lagoon tract				
Water: sample and determine basidiomycete and ascomycete fungi			1	
Panicum maximum (Guinea grass): use grazing to help control growth			7	
Vegetation: survey and collect specimens except endangered species			2	
Sugar cane: eliminate by cattle grazing			1	
Grass: cut and remove for livestock			10	
Canals: provide access to existing irrigation and drainage structures			2	
Feral primates: collect data on ecology, distribution, and behavior			3	
Dendroica discolor (prairie warbler) and *Parula americana* (northern parula): investigate the use of several habitats			2	
Bird nesting: study reproductive success of nesting birds, notably exotic finches			2	
Vegetation: collect samples for analysis of habitat and nest site selection by birds			2	
Monitor: Neotropical migrant and resident landbirds			1	
Bursera simaruba (gumbo-limbo) and *Hymanea courbaril* (West-Indian-locust) trees: collect leaf and seed samples for study of gene flow among forest fragments			1	
Myiarchus antillarum (Puerto Rican flycatcher) and *Icterus dominicensis* (Greater Antillian oriole): nesting and breeding season observations			1	
Crotophaga ani (smooth-billed ani): tracking, blood samples and banding			3	1
Hay: cut and remove for silage			8	1
Gastropods and bivalves: collection and identification			1	1
Water: collect samples for determination of ionic composition and salinity				1
Grazing: livestock forage				13
Subtotal			47	17
Laguna Cartagena—Tinaja tract				
Vegetation: survey and collect specimens except endangered species			1	1
Total	2	15	116	41

[a] Permits first granted in 1979.

Guayacán of 35 ha and Cueva of 20 ha—within the Boquerón Forest (Post 1978). Population densities were high and the birds usually forged alone or in stationary (passive) flocks. The stationary flocks were usually composed of birds that had gathered to consume insects foraging in different patches of vegetation. Aggressive behavior occurred frequently and was common among the same species or those with similar foraging behavior

Despite their known importance as critical habitat for fish and bird species, pressures continue for the development of mangrove areas as recreation and tourism sites. The 1976 master plan for Commonwealth forests outlines issues and recommendations concerning wildlife protection and potential uses (Department of Natural Resources 1976). The master plan also states that the Boquerón Forest never had a management plan; however, as long ago as 1875, the "Inspección de Montes" (a forestry agency under Spanish authority) attempted to manage the annual harvest of bark and fuelwood in the Boquerón mangrove (Dominguez Cristóbal 2000, 2001).

Official seal of Spanish foresters

Official seal of Puerto Rican foresters used for correspondence, 1875-1889

Boquerón Commonwealth Forest. The Boquerón Forest has a long history of human activity. As early as 1875, the local forestry agency (Inspección de Montes) attempted to control the annual removal of bark and fuelwood from these mangrove woodlands. (Photo by Peter L. Weaver)

Boquerón Wildlife Refuge

During the 1950s, both Ciénaga El Anegado (about 780 ha) and Laguna Guánica (about 450 ha) were drained as part of the Lajas Valley irrigation project; earlier observations noted at least 24 bird species in the vicinity (Beatty 1931, Bonnett and Tirado 1950). In addition, the project resulted in serious deterioration of the Cartagena Lagoon. In 1964, the Puerto Rico Department of Agriculture designated 182 ha of the Boquerón Forest as the Boquerón Wildlife Refuge to protect the flora and fauna, including mangroves, sea-grass beds, and pelicans (Cruz Alonso 1997, Departamento de Recursos Naturales 1982). Laguna Rincón is in the western part of the refuge (Burger and others 1992) (fig. 1). The lagoon occupies 74 ha and connects with Bahía Boquerón via a canal that is 0.2 km long and 0.75 m deep (Negrón González 1986). About 40 percent of the refuge is comprised of three mangrove species: (1) *Avicennia germinans*, (2) *Laguncularia racemosa*, and (3) *Rhizophora mangle*. Much of the remainder is occupied by water with submerged, emergent, and floating vegetation (Chabert and others 1982).

The Boquerón Wildlife Refuge includes a water impoundment that was built to help mitigate the loss of wetlands in the Lajas Valley a decade earlier (Chabert and others 1982). The impoundment measures 4 km in length and has six flood gates constructed along dikes to control water levels. The impounded wetland system is composed of a series of canals and small water bodies which are influenced by five sources of water, the first three being primary:

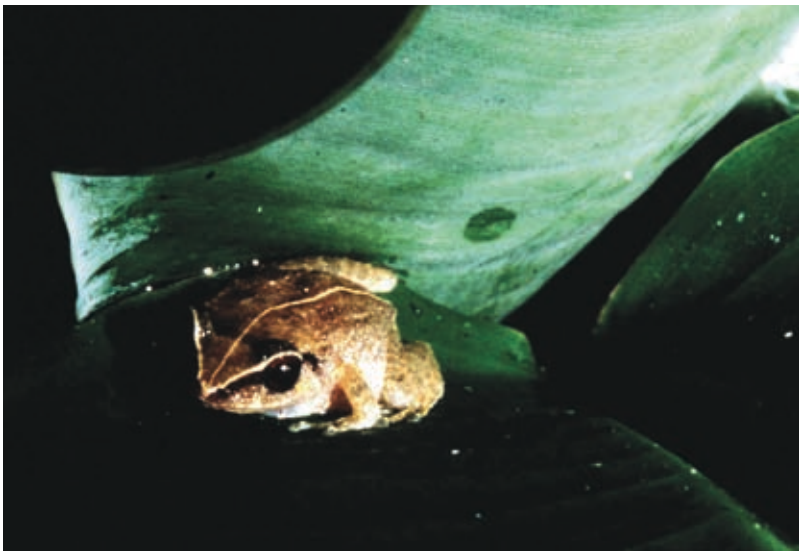
- The brackish Laguna Rincón (to the west), which varies in salinity according to rainfall
- The Lajas Valley irrigation canal (to the east), which drains the western part of Lajas Valley and provides the greatest portion of fresh water
- Direct rainfall captured during the wet season
- Quebrada Boquerón (to the north), which dilutes brackish water coming from Laguna Rincón
- Runoff from areas south of the refuge

The impoundment structures retain water in the lagoon, controlling salinity, and creating open areas for the avifauna. The refuge also has a boardwalk for recreational use.

Boquerón Wildlife Refuge. A boardwalk conducts visitors through mangrove forest. The refuge has 124 bird species in 30 families, 60 of which are seen regularly. (Photo by Peter L. Weaver)

Several surveys of the refuge disclosed 124 bird species in 30 families, about 60 of which are seen regularly (Chabert and others 1982) (table 6). Bird populations are greatest during the winter months when the refuge provides a rest area for migratory species from North America. The refuge also has a rookery of *Nyctcorax nyctcorax* (black-crowned night herons). Other surveys showed the presence of (table 5):

- Mammals—native *Noctilio leporinus*, and the introduced species *Herpestes auropunctatus* and *Ratus ratus*
- Amphibians—*Bufo marinus*, *Eleuterodactylus antillensis*, *Eleuterodactylus coqui*, and *Leptodactylus albilabris*
- Reptiles—*Ameiva exsul*; *Anolis cooki*, *Anolis cristatelis*, and *Anolis puchellus*; and *Trachemys stejnegeri*



Frog. Eleutherodactylus antillensis *(Puerto Rican red-eyed frog) is found at the Boquerón Wildlife Refuge.* (U.S. Fish and Wildlife Service photo)

Both of the exotic mammals negatively impact bird populations, often feeding on eggs. In contrast, the amphibians and reptiles constitute an important part of the diet of many birds.

The lagoon contains at least 35 different genera of phytoplankton; moreover, several species of fish occur there, the most abundant being *Tilapia mossambicus*, *Centropomus undecimalis*, *Mugil curema*, and *Caranx latus* (Negrón González 1986) (table 5). *Tilapia mossambicus*, an introduced species, is more common than native species which also include *Megalops altanticus* (Burger and others 1992). Currently, the refuge is managed for hunting and fishing. It also provides opportunities for outdoor education, recreation, tourism, and crab catching. Unfortunately, dumping of garbage in the vicinity has been a problem.

Guánica Commonwealth Forest

The Guánica Forest, lying 25 km east of Cabo Rojo along the south coast, occupies about 4016 ha (table 1, fig. 1). The forest was created in 1919 and was designated as a biosphere reserve in the United Nations Educational, Scientific and Cultural Organization—Man and the Biosphere Program in 1981 (Departamento de Recursos Naturales 1985). Guánica is a semideciduous coastal limestone forest that was cut in the past for agriculture, wood, and fuel. Today, much of the woody vegetation is dense and of small dimensions (Murphy and Lugo 1986b). Tree species with multiple stems are common, a condition that appears due to environmental stresses such as drought, wind-transported salt, and periodic hurricanes (Dunphy and others 2000).

Guánica, the best studied Subtropical Dry Forest on the island, supports nine vegetation types. Dry deciduous forest and dry forest with evergreen species account for 80 percent of the area (Dugger 1979, see endnotes). The remaining types include mangroves, natural salinas, beaches, rocky areas with cactus, thorn forest, plantations, and disturbed areas. Guánica receives about 800 to 900 mm/year of rain and has a mean annual temperature near 26 °C (Ewel and Whitmore 1973, Lugo and others 1978). Actual and pan evapotranspiration average about 700 and 2000 mm/year, respectively. Ravines and sinkholes have lower air temperatures and higher humidity, and may support plant assemblages different from the surrounding scrub vegetation (Farnsworth 1993). Extremely dry years rather than average years may be the most important factor controlling the forest structure and composition (Murphy and Lugo 1986a). Coppicing is common during succession and helps to hasten recovery.

The flora of Guánica contains at least 500 species of vascular plants, 19 endemic to Puerto Rico, in 85 families (Quevedo and others 1990). Bird species number more than 150 with 10 endemic to the island (Canals Mora 1990). Numerous caves provide habitat for five species of bats, one-third of the island's native mammals (Conde Costas and González 1990).

From 1922 to 1970, about 150,000 trees representing 9 species including 2 natives were planted on 150 ha in Guánica Forest (Wadsworth 1990). Guanica's low rainfall and recurrent droughts resulted in poor survival and slow growth for most species and indicated the importance of the dry forest for uses other than timber production. However, the introduced *Haematoxylon campechianum*, planted in 1924, showed 75 percent survival after

Guánica Forest. Continuous monitoring of resident and migratory birds has been carried out at Guánica since the 1970s. Guánica, the largest forest in Puerto Rico's reserve system, also has a visitor's center.
(Photo by Jorge Saliva)

18 years although growth was slow (Wadsworth 1943). Moreover, other exotics such as *Leucaena leucocephala* and *Swietenia mahagoni* appear to be permanent additions to the flora of the dry forest. Of the 167 tree species reported for the Guánica Forest, 23 were introduced (Chinea 1990). Of the introduced species, only eight showed some degree of success, three in forested conditions and five in the open.

Past measurements of tree diameters showed slow growth in comparison to wetter areas on the island (Anon. 1951, Wadsworth 1990, Weaver 1979). Forest studies were initiated in the 1970s and permanent plots were established during the 1980s; subsequently, information has been published on forest structure, biomass, and nutrient cycling (Lugo and Murphy 1986; Lugo and others 1978; Murphy and Lugo 1986b, 1990; Murphy and others 1995). It is probable that most of the plant studies and virtually all the avifaunal studies carried out at Guánica are applicable to much of the Subtropical Dry Forest region in the southwest, including the F&WS refuge sites.

Los Morrillos de Cabo Rojo Lighthouse

Cabo Rojo, the southwest tip of Puerto Rico, is a tombolo that is comprised of two separate limestone islands of Miocene and Oligocene age connected to each other and the mainland by sand bars (Kaye 1959, Monroe 1976, Weaver 1976). The 105-ha property is controlled by the Department of Natural Resources. The area around the lighthouse, previously under the U.S. Coast Guard, is currently managed by the Cabo Rojo municipality as part of SBAPES.

Wave-cut cliffs characterize the island units of the tombolo where the Cabo Rojo Lighthouse is located. The lighthouse, constructed in 1882 and recently restored as a museum and educational center, is recorded on the National Register of Historic Sites of the U.S. Department of the Interior (Departmento de Recursos Naturales y Ambientales 2000b). The lighthouse beam, which emanates from 37 m above sea level, is visible for nearly 25 km (Cerame Vivas 1988).

Los Morrillos de Cabo Rojo (Cabo Rojo Lighthouse area). A lone hiker ascends the trail to the Cabo Rojo Lighthouse. Built in 1882, the lighthouse casts a beam that is visible for nearly 25 km. (Photo by Peter L. Weaver)

The environmental impact statement developed for the lighthouse and surrounding areas contained the following details on flora and fauna (Municipio Autónomo de Cabo Rojo 1998):

- The highly impacted vegetation is secondary and contains at least 52 plant families with at least 147 species, 3 of which—*Bulbostylis pauciflora, Polygala hecatantha*, and *Waltheria calcicola*—are listed as critical.
- The avifauna is represented by 27 bird families with 52 species. Two species—*Agelaius xanthomus* and *Pelecanus occidentalis*—are listed as critical, and two others—Charadius alexandrinus and Sterna antillarum—are listed as critical and vulnerable (table 6).
- The herpetofauna is represented by seven lizards (two ameiva and five anoles), with *Anolis cooki* listed as critical and vulnerable (table 5).
- During the past several years two sea turtles—*Eretmochelys imbricata* and *Dermochelys coriacea*—have been recorded as using nearby beaches for nesting.

Parguera Natural Reserve

The Parguera Natural Reserve occupies 408 ha along the coast between the Boquerón and Guánica Forests (table 1, fig. 1). The reserve, managed by the Conservation Trust of Puerto Rico, contains numerous beaches, cays, salt flats, and islands dominated by mangroves, beach thicket, salt tolerant vegetation, and scrub woodland (Anon. 1982).

The fishing village of Parguera and surrounding areas were first brought to national attention through an article in National Geographic describing the "Bahía Fosforescente," which is situated a short distance to the east (Zahl 1960). Subsequently, the bioluminescent organisms in the bay were studied

Parguera Natural Reserve. The 408-ha reserve, managed by the Puerto Rican Conservation Trust, is situated near the fishing village of Parguera. Dry scrub forest, mangroves, and salt flats dominate the reserve. A bioluminiscent bay, numerous coral and fish species, scenic views, and opportunities for boating are available to tourists. (Photo by Joseph Schwagerl)

and plans devised for the protection of the area, including the watershed above the bay (National Park Service 1968, Seliger and others 1971). Floral and faunal surveys in and adjacent to the reserve reported (tables 1, 5, and 6):

- 184 species of plants, including the endemics *Cordia rickseckeri, Machaonia portoricensis, Rondeletia inermis, Thounia striata*, and *Wedelia lanceolata*; species listed as critical such as *Rochefortia acanthophora* and *Bulbostylis pauciflora*; and species listed as endemic and critical such as *Leptocerus quadricostatus* and *Psychilis krugii*
- 64 species of birds, including the endemics—*Caprimulgus noctitherus*, *Loxigilla portoricensis* (Puerto Rican bullfinch), *Todus mexicanus* (Puerto Rican tody), and *Vireo latimeri* (Puerto Rican vireo); the federally endangered *Pelicanus occidentalis*; the endangered endemic *Agelaius xanthomas*; and the rarely seen *Stercorarius pomarinus* (pomarine jaeger) five species of *herpetofauna* (one gecko, two ameivas, and two anoles); including the endemics *Sphaerodactylus nicholsi* and *Ameiva wetmorei*

Surveys for native mammals were unavailable in 1981 (Departamento de Recursos Naturales 1981). At that time, however, the bat *Noctilio leporinus* was considered a probable resident. Also, feral *Macaca mulatto*, long ago having escaped from Isla Magueyes, still occasionally roam the reserve.

Punta Guaniquilla Natural Reserve

Since 1976, the 170-ha Punta Guaniquilla Natural Reserve has been administered by the Conservation Trust of Puerto Rico. The property contains the remnants of Hacienda La Romana, a sugar producing estate built during the 1870s (Fuentes Santiago and Quevedo Bonilla 2002; Ramos y Ramírez de Arellano 1986, see endnotes). The ruins of the Hacienda including walls, a well and a cistern, are still evident today. Several archeological sites, probably Taino, have also been identified through historical records and verbal accounts.

The reserve extends from sea level to 46 m in elevation at Cerro Guaniquilla. There are two cave systems in limestone of Cretaceous age, one reputed to have contained petroglyphs in the past (Monroe 1976; Ramos y Ramírez de Arellano 1986, see endnotes). The other, erroneously associated by the public with the death of the famous Cabo Rojo pirate, Roberto Cofresí (1791–1825), has dozens of tunnels. Actually, it was Cofresí's nephew, Antonio Cofresí, an interpreter in the Port of Mayagüez, who died in the cave.

The land contains upland and wetland habitats with seven major vegetation types (Quevedo Bonilla 2000, Vázquez 1997, Vázquez and Kolterman 1998):

- Pasture—some areas heavily impacted by grazing
- Shrubland—areas in transition to woodland
- Woodland—canopy from 6 to 9 m tall and dominated by a few tree species
- Evergreen forest—canopy to 12 m with a mixture of several tree species
- Marsh—flooded seasonally for extended periods
- Beach—sand, rocky areas, and few tree species including red mangrove
- Beach thickets—to 5 m tall with several tree species including white and black mangroves

The vascular flora consists of 253 species, 70 percent of them shared with Guánica Forest, and 35 percent of them trees. Endemic trees include the *Gaussia attenuata*, *Machaonia portoricensis*, *Rondeleteia inermis*, and *Thouinia striata*. The other endemic species are *Hohenbergia antillana* and *Zamia portoricensis*. The presence of *Cynometra portiricensis*, *Oxandra lanceolata*, and *Stahlia monosperma* suggest that the reserve could be considered as critical habitat for these species. Eighty-one bird species have been identified at the reserve (Fuentes Santiago and Quevedo Bonilla 2002). Five are endemic and three are classed as rare or extremely rare (table 6).

Laguna Guaniquilla occupies 9 ha of the reserve (Negrón González 1986). The lagoon has a mean depth of 0.4 m and surrounds rocks that have been eroded into attractive formations. The lagoon was previously connected to the sea via a canal that was closed around 1955 to retain fresh water runoff (Ramos y Ramírez de Arellano 1986, see endnotes). Before then, the lagoon was used to trap marine fish where they were grown for domestic use. The only fish species recorded in the lagoon today are *Tilapa mossambicus*, *Mugil curema*, and *Gerres cinereus*. *Tilapa mossambicus* accounted for two-thirds of the catch. In the past, the area was used by *Dendrocygna arborea* (West Indian whistling duck) as a nesting site.

General Observations and Research in Southwestern Puerto Rico

Major wildlife research for the refuge sites is summarized below along with information from other protected areas in southwestern Puerto Rico. Most of the formal research has been carried out at four sites: the Cabo Rojo and Laguna Cartagena NWRs and the Commonwealth forests at Boquerón and Guánica. In a few instances, important observations not available from the southwest have been reported from other areas.

All research activities carried out partially or completely on the refuges—either at Cabo Rojo (Headquarters or Salinas tracts) or at Laguna Cartagena (Lagoon or Tinaja tracts)—are included as refuge studies. In some instances, both refuges were involved along with other sites, usually the Boquerón or the Guánica Commonwealth Forests.

Punta Guaniquilla Natural Reserve. Managed by the Puerto Rican Conservation Trust, the 152-ha reserve contains the remains of Hacienda La Romana. The reserve is also well known for its limestone rocks which have eroded into attractive formations. (Photo by Peter L. Weaver)

Flora—Mangroves and Phenology

Between 1974 and 1989, mangroves throughout Puerto Rico showed a 39.5-percent increase in area (Torres Rodríguez 1993). Along the entire southwestern coast from Guánica to Punta Guaniquilla, sampled mangrove areas increased from about 800 to 970 ha (21.2 percent). Within this region, the areas around Guánica and Cabo Rojo combined increased from 356 to 537 ha (50.8 percent) whereas the area around Parguera decreased slightly from 445 to 433 ha (2.7 percent). Several reasons were suggested for the increase in mangrove areas including a decline of agriculture, reduction in conversion to other uses, isolation in some instances, legal protection, and the natural recovery of mangrove areas when left undisturbed.

Information on phenology (flowering, fruiting, and leaf loss) is important for determining potential periods of limited food supply and possible habitat preferences for animal populations, particularly during droughts. Likewise, data on the origin of tree species are useful for the restoration of native habitat. Although detailed studies are not available for all of the island's tree species, general phenological observations have been recorded over the years (Francis and Lowe 2000, Little and Wadsworth 1964, Little and others 1974). This information has been summarized for 162 tree species growing on or near the refuges (appendix A). Of the total, 135 trees are native, i.e., about 30 percent of the island's total native species, and the remainder are introduced. Of the natives, 13 are endemic to Puerto Rico. Slightly more than 100 species are evergreen, about 50 are deciduous, and most of the remainder may be evergreen or deciduous depending upon weather conditions (appendix A).

Patterns of flowering and fruiting for 48 woody species in deciduous forest at Guánica were described as complex, with considerable variability within and among species (Murphy and others 1995). A 3-year study showed that flowering is rarest during the February to -March dry season and more common from April through October, after which it begins to decline. Fruits, in turn, are relatively abundant throughout the year when all 48 woody species are considered together; most fruits, however, seem to fall during the dry season. About one-half of the 48 species bear fruit twice annually, and nearly one-quarter have some fruiting specimens at least every other month (Murphy and others 1995). In addition, another 3-year study at Guánica showed that the amount of leaves, as determined by measures of leaf area and forest cover, was least during dry season and greater during the rest of the year (Murphy and Lugo 1986b).

Fauna—Birds

Early observations in western Puerto Rico and offshore islands revealed more than 160 bona fide species and subspecies, nearly one-half of which were migratory (Danforth 1926, 1931, 1936; Struthers 1923). In the early 1960s, a checklist updated known species and clarified Spanish nomenclature for the island's birds (Leopold 1963). Later, as part of Puerto Rico's encyclopedia of natural resources, historical bird records from 1535 to present, including extinct species, were compiled by the Department of Natural Resources (Chabert Llompart and others 1986). Notes on bird feeding habits, reproductive ecology, behavior, and vocals were included. Several other publications highlight species' identification, some with photographs or sketches of the island's species (Hernández-Prieto 1994, Oberle 1999, Ortiz Rosas 1981, Toro McCown and Chabert 1986) (see also table 6, footnotes). In addition, bird species' guides (Raffaele 1983, 1989) include recent arrivals and summarize identifying characters, English and local names, favored habitats, flight and feeding behavior, voice, nest data, and regional distributions for all species among other observations.

Cabo Rojo National Wildlife Refuge Studies—Headquarters Tract and Municipality

Flora—Tree Genetics, Mistletoe, and Restoration

Landscape fragmentation can lower visitation by pollinators and lead to inbreeding and increased genetic drift (Dunphy 2003, Dunphy and others 2004). Accurate estimates of gene flow, however, may provide information on how certain species will endure habitat losses. Gene exchange in fragmented forest was explored for three species: (1) *Bursera simaruba* and (2) *Hymenaea courbaril*, both native

tree species; and (3) *Albizia lebbeck*, an exotic tree introduced during historic times. For all species, a substantial proportion of seed production was the result of gene-flow pollen. *Hymenaea courbaril*, a bat pollinated species, had the lowest gene-flow rate. Genetic diversity values were higher in *Bursera simaruba* and *Albizia lebbeck* than for other species with similar life history characteristics, and conversely, lower in *Hymenaea courbaril*. No relationship was found between gene-flow rates and distance to nearest neighbor or stand size. In another study, an analysis of 16 populations of *Rhizophra mangle* from the Dominican Republic; Florida; Panama; and Cabo Rojo, Puerto Rico, i.e., Bahía Sucia and the Boquerón Wildlife Reserve, was carried out to determine genetic variation within the species (Pérez Laguillo 1998).

Dendrophthora bermejae, a recently discovered endemic mistletoe, is confined to a few localities in Cabo Rojo, including Sierra Bermeja (Kuijt and others 2005). The mistletoe's only known host is *Guaiacum officinale*. The mistletoe is currently threatened by residential, commercial, and tourist development and should be established in protected areas in southwestern Puerto Rico.

An attempt was made to assess the potential of 16 native tree species for restoration of subtropical dry areas, including the refuge sites (Caracal Velez 2001). Light and soil requirements, dry storage longevity of seeds, and early seedling survival were investigated in greenhouse conditions. All of the species tested grew naturally within the refuges and were suitable for reforestation.

Fauna—Birds

***Agelaius xanthomus* (yellow-shouldered blackbird)—** In 1974, an early morning survey of the Cabo Rojo Headquarters tract disclosed 26 bird species, 7 percent of which were *Agelaius xanthomus* (Wiley 1974, see endnotes). The tract was suggested as a buffer zone to protect the mudflats on the Salinas tract to the south. At that time, the blackbirds used the Headquarters tract for feeding and daytime roosting.

Cathartes aura* (turkey vulture)—Cathartes aura*, the only falconiformes established in Puerto Rico, is frequently sighted between Cabo Rojo and Ponce (Perez Rivera and Cotte Santana 1977, Santana and others 1986a). Nests have been located on the refuges and in nearby Lajas caves and in the Cerro de Cotui in San Germán. Observations made near Lajas show that peak soaring occurred in the early afternoon. The minimum home range during an 18-month period was 460 km^2. Daily range, however, varied from 1.2 to 30.5 km^2. A census suggested that Puerto Rico was not an important wintering area for migrating vultures (Santana and others 1986b). Other surveys report on the geographical distribution, and feeding and nesting habits of *Cathartes aura*, *Buteo jamaicensis* (red-tailed hawk), and *Falco sparverius* (American kestrel) (Pérez Rivera and Cotte Santana 1977).

Columbids (pigeons and doves)—Predation accounts for 81 percent of columbid nest losses (Rivera-Milán 1996). Moreover, in the Guánica and Cabo Rojo Forests, the total amount of rainfall during the first 6 months of the year accounted for about 70 percent of the variability associated with nest density estimates during the reproductive peak. The presence of food plants and watering areas at the Headquarters tract, along with protection, could benefit columbid populations (Wiley 1974, see endnotes).

***Dendroica adelaidae* (Adelaide's warbler)—** The vocal behavior of the *Dendroica adelaidae* was studied in relation to its social behavior and ecology (Staicer 1991). Breeding was seasonal with individuals maintaining monogamous pair bonds and exclusive pair territories throughout the year; however, when unpaired, only males maintained territories. Paired birds used duets of male songs and female calls.

***Myiarchus antillarum* (Puerto Rican flycatcher)—** The foraging modes and resource use by *Myiarchus antillarum* are diverse (Cruz and others 1986). The flycatchers capture prey nearly one-half of the time when both the bird and prey are in the air. The remaining captures are when both are on a substrate or when the prey is on a substrate and the bird on the wing. Flycatchers also have a varied diet which includes mollusks, arthropods, and vertebrates, e.g., *Anolis* spp.; and occasionally, fruits. During the late 1980s, breeding biology and growth patterns of flycatchers were studied (Torres Báez and Collazo 1992). Flycatchers breed from February through June with a peak in May and June. About three-quarters of the nests fledged at least one young. Flycatchers

accept artificial cavities and will use wooden nest structures. Nest cavity dwellers fledge better than those that nest on the soil or on platforms.

***Dendroica discolor*, *Dendroica tigrina*, *Parula americana* (prairie, Cape May, and northern parula warblers)—**The behavior of *Dendroica discolor*, *Dendroica tigrina*, and *Parula americana* was studied to identify factors of importance for maintaining wintering populations (Staicer 1992). Most individuals exhibited strong site fidelity within and among wintering seasons. Usually they roamed independently, but sometimes were found in small, cohesive flocks. *Dendroica tigrina* maintained intraspecific territories and chased away other species. *Parula americana* were more plastic in behavior, ranging from territorial to gregarious to wandering. *Dendroica discolor*, in turn, was more prone to avoid other warblers, moving around widely. Current long-term studies demonstrate population declines for all three species in the wintering habitat at Guánica Forest (Arendt and collaborators 1992).

Falco sparverius* (American kestrel)—Falco sparverius* feeds on insects, lizards, and mice (Perez Rivera and Cotte Santana 1977). The species has purportedly declined because of the lack of nesting sites. In response, 20 nest boxes were installed on the Cabo Rojo NWR, mainly at the Headquarters tract, where 2 currently have active nests.

Other Fauna

Numerous *Antiacarsia gemmatalis* (velvet bean caterpillar) larvae were observed feeding on the weedy legume *Tephrosia cinerea* at Cabo Rojo (Gregory and others 1991). Three bird species: (1) *Molothrus bonariensis*, (2) *Quiscalus niger* (Greater Antillian grackle), and (3) *Agelaius xanthomus* feed on the larva. Apparently, this is the first report of the caterpillar's native host plant in the West Indies.

Gecko populations of *Sphaerodactylus nicholsi* at the Cabo Rojo NWR vary with habitat, preferring evergreen vegetation that offers cover from insolation (López-Ortiz 1999). Evergreens help stabilize temperatures and provide leaf litter and humus during the year, supporting populations of arthropods. Arboreal lizards are sympatric and are potential predators.

Cabo Rojo National Wildlife Refuge Studies—Salinas Tract

Lagoon System and Its Wildlife

During autumn migration and winter months, the hypersaline lagoon system of the salt flats is the most important converging point for migrating shorebirds in Puerto Rico (Grear 1992a, 1992b; Grear and Collazo 1999). Surveys recorded 32 species of shorebirds with *Calidris pusilla* and *Calidris mauri* (small calidrids) accounting for 60 to 70 percent of the species. The maximum populations were recorded in mid-October when changes in invertebrate abundance coincided with fluctuations in lagoon salinity. Shorebird diets were associated with food abundance and changes in water levels. Every site within the salt flats serves as an important habitat for at least one shorebird species. Additional studies should focus on the hydrology of the lagoons and the effects of water level fluctuations on salinity; the availability of primary producers, i.e., algae; and prey dynamics. The abundance of calidrids and their prey was correlated with the algal substrate. Fishermen report that two families of fish—Centropomidae (snook) and Mugilidae (mullets)—regularly enter the lagoons (Negrón González 1986) (table 5).

Artemia spp. (brine shrimp) are suitable food for a wide variety of organisms, including crustaceans and fishes, and are also used in the development of aquacultural systems. *Artemia* populations in Laguna Fraternidad were influenced mainly by fluctuations in temperature and salinity and not other factors such as pH, dissolved oxygen, or turbidity (Bonilla Soto 1984). The highest shrimp populations were recorded in May; however, shrimp were absent in August because of critical temperature and salinity levels. The lethal upper temperature and salinity limits for brine shrimp are 36 °C and 200 parts per thousand (p/t).

The density and distribution of *Trichocorixa* spp. (water-boatmen) and *Artemia* spp. were monitored from early September to early November, the fall migratory season (Tripp 1996, Tripp and Collazo 2003). The former were recorded in areas of lowest salinity (<65 p/t) and the latter in areas with the highest salinity (≥106 p/t). The foraging value of the salt flats for shorebirds may be enhanced by maintaining salinity at <65 p/t in selected

management units, and by controlling water depth. In a second study carried out from January through December, populations of *Artemia salina* and *Gomphosphaeria aponina* (phytoplankton) increased during the period of heaviest rainfall, coincident with lowest salinity (Mercado Alvarez 2003). Alterations of populations were noted, suggesting that the shrimp feed on the phytoplankton. Samples of nitrates, nitrites, dissolved oxygen, and pH were also collected.

Fauna—Shorebirds and Wading Birds

Charadrius alexandrinus **and** ***Charadrius wilsonia*** **(snowy and Wilson's plovers)—**A snowy plover was first reported on the salt flats near the Cabo Rojo Lighthouse in 1928 (Danforth (1929). In 1988, a study of the snowy and Wilson's plovers reported on their abundance, nesting chronology, nesting success, nesting habitat, and habitat use (Lee 1989). Peaks in the abundance of snowy plovers apparently coincide with the influx of migrants. Nest sites differed by species. Wilson's plovers preferred live vegetation nearby whereas the snowy plovers nested on open sand. Chick mortality for both species appeared high. Causes of nest failure were due to abandonment for the snowy plover, and human disturbance and flooding for the Wilson's plover. Sandflats appeared to be important roosting sites for both species.

Calidris fuscicolis, Calidris mauri**,** ***Calidris minutilla*****, and** ***Calidris pusilla*** **(white-rumped, western, least, and semipalmated sandpipers)—** Banding of *Calidris pusilla* and *Calidris mauri* from 1989 to 1993 provided information on their residency rates, i.e., length of stay in the 1992 season; annual return rates between 1989 and 1991; and their populations in 1992 for the Cabo Rojo Salt Flats and nearby Boquerón Forest at Punta Pitahaya (Rice 1995). The residency rates suggested that the salt flats serve as both stopover and wintering area. Moreover, the return rates suggested that the salt flats are traditionally used by both species. About 7,300 birds of both species were estimated to use both areas in the fall of 1992, with Cabo Rojo accounting for about 90 percent of the total.

Nonbreeding territorial behavior for *Calidris pusilla*, *Calidris minutilla*, and *Calidris mauri* was studied at the Cabo Rojo Salt Flats (Tripp and Collazo 1997). Territorial birds defended areas with greater prey densities than nonterritorial birds, using territories as large as competition permitted. The cost of territorial behavior may be offset by foraging in areas where prey density is greater, or through increased foraging efficiency. Nonterritorial birds, however, also foraged in areas where prey was more abundant than for average sites within the lagoon.

Three short-term student studies examined Calidrid species at Fratrenidad Lagoon, a water body where foraging areas remain relatively constant diurnally. The first showed that Calidrid species preferred the shallow and warmer north shore of the lagoon, possibly because of differences in depth, or the lack of littoral vegetation that could hide avian predators (Santos 1988, see endnotes). The second study looked at habitat selection and foraging behavior in mixed flocks of *Calidris fuscicolis*, *Calidris mauri*, *Calidris minutilla*, and *Calidris pusilla (Hopping 1989, see endnotes)*. The third investigated bill morphology of *Calidris mauri*, *Calidris minutella*, and *Calidris pusilla* in regard to prey size and substrate preferences (Bailey 1990, see endnotes).

A recurrent census of migratory and resident shorebirds identified 28 species between 1985 and 1992 (Collazo and others 1995). The highest number of individuals was recorded between August and December and in March. Migrants accounted for 87 percent of the annual counts. Calidrid sandpipers, *Tringa flavipes* (lesser yellowlegs), and *Calidris himantopus* (stilt sandpipers) were the most abundant migrants and *Himantopus mexicanus* (black-necked stilts), the most common resident bird. Peak daily counts ranged from about 3,500 to over 8,000 individuals. Distribution of the birds was affected by food availability and hydrological conditions, both a function of the salt extraction operations.

The stomach contents of 35 wading birds of 4 species were examined in 1994 and 1995 to determine their feeding habits (Miranda 1995b, Miranda and Collazo 1997a). Eleven prey groups were identified including 7 families of fish, 2 genera of crustacea, a lizard, and insects. *Egretta tricolor* (tricolored herons) fed on guppies and snook. *Ardea alba* (great egrets) and *Egreta thula* (snowy egrets) fed mainly on shrimp and guppies, and *Egreta caerulea* (little blue herons) fed exclusively on fiddler crabs. A modified throw-trap was used to sample prey in shallow water mangrove swamps (Miranda and Collazo 1997b). The trap was light, easy to use, and suitable for sampling prey in areas with an uneven bottom in a standardized fashion.

Fauna—Sea Turtles

Dermochelys coriacea were reported nesting in 1991, 1994, and 1997 and *Eretmochelys imbricata* in 1999 on the beaches of southwestern Puerto Rico (Jiménez Marrerro 2000, see endnotes). A survey of the beaches at Bahía Salinas, Punta Águila, and Playa Combate in the winter of 1999–2000 showed that motor vehicles cause serious problems. The beaches were judged satisfactory for turtle nesting, and their actual use could be documented by increased monitoring.

Laguna Cartagena National Wildlife Refuge Studies—Lagoon Tract

Water Quality, Insects, and Earthworms

Physical and chemical conditions of the lagoon were assessed, including pH, temperature, dissolved oxygen, nutrients, and heavy metals (Deliz Quiñones 2005). Lagoon conditions, vegetation, and insect populations all varied during the year. Ammonia and phosphate were at high levels, and dissolved oxygen and lagoon depth showed significant fluctuations. Sampling yielded 67 species of insects in 33 families. Insect abundance and diversity were related mainly to the amount of dissolved oxygen.

Only four earthworm species were encountered at Cartagena Lagoon (Alfaro and Borges 1996). The low diversity and density of earthworms was attributed to several factors, including high organic matter accumulation, the high resistance to penetration in the topsoil layer, high salinity, sand content in deeper soil layers, and the effects of rainfall on shallow soils.

Native Bird Species

Populations of four native aquatic birds: (1) *Anas bahamensis* (white-cheeked pintail), (2) *Dendrocygna arborea* (West Indian tree duck), (3) *Fulica caribaea* (Caribbean coot), and (4) *Oxyura jamaicensis* (ruddy duck) were abundant at the beginning of the 20th century (Bonilla and others 1992). All species were negatively affected by habitat loss, i.e., drainage of the Ciénaga El Anegado and Laguna Guánica, and deterioration of the Cartagena Lagoon during the 1950s and 1960s; excessive hunting and egg removal; occasional flooding; and predation by rats and mongooses. Islandwide waterfowl investigations indicated that all species are less common today and their hunting has been prohibited by the Department of Natural Resources (Belitsky 1978, Bonilla 1992, Chabert 1984, see endnotes for each). Interestingly, all four species have been reported recently at the Cartagena Lagoon, including nesting individuals of *Dendrocygna arborea*. Only one *Fulica caribaea* was reported in 1991–92 at Cartagena Lagoon. In addition, an *Anas rubripes* (American black duck) recorded at the lagoon January 1980 was later shot by a hunter (Colón 1982b). The previous recording for this species was at Laguna Guánica in December 1935.

Communal breeding of *Crotophaga ani* (smooth-billed ani) was studied at Cabo Rojo and Laguna Cartagena where groups ranged from 2 to 9 adults with communal clutches between 11 and 25 eggs (Startek 1997). DNA loci were used to examine the mating system and extent of reproductive skew, i.e., the distribution of reproduction among group members. Within four focal groups, suggestions of monogamy, polygamy, and incidents of intraspecific brood parasitism were found. Alternative strategies to monogamy may be more prevalent than previously believed, and the reproductive skew may be affected by the availability of limiting resources during the breeding season. A second study addressed specific DNA markers, parentage of buried eggs, and adult relatedness (Blanchard 2000). Evidence emerged for an egalitarian system with low reproductive skew. The most significant factors affecting bias were the order of egg laying, timing, and number of breeding females.

Members of a group tended to stay together during regular activities such as roosting, foraging, and resting, where they are better able to defend their nests and territories than would a single pair (Lentz 2005). Shared incubation and sentinel behavior during foraging are group behavioral activities that may lower mortality. Territory quality, i.e., as determined by the time of first breeding and chances for renesting or second breeding, correlated negatively with group size. Moreover, ani habitats were not saturated, i.e., suitable breeding habitat was available but unoccupied. *Buteo jamaicensis*, *Felis domesticus* (domestic cat), *Rattus rattus*, and *Solenopsis invicta* (fire ants) were observed preying on ani nests (Lentz 2005).

Laguna Cartagena National Wildlife Refuge Studies—Tinaja Tract

Secondary Succession and Restoration

The natural recovery of trees after the elimination of fire and grazing was assessed on the Tinaja tract, including species-site relationships and changes in species composition over time (Weaver and Chinea 2003, Weaver and Schwagerl 2005). Past land use history, slope, and distance to drainages accounted for variability in species occurrence. The survey disclosed at least 161 tree species on the Tinaja tract. The 10 most common species accounted for nearly 60 percent of the stems and the 43 least common species, each with 5 or fewer individuals, accounted for only 2.2 percent of the stems. In addition, the survival, growth, and future potential of tree species for site restoration were evaluated for both refuges (Weaver and Schwagerl 2004).

Boquerón Commonwealth Forest

Fauna—Bird Species

Agelaius xanthomas* (yellow-shouldered blackbird)—Agelaius xanthomas*, endemic to Puerto Rico, including Isla Mona, declined from very abundant in 1864, to common in 1927 through the 1940s, to uncommon and restricted in range in the early 1970s (Post and Wiley 1976). The range in the 1970s was from Ensenada to Punta Guaniquilla in southwestern Puerto Rico. Among the factors suggested for its decline were loss of feeding habitat, reduction in nesting habitat, introduced rats and mongooses, fowl pox, and two competitive bird species—*Margarops fuscatus* (pearly-eyed thrasher) and *Molothrus bonariensis*. Higher blackbird nest success on cays as compared to mainland sites was attributed to the lack of brood parasitism offshore.

The roosting behavior of the blackbird was studied along with observations on the *Margarops fuscatus* and *Quiscalus niger* (Post and Post 1987). All of these species use primary (nocturnal) and secondary (diurnal) roosts. Primary roosts are located in predator-free sites, i.e., offshore islands, and secondary roosts in subcanopy trees near food sources. Blackbirds do not stay in nesting colonies at night unless they are incubating or brooding. Predator mobbing was common, and arrival and departure patterns from roosting sites varied among species.

The blackbird was listed as endangered in 1976 because of brood parasitism by *Molothrus bonariensis*, an activity that reduced its nesting success (López-Ortiz and others 2002, Post 1981a, Wiley and others 1991). Between 1974 and 1982, blackbird populations declined by about 80 percent. Radio telemetry was used to learn more about blackbird patterns of movement and habitat use during the nonbreeding season (Cruz-Burgos 1999). The mean home range was about 230 ha during both the pre- and postbreeding season. *Prosopis juliflora* stands and residential areas with household feeders were used more frequently during the prebreeding season; caterpillars and vegetable matter were favored in scrub and mangrove woodlands during the postbreeding season. Foraging was mainly during the morning and afternoon, with the midday spent resting and preening.

An artificial nest structure program, initiated in the Boquerón Forest in 1984 and coupled with removal of *Molothrus bonariensis*, improved the blackbird's reproductive success (Wiley and others 1991). Blackbirds accepted the nest boxes which were concentrated in mangrove habitats. *Avicennia germinans* trees were later surveyed in areas east and west of Punta Pitahaya (Reitsma 1998, see endnotes). The dramatic increase in the number of natural blackbird nests was probably due to the success of the artificial nest structures installed during the past several years. From 1996 to 2000, the percentage of blackbird nests in natural substrates as opposed to artificial structures increased from about 1 to 35 percent (López-Ortiz and others 2002).

In 1987, a flock of about 300 blackbirds were sighted foraging on caterpillars along with *Quiscalus niger*, and 1 day later, about 100 blackbirds with *Quiscalus niger* and *Molothrus bonariensis* (McKenzie and Noble 1989). Both were in a woodland of *Prosopis juliflora* near the Boquerón Forest north of Punta Pitahaya. A study of blackbird ectoparasites near Parguera showed 3 species of avian biting lice on 69 percent of the 265 birds sampled, with greater occurrence on males than females (Post 1981b). Also, three species of mites were reported in blackbird nests. The frequency of avian pox lesions was also recorded and it was suggested that

deformities resulting from avian pox could reduce blackbird life expectancy. One incident of the capture of a blackbird in flight by *Falco sparverius* was thought to be related to pox lesions (Miranda 1995a).

Since 1980, the Commonwealth Department of Natural Resources and the F&WS have undertaken measures for the recovery of the blackbird including trapping and removing *Molothrus bonariensis* from blackbird nesting areas; evaluating and controlling other pests infesting blackbird nests and chicks; and installing, cleaning, and repairing artificial blackbird nest structures (Román Cordero 1992, Ventosa Febles 1991). The work is being carried out in the salt flats and mangroves of Boquerón Forest. The program has had a positive effect on the blackbirds, increasing their nest success and the number of birds fledged.

Molothrus bonariensis* (shiny cowbird)—Molothrus bonariensis* ranges from Patagonia to Hispaniola. The species was first seen in Vieques in 1860, and first recorded in Puerto Rico in 1955, although it had apparently arrived earlier (Cruz and others 1998; Post and Wiley 1977a, 1977b). The species is kept as a cage bird and its movement has probably been facilitated by humans. Once in Puerto Rico, the cowbird, a host generalist, encountered avian species with no history of social parasitism (McKenzie and Noble 1990, Wiley 1985). Cowbird puncturing of eggs was examined between 1982 and 1988 (Nakamura and Cruz 2000). The frequency of punctures was related to the number of cowbird eggs in the nest. Moreover, cowbirds punctured eggs indiscriminately, i.e., their own as well as those of the host. Egg puncturing occurred at any time during incubation, and clutches with damaged eggs were abandoned by the host.

Cowbirds are good colonists because of their flexibility in habitat selection, diverse diet, gregarious behavior, and fecundity; moreover, cowbirds are host generalists, successfully parasitizing at least 11 species in Puerto Rico (Cruz and others 1989; Wiley 1985, 1988). A study in southwestern Puerto Rico showed that cowbirds used *Prosopis juliflora* woodland about 75 percent of the time; and agricultural land, littoral woodland, mangrove, scrub, and open fields the remainder (McKenzie and Noble 1990). In mangroves, 42 percent of resident nonraptorial land bird species were affected (Wiley 1985). The cowbirds do not parasitize birds in proportion to their abundance (Wiley 1988). The food habits and egg size of *Molothrus bonariensis* are similar to those of their hosts, suggesting that they choose hosts based partly on those characters. Cowbirds locate nests by watching potential hosts in likely habitats, using cues such as nest building and territorial defense. Cowbird parasitism peaks with the host's first day of egg laying. Hosts with covered nests, or cavities, were as vulnerable as those with open nests. The response to parasitism among host species varies (Cruz and others 1985). Host clutches in parasitized nests average smaller than those in nonparasitized nests; moreover, nest success at nonparasitized nests averaged higher than parasitized nests.

Patagieonas leucocephala* (white-crowned pigeon)—Patagieonas leucocephala*, widely distributed in the Caribbean, has declined throughout its range, including the mangroves in Boquerón Forest, because of habitat destruction (Wiley 1979). During the nonbreeding season, the birds disperse into hills and mountains. The unsuitability of some southern coastal forests may be due to the lack of nearby feeding habitat because previous foraging habitat was converted to sugar production. Several recommendations to increase populations are: maintain a closed hunting season; establish nesting and feeding sanctuaries in critical areas not currently protected; protect existing and new nesting and feeding habitats; establish no-hunting buffer zones; monitor population size, distribution, and breeding effort; and establish cooperative research and management programs with other countries. A compendium of information on the pigeon—communication, breeding biology, interspecific interactions, food habits, and behavior—has been summarized in a monograph from observations elsewhere in Puerto Rico (Wiley and Wiley 1979).

Seiurus novaboracensis* (northern waterthrush)—Seiurus novaboracensis* was studied during four nonbreeding seasons in *Avicennia germinans* mangrove forest (Reitsma and others 2002). The birds demonstrate high site fidelity within and between seasons. Feeding areas were small with considerable overlap among birds. Waterthrushes show high plasticity in their use of habitat during the nonbreeding season but may rely on mangroves for overwinter survival. Waterthrush densities are inversely associated with water level. Hurricane

Georges had a major impact on mangrove habitat in the southwest, and forced the birds on the study plot to migrate to overnight roost sites in nearby *Rhizophora mangle* mangroves.

Guánica Commonwealth Forest

Climatic Influences

Several years ago, preliminary studies using a linear strip census showed that species diversity, excluding migrant warblers and nocturnal birds, was greater at Guánica Forest than in the Luquillo Rain Forest of northeastern Puerto Rico; similarly, bird density counts were greater at Guánica than at Luquillo (Kepler and Kepler 1970). The greater bird species diversity in dry forest communities as compared to wet communities was attributed to former climatic conditions during the Pleistocene when the West Indies were both larger and drier than today (Faaborg and Arendt 1990, 1992b).

Monitoring of bird species at Guánica Forest provided information on the impacts of droughts on bird populations. When rainfall is insufficient at the end of the dry season, resident birds are unable to breed successfully, regardless of the quantity of rainfall later during the year (Faaborg and Arendt 1992b, Faaborg and others 2000). Annual rainfall patterns, particularly the rainfall during the first 6 months of each year, are related to population levels and survival rates (Dugger and others 2000). The relation between rainfall patterns and plant production and insect productivity are not yet known. In 1998, Hhurricane Georges caused considerable habitat damage in the Guánica Forest, including the traditional mist netting areas (Faaborg and others 2000). Site damage will likely dominate other factors affecting bird populations for some time. Determining the long- term impact of the storm on populations will require additional monitoring.

In general, hurricanes, which periodically traverse the island (fig. 8), have both direct and indirect impacts on bird populations (Wiley and Wunderle 1993). Direct effects include mortality due to wind, rain, storm surges, and geographic displacement of individuals. Indirect effects include poststorm loss of food supplies or foraging sites, loss of nest or roosting sites, increased vulnerability to predation, and microclimatic changes. Birds respond in the short-term through shifts in diet, foraging sites or habitats, and changes in reproduction. Long-term responses may involve greater use of secondary vegetation. The most vulnerable species would have a diet related to plant production—nectar, fruit, or seeds. Moreover, they would normally occupy and forage in closed-canopy forest. Small, local populations living in isolated woodland fragments would be most prone to extinction. Recovery of bird populations in posthurricane conditions would be dependent on the amount of damage to the vegetation as well as inherent species' characteristics like the reproductive rate. Recruitment from undisturbed habitat in the vicinity would be important and highlights the need to protect sufficiently large areas of critical habitat to maintain wildlife populations in the long term.

Post-Hurricane Georges observations of bat populations within the Luquillo Rain Forest showed that larger bat species were negatively impacted more than smaller ones (Jones and others 2001). Moreover, as with the birds, frugivorous and nectarivorous species were more affected than insectivorous species. Similar posthurricane results probably apply to bat species throughout the island, including the southwest.

Flora—Forest and Tree Species

Two studies dealing with recovery have been carried out in Guánica's Subtropical Dry Forest. The first, initiated 13 years after clearcutting 1 ha of forest, showed that plant height reached 40 percent of the adjacent mature forest and that the secondary vegetation contained nearly 60 percent of the species of nearby mature forest (Dunevitz 1985). Sprouts and seedlings each accounted for one-half of the stems >1 cm. In the second, recovery was observed 45 years after several human uses, i.e., baseball park, charcoal pits, farmlands, and house sites, had been abandoned (Molina Colón 1998). The type and rates of tree regeneration, plant diversity, and chemical and physical characteristics of the soil varied among sites.

Two additional studies dealt with particular plant species. *Trichilia triacantha*, a small, evergreen tree endemic to southwestern Puerto Rico, was listed as endangered in 1988. A study of 109 plants in 10 populations showed a high level of synchrony in flowering and fruiting, and a low production of fruit (Ventosa Febles 1997). Habitat loss and low fruit production are the principal threats to survival

of the species. Given the small size and attractive nature of the plant, its survival could be improved if it were planted as an ornamental (Little and others 1974). The second species, *Tilandsia recurvata*, is an epiphyte that grows in many areas, including Guánica Forest, where its abundance is correlated with host-tree height, basal area, and the amount of branching (Molina Colón 1986). *Swietenia mahogani* and *Pithecellobium unguis-cati* are common hosts. The former is relatively abundant within the forest and the latter has large basal areas and a high degree of branching. The occurrence of *Tilandsia recurvata* also varies with position within the trees, i.e., center vs. periphery and trunk vs. branches. When growing on *Bucida buceras*, greater quantities of the epiphyte were found on open-grown trees as opposed to those growing in dense stands.

Fauna—Bird Monitoring Studies

Fluctuations of populations of migratory birds may be due to limiting factors that occur on the breeding grounds, during migration, or at wintering sites. In 1972, annual mist netting and bird banding was initiated in Guánica Forest to determine species' abundances and community patterns for resident and migratory bird populations (Faaborg and Winters 1979, 1980; Faaborg and others 2000). Monitoring activities were expanded in 1989 and 1991 and have provided a wealth of important ecological information such as the impact of drought on certain species and their subsequent recovery, changes in species composition over time, and the survival and longevity of certain species. Some of the major findings include:

- Decline in migratory warblers—Long-term mist netting of migratory warblers in Puerto Rico's Guánica Forest has documented their decline from 1973 through 1990 (Faaborg and Arendt 1992a). Typical explanations for declines in migrants include forest fragmentation and the loss of breeding habitat in temperate areas, and the loss of wintering habitat in the tropics. Guánica Forest, however, has not experienced human -induced changes in either structure or composition since the initiation of monitoring. These data suggest that explanations for declines in migrant warbler species based mainly on habitat destruction in the tropics are simplistic and may be ignoring important ecological patterns in the temperate zone (Faaborg and Arendt 1989b, 1990).
- Bird density declines with rainfall patterns—Declines in the density of resident bird populations from 1972 to 1990 were associated with droughts whereas winter migrants seemed unaffected (Faaborg and Arendt 1989b, 1990, 1992b; Faaborg and others 1984). The pattern may reflect the fact that winter residents return during the humid part of the year (September and October), and, furthermore, do not have to feed young during the dry season. In contrast, the success of resident breeding species seems to depend on sufficient rainfall during May and June which normally ends the December through April dry season.
- Foraging guilds of avian populations—Mist netting showed that the absence of May to June rains most affected resident birds that breed during this period (Faaborg 1982, Faaborg and Arendt 1990). Frugivorous birds and nectarivorous birds tended to fluctuate more in numbers than insectivorous birds. It appears that insects may provide a scarce but predictable resource that attracts migratory species and, in turn, restricts the breeding season of resident insectivores. This restriction exposes breeding birds to variable conditions early in the wet season. The relative unpredictability of fruit, seed, and flower resources seem to limit migratory species that use these foods, and release resident members of these guilds from some of the restrictions in breeding.
- Migratory land birds in the Caribbean— A total of 24 regional and local collaborators documented the current status of North American land-bird migrants with regard to species diversity, regional and island distributions, general abundances, positive and negative factors affecting populations, measures needed to mitigate negative impacts on migrant numbers, and views on the probable future of migrant land birds within the region (Arendt 1992). Habitat specialist species are showing signs of population decline, whereas, migrant habitat generalists, because of their capacity to adapt to a variety of habitat types, including those altered by human activity, may not be threatened with extinction, or even future decreases in their populations. The Caribbean Islands are characterized by rough topography and vegetation types that regenerate well after disturbance. Both of these attributes seem favorable for the continued survival of migratory land birds.

- Avian demography (longevity)— Mist netting and bird banding during 15 years resulted in the capture of 39 species, 21 of which were recaptured (Faaborg and Arendt 1989a). Among the oldest age estimates for recaptured birds were 14.5 years for a Todus mexicanus, and 11.6 years for a Myiarchus antillanum and a Margarops fuscatus. These survival rates are among the longest recorded. The basic theory that describes reproductive strategy for bird species is that tropical birds have small clutches and long life spans whereas temperate birds have large clutches and short life spans. Guánica data support this generalization (Faaborg and Arendt 1995). The general impression is that resident species in southwestern Puerto Rico "are rather long-lived despite the seeming harshness of the seasonality of the dry forests in which they live" (Faaborg and Arendt 1989a, p. 12).
- Population fluctuations, degree of philopatry, and sex ratios— Mist netting from 1973 to 1984 captured from 8 to 31 birds of 10 migratory species, ranging from 3 to 7 species in any particular year (Faaborg and Arendt 1984, 1990). Winter resident populations showed one set of species that appeared fully integrated into the Guánica Forest bird community, e.g., *Mniotilta varia* (black-and-white warbler), *Setophaga ruticilla* (American redstart), and *Seiurus aurocapilla*; with fairly stable populations and high site fidelity from year to year, and another set of different species whose populations fluctuated considerably. *Mniotilta varia* and *Setophaga ruticilla* populations showed a dominance in numbers of females.
- Measurement of avian populations and morphological characters— Mist nets were used to monitor the size, composition, and survival rates of bird populations in the Guánica Forest (Faaborg and others 2004). Point counts and mist netting yielded different results for species abundances. Mist net samples declined rapidly over a 3-day period due to net avoidance. Mist netting samples indicate avian populations that are resident in the vicinity; moreover, they capture most birds within 3 days in areas with low vegetation like Guánica Forest. Temporal variation in the measurement of select avian morphological characters, i.e., body mass and wing length, is minimal when the data are recorded at the same time of the year (Arendt and Faaborg 1989). In addition, measuring instruments used in the field are precise, sampling techniques are comparable, and the influence of particular investigators is generally minimal.
- Overwintering warblers and additional monitoring— Mist netting and bird banding between 1989 and 2003 provided data on *Mniotilta varia, Setopahga ruticilla*, and *Seiurus aurocapilla* to estimate abundance and survival rates in relation to rainfall in both the overwintering and breeding areas (Dugger and others 2004). The three species came mostly from the Eastern United States. Relationships between rainfall and habitat quality, and winter resident demography are complex and involve the effects of other species. Continued monitoring of wintering and permanent resident populations will be needed to understand how these populations fluctuate together.

Fauna—Individual Bird Species

***Caprimulgus noctitherus* (Puerto Rican nightjar)—** Previously thought extinct, the Puerto Rican nightjar was rediscovered in March 1961 (Reynard 1962). Today, the species is known from the Guánica Forest, the hills around the town of Guayanilla, and Susua Forest (Kepler and Kepler 1973, Vilella and Zwank 1987). Also, a single individual was located in the hills around Parguera, and seven more were found in the Sierra Bermeja, including the Tinaja tract (Vilella and Zwank 1993b). In Guánica Forest, the species averages about one pair on 5 ha for elevations above 75 m. The density is highest in deciduous forest, evergreen forest, and plantation uplands. Originally, the species was probably restricted to the lower slopes and Coastal Plains of the island.

Nesting occurs from mid-April to July when the species deposits one or two eggs in leaf litter (Noble 1986). Nests were situated in forested areas characterized by larger amounts of leaf litter biomass, overhanging cover, and a more open understory and midstory than random sites. Incubation lasts 19 days. About 87 percent of the nests produced at least one fledgling (Vilella 1995a, 1995b). Populations in Guánica appear to be at equilibrium and at carrying capacity; moreover, existing populations may be greater than suggested earlier because not all available habitat in Puerto Rico's southwest has been surveyed (Noble and others 1986, Vilella and Zwank 1987).

The Guaynilla Hills were selectively cut for lumber and charcoal during the 1880s and today contain some open areas grazed by goats (Vilella and Zwank 1987). The species has been recorded on grazing lands where a tree canopy exists, but apparently it avoids riparian habitats. Conservation of existing forests and acquisition of private tracts would help to ensure the survival of the species.

***Loxigilla portoricensis* (Puerto Rican bullfinch)—** Bullfinches feed alone, in pairs, or in inter- and intraspecific groups up to five individuals (Pérez-Rivera 1994). The species has an ample diet, using a wide variety of plants along with insects and snails. Although the bullfinch forages from the ground level into the canopy, most feeding in the Guánica Forest occurred in the upper stratum where it favored the edge of the canopy. Fruit gleaning, and insect searching and gleaning accounted for nearly 90 percent of its foraging.

***Tachornis phoenicobia* (Antillean palm swift)—** *Tachornis phoenicobia*, a previously unrecorded vagrant was observed in Guánica Forest, apparently attracted by swallows and/or insects on which they were feeding (Kepler 1971, 1972). They were seen in July, the putative breeding period within their ranges.

Vireo latimeri* (Puerto Rican vireo)—Vireo latimeri* is an endemic resident in Puerto Rico that does not routinely disperse over long distances, at least within Guánica forest (Woodworth and others 1998). Vireo breeding season length, apparently affected by rainfall, varies by year (Woodworth 1997). Most young vireos spend a prolonged period in their natal territory, and later settle within one to three territory widths of their natal nest, factors that may increase their survival. Vireos are declining in Guánica Forest because of nest parasitism by *Molothrus bonariensis* and predation by rats, feral cats, and mongooses (Faaborg and others 1997; Woodworth and others 1998, 1999). *Molothrus bonariensis* parasitizes about 75 percent of the vireo nests, reducing fledging by more than 80 percent (Woodworth 1997). The combination of restricted breeding season, high predation and parasitism rates, and low seasonal fecundity suggest that the species is in danger of extirpation in portions of its range. Despite the highly seasonal environment and the stress of renesting as many as six times per season, vireos have relatively high survival rates. A longevity record for the vireo of 13 years and 2 months was estimated by use of a model (Woodworth and others 1999). Another model that considered the implications of parasitism and nest predation was used to evaluate alternative options for management of the species (Woodworth 1999). Recovery efforts should begin before species' numbers decline further (Faaborg and others 1997).

***Zenaida aurita* (Zenaida dove)—**A 10-year study provided information on the behavior, breeding, diet, and habitat of the dove and showed that the dove occupies a variety of habitats including forest edges, mangrove, dry scrub, mixed agriculture, and urban areas (Wiley 1991). Nests, found in all months of the year, were generally placed in trees but were also built on the ground when predators were absent. Point counts and nest counts carried out in Guánica Forest between 1986 and 1996 showed that the density of active nests was higher in areas dominated by semideciduous vegetation than areas of deciduous vegetation or thorn scrub (Rivera-Milan 1997). Population declines during the measurement period were correlated with lower 6-month rainfalls at the beginning of the year. Moreover, the 6-month rainfall accounted for about 70 percent of the variability associated with nest density estimates during the reproductive peak in the Guánica Forest, but only 9 percent of the variability in patches of moist forest elsewhere (Rivera-Milán 1996). In the mid-70s, the dove was the principal bird species sought by the island's 7,000 hunters (Maldonado Colón and Pérez Rivera 1977). Guánica is a key habitat for reproduction of Zenaida doves in the dry zone, and conservation of dry forest in the southwest is critical for maintaining dove population levels.

Fauna—Lizards and Geckos

Thirteen species of lizards are represented in the dry forests of southwestern Puerto Rico; moreover, Guánica Forest, with 10 species, has the richest dry forest lizard community on the island (Genet and others 2001) (table 5). The species *Anolis cristatellus* and *Sphaerodactylus nicholsi* are widespread and abundant in all forest types at Guánica while *Anolis cooki* is restricted to coastal scrub. All three species were also recorded on F&WS refuges (table 5). *Anolis cristatellus* and *Anolis cooki* are morphologically and ecologically similar species, and the former is dominant where both species coexist (Genet 2002).

The fragmented landscape and patchy distribution of *Anolis cooki* suggest that the range of the species is shrinking and that it deserves immediate conservation attention.

Future Activities

The refuge properties, which today total about 6 km^2, should remain a nesting and feeding sanctuary for avifauna (Wiley 1979). Recognizing that future development of Puerto Rico's southwest may include hotel complexes and tourist attractions, the F&WS should implement an aggressive management program with local Commonwealth and Federal Agencies, nongovernmental organizations, and universities. Research should be aimed at improving management. Moreover, public support should be sought through educational programs that highlight the area's wildlife as part of a memorable outdoor experience.

Reforestation and secondary forest recovery on abandoned farmlands is the critical need to enhance wildlife habitat and help prevent wildfires. Scattered trees in savannas and grasslands and remnant trees surviving after forest clearing function in a role similar to gaps in forested areas (Belsky and Canham 1994, Guevara and others 1986). Birds and bats frequently transport fruits and seeds to isolated trees where they perch to consume them. Later, the fruits or seeds are regurgitated or dropped to the soil. Microclimate and soil conditions under and immediately surrounding scattered trees are more favorable for regeneration than in open fields dominated by grass cover.

Reforestation in abandoned fields should use tree species in designs that facilitate rapid recovery. Simultaneously, if carefully selected, the trees will provide nesting and foraging habitat for wildlife species. Exotic vs. native species will always be an issue in reforestation efforts. The main objective, initially, should be to develop forest structure, providing habitat for native bird species and reducing the threat of fire. Native tree species should be favored.

Several existing research papers have cited plant species (including trees) that could be used in reforestation efforts and simultaneously serve particular bird species:

- *Agelaius xanthomus*—24 tree species mentioned as habitat and 26 tree species for daily activities (Cruz-Burgos 1999)
- *Columba leucocephala*—at least 19 tree species used for food and/or nesting (Wiley 1979, Wiley and Wiley 1979)
- *Falco sparvarius*—nests in tree cavities of Cocos nucifera, Machaerium lunatum, Mangifera indica, Persea americana, Roystonea borinquena, and cavities in cactus (Pérez Rivera and Cotte Santana 1977)
- *Loxigilla portoricensis*—uses parts of 41 species of plants as food sources and also forages on animal matter in the upper stratum in Guánica dry forest (Pérez-Rivera 1994)
- *Geotrygon montana* (ruddy quail dove)—uses 14 plant species, including fruit trees, along with several grass species as food (Pérez-Rivera 1979)
- *Patagioenas leucocephala*—uses 10 tree species as food sources or nesting sites (Wiley 1979)
- *Zenaida aurita*—one study showed that the dove uses at least 31 plants as food and at least 35 tree species for nesting (Maldonado Colón and Perez Rivera 1977) and another study indicated that the dove uses 77 plant species for various purposes (Wiley 1991)
- Sixteen bird species use the *Roystonea borinquena* for nesting sites (Pérez Rivera 1977). Numerous bird species use 120 listed plant species as food (Soil Conservation Service 1973, see endnotes)..
- Birds and mammals—50 species of plants [bromeliads, palms, grasses, and dicots (including mangroves)] used as sources of water and food in the nearby U.S. Virgin Islands (Department of Planning and Natural Resources 1988)

Future F&WS management activities should include:

- Expansion of refuge properties in southwestern Puerto Rico to form a network of critical habitats for wildlife conservation. Human population will continue to increase (fig. 2) and will be accompanied by conversion of wildlife habitat. An appropriate agency response would be the continual acquisition of all available land when feasible, including additional tracts in Sierra Bermeja (Aukema and others 2006).

- Continuation of reforestation efforts as a means of stimulating habitat restoration and forest regeneration (Parrotta and others 1997)
- Management of the Cartagena Lagoon to enhance populations of resident and migratory birds, including the target bird species which have experienced declines (Díaz-Soltero 1990)
- Management of the Candeleria and Fraternidad Lagoons in the Salinas flats for populations of shore birds through the increase of edge habitat (construction of mounds or small islands) and possibly through modification of the water level regimen
- Peer review of major F&WS management proposals and plans among local and Federal Agencies, particularly when they may lead to major habitat modification
- Development and maintenance of a small Caribbean reference library of relevant local literature and refuge studies to facilitate future management and research activities
- Fire control through adequate training, construction and maintenance of fire breaks, prescribed burning, surveillance, public education, and community involvement
- Cooperative efforts with the municipal governments and hotels to provide educational opportunities for residents and visitors to southwestern Puerto Rico
- Eradication of alien species, e.g., monkeys, and removal of unauthorized livestock that negatively impact native wildlife or their habitat
- Limitation of road construction and other habitat fragmentation to reduce the invasion of exotic flora and fauna into areas of critical wildlife habitat (Clark 1993, Faaborg and Arendt 1990, Vilella and Swank 1993a)
- Presentation of research and management activities on a periodic basis, i.e., symposia among cooperators and to the public in nearby population centers like Boquerón, Lajas, and Magüayo
- Monitoring compliance of refuge regulations, including hunting and special use permits, i.e., commercial salt extraction and grass harvest
- International cooperation among conservationists, resource managers, policymakers, and the public to promote programs beneficial to migratory land birds (Arendt 1992)

Future research activities should include all levels of biological diversity—genetics, species, communities, and ecosystems (Clark 1993)—involving most of the following:

- Partnerships with domestic scientists at government agencies and universities to carry out research on cultural, scientific, and historic resources for refuges and surrounding lands (Meretsky and others 2006)
- Compilation and publication of data from monitoring projects, i.e., bird surveys, nesting activities, bird banding, and water-quality monitoring at Cartagena Lagoon; and identification of future data needs and studies
- Investigation of the ecology, behavior, and habitat requirements of native wildlife species (Díaz-Soltero 1990)
- Stimulation of forest succession on the barren upper slopes of Cerro Mariquita through innovative techniques, i.e., use of artificial bird perches (McClanahan and Wolfe 1993)
- Recurrent plant inventories, including the permanent Tinaja plots and vegetation on other tracts, to determine changes in structure and species composition over time
- Monitoring of tree plantings to determine their survival, growth, and future potential for habitat restoration, and verification of associated changes in habitat utilization by wildlife (Weaver and Schwagerl 2004, 2005)
- Determination of flowering and fruiting patterns by plant species (Aukema and others 2006)
- Monitoring avifauna feeding, nesting, and migratory habits (Grear 1992a, 1992b)
- Monitoring long-term population dynamics to determine temporal, e.g., population fluctuations over time, and spatial changes, e.g., differential use of habitats, for both migrant and resident species (Arendt 1992)

- Monitoring biological diversity of animal species other than birds, e.g., mammals, reptiles, amphibians, fishes, and insects; to determine their critical habitats, population numbers, roles in refuge ecosystems, and dynamics over time, i.e., in reponse to vegetation changes, introduced species, and climatic events
- Propagation of rare and endangered species for use in planting trials or as ornamentals within the region to enhance their survival
- Developing a brochure on major refuge insects, including butterflies (Ramos 1982)
- Monitoring the salt operations at Cabo Rojo to determine their impact on wildlife species, and simultaneously assessing the possible impacts of alternative management strategies for the salt ponds
- Excavating and interpreting shell mounds for refuge visitors

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Appendix A

Alphabetical listing by scientific name of all tree species that were mentioned in the text or tables, and of other plant species mentioned only in text. Ecological information is provided only for tree species [a]

Scientific name	Common names		Ecological information		Habit [c]	Origin [d]
	English	Spanish	Flower [b]	Fruit [b]		
			months			
Tree species (text and other tables)						
Acacia farnesiana (L.) Willd.	Sweet acacia	Aroma	NO-FE	?	D	N?
Acacia tortuosa (L.) Willd.	Twisted acacia	Casia	YR	YR?	D	N
Acrocomia media O.F. Cook	Prickly palm	Corozo	YR	YR	E	N
Adelia rincilla L.	NA	Cotorro	FA-SP	WI-SU	D	N
Albizia lebbeck (L.) Benth	Tibet	Acacia amarilla	AP-SE	YR	D	I
Amyris elemifera L.	Sea amyris	Tea	MA-OC	YR	E	N
Andira inermis (W. Wright) DC.	Cabbage angelin	Moca	JA-FE+MA-SE	MA-DE	D	N
Annona glabra L.	Pond Apple	Corozón	SP	SU	D	N
Annona muricata L.	Soursop	Guanábana	JU-OC	FA	E	N
Annona squamulosa L.	Sugar Apple	Anón	YR	YR	D	N
Avicennia germinans (L.) L.	Black mangrove	Mangle prieto	YR	YR	E	N
Bauhinia monandra Kurz	Butterfly bauhinia	Mariposa	YR	YR	E	I
Bourreria succulenta Jacq.	Pigeon berry	Palo de vaca	YR	YR	E	N
Bucida buceras L.	Oxhorn bucida	Ucar	YR	YR	E	N
Bunchosia glandulosa (Cav.) L.C. Rich.	NA	Café forestero	MA-OC	JU-AU	E/D	N
Bursera simaruba (L.) Sarg.	Terpentine tree	Almácigo	SP-SU	SP-SU	D	N
Byrsonima lucida (Mill.) L.C. Rich.	Long Key byrsonima	Palo de doncella	YR	YR	E	N
Byrsonima spicata (Cav.) HBK.	NA	Maricao	YR	YR	E	N
Calophyllum calaba L.	Santa-maria	María	SP-SU	SP-WI	E	N
Calotropis procera (Aiton) W.T. Aiton	Giant milkweed	Algodón de seda	YR	YR	E	I
Canella winterana (L.) Gaertner	Canella	Barbasco	YR	YR	E	N
Capparis amplissima Lam.	NA	Burro blanco	YR	YR	E	N
Capparis cyanophallophora L.	Jamaica caper	Burro prieto	YR	YR	E	N
Capparis flexuosa (L.) L.	Limber caper	Palinguan	YR	YR	E	N
Capparis hastata Jacq.	NA	Burro	YR	YR	E	N
Capparis indica (L.) Fawe & Rendle	Linguam	Sapo prieto	YR	YR	E	N
Carica papaya L.	Papaya	Lechosa	YR	YR	E	I
Casearia aculata Jacquin	NA	Cambrón	YR	YR	D	N
Casearia guianensis (Aublet) Urban	Wild coffee	Palo blanco	YR	YR	E	N
Cassine xylocarpa Vent.	Marble-tree	Coscorrón	YR	YR	E	N
Cedrela odorata L.	Spanish cedar	Cedro hembra	YR	YR	D	N
Ceiba pentandra (L.) Gaertner	Silk-cotton-tree	Ceiba	DE-FE	SP-SU	D	N
Chamaesyce articulata (Aublet) Britton	NA	NA	YR	YR	D	N

continued

Appendix A (continued)

Alphabetical listing by scientific name of all tree species that were mentioned in the text or tables, and of other plant species mentioned only in text. Ecological information is provided only for tree species [a]

Scientific name	Common names		Ecological information		Habit [c]	Origin [d]
	English	Spanish	Flower [b]	Fruit [b]		
			months			
Chryobalanus icaco L.	Coco-plum	Hicaco	YR	YR	E	N
Citharexylum fruiticosum L.	Fiddlewood	Péndula	YR	YR	E	N
Citrus aurantifolia (Christm.) Swingle	Lime	Limón ágrio	SP-JL	SU-FA	E	I
Citrus limon (L.) Burm. f.	Lemon	Limón de cabro	SP	SU-FA	E	I
Clerodendron aculeatum (L.) Schlecht	Haggarbush	Escambrón	YR	YR	?	N
Clusia rosea Jacquin	Wild-mammee	Cupey	YR	YR	E	N
Cnidoscolus aconitifolius (Mill.) I.M. Johnst.	NA	Papayuelo	YR	O	E	I
Coccoloba diversifolia Jacq.	Doveplum	Uvilla	YR	YR	E	N
Coccoloba microstachya Willd.	NA	Uverillo	SU-FA	WI	E/D	N
Coccoloba swartzii Meissn.	NA	Ortegón	JU-SE	JU-SE	E	NE
Coccoloba uvifera (L.) L.	Sea grape	Uva de playa	YR	YR	E	N
Coccoloba venosa L.	Chicory-grape	Calabreña	MA-SE	OC	D	N
Cocos nucifera L.	Coconut	Palma de coco	YR	YR	E	I
Colubrina arborescens (Mill.) Sarg.	Coffee colubrina	Abeyuelo	SP-FA	SP-FA	E	N
Colubrina elliptica (Sw.) Briz. & Stern	Soldierwood	Mabí	JL-NO	JL-JA	E	N
Comocladia dodoaea (L.) Urban	Pioson ash	Carrasco	WI-SP	SP-SU	E	N
Conocarpus erectus L.	Button mangrove	Mangle botón	YR	YR	E	N
Cordia alliodora (Ruiz & Pav.) Oken	Onion cordia	Capa prieto	YR	YR	E	N
Cordia collococca L.	Red manjack	Cerezo	SP-SU	SP-SU	D	N
Cordia rickseckeri Millsp.	Manjack	San Bartolome	YR	YR	D?	N
Cordia sulcata DC.	White manjeck	Moral	SP-FA	YR	D	N
Crecentia portoricensis Britton	NA	NA	?	?	E	NE
Crescentia cujete L.	Calabash tree	Higüero	YR	YR	E/D	N
Crescentia linearifolia Miers.	NA	Higüerito	YR	YR	D	N
Crossopetallum rhacoma Crantz	Florida crossopetalum	Coral	YR	YR	E/D	N
Croton astroites Dryander	NA	Marán	YR	YR	E	N
Delonix regia (Bojer) Raf.	Flamboyant tree	Flamboyán	MA-JL	YR	D	I
Erithalis fruticosa L.	Black torch	Jayajabico	YR	YR	E	N
Erythroxylum aerolatum L.	Thin-leaf erythroxylum	Indio	OC-JU	?	D	N
Erythroxylum rotundifolium Lunan	Brisselet	Rocio	SU-FA	SU	D	N
Eugenia biflora (L.) DC.	NA	Hoja menuda	SP-SU	SP-SU	E	N
Eugenia ligustrina (Sw.) Willd.	NA	Palo de muleta	MA	?	E	N
Eugenia monticola (Sw.) DC.	Black-cherry	Biriji	SP-FA	SP-FA	E	N
Eugenia pseudosidium Jacq.	Wild guava	Quiebrahacha	YR?	YR?	E	N
Eugenia sessiliflora Vahl	NA	NA	SP-SU	SP-SU	E	N

continued

Appendix A (continued)

Alphabetical listing by scientific name of all tree species that were mentioned in the text or tables, and of other plant species mentioned only in text. Ecological information is provided only for tree species [a]

Scientific name	Common names		Ecological information		Habit [c]	Origin [d]
	English	Spanish	Flower [b]	Fruit [b]		
			months			
Eugenia woodburyana Alain	NA	Hoja menuda	?	?	E	NE
Eugenoa procera (Sw.) Poir.	NA	Hoja menuda	SP-FA	SP-FA	E	N
Exostema caribaeum (Jacq.) R. & S.	Caribbean princewood	Albarillo	YR	YR	E	N
Ficus benjamina L.	Benjamin fig	Laurel de Benjamina	?	SP-FA	E	I
Ficus citrifolia Mill.	Shortleaf fig	Jagüey blanco	YR?	YR	E	N
Gaussia attentuata O.F. Cook Beccari	Puerto Rico Ilume-palm	Palma de lluvia	YR	YR	E	NE
Gliricidia sepium (Jacq.) Kunth ex Walp.	Mother-of-cacao	Mata-ratón	WI-SP	WI-SU	D	I
Guaiacum officinale L.	Lignum-vitae	Guayacán	SP-FA	SP-FA	E	N
Guaiacum sanctum L.	Holywood lignum-vitae	Guayacán blanco	SP-FA	SP-FA	E	N
Guapira discolor (Spreng.) Little	Barrehorno	Barrehorno	SP-SU	SU-FA	E	N
Guapira fragrans (Dum.-Cours) Little	Black mampoo	Corcho	SP-SU	SP-SU	E	N
Guazuma ulmifolia Lam.	West Indian elm	Guácima	SP-FA	YR	E/D	N
Guettarda elliptica Sw.	Velvetseed	Cucubano liso	SP	SU	E	N
Guettarda scabra (L.) Vent.	Greenhart	Palo de cucubano	YR	YR	E	N
Gymnanthes lucida Sw.	Oysterwood	Yaití	SP-FA	SP-FA	E	N
Haematoxylum campechianum L.	Logwood	Campeche	DE-MA	?	D	I
Helicteres jamaicensis Jacq.	Cowbush	Cuernecillo	YR	YR	E	N
Hippomane mancinella L.	Manchineel	Manzanillo	SP-OC	YR	E	N
Hymenaea courbaril L.	West Indian locust	Algarrobo	SP-FA	?	E	N
Inga laurina (Sw.) Willd.	Sweetpea	Guamá	YR	YR	E	N
Inga vera Willd.	NA	Guaba	YR	YR	E	N
Jaquinia arborea Vahl	Torchwood	Barbasco	WI-SU	SP-FA	E	N
Krugiodendron ferreum (Vahl) Urban	Ironwood	Bariaco	YR	YR	E	N
Laguncularia racemosa (L.) Gaertn.	White mangrove	Mangle blanco	YR	YR	E	N
Lantana camera L. var. camara	Lantana	Lantana	YR	YR	E	N
Leucaena leucocephala (Lam.) de Wit	Tantan	Zarcilla	YR	YR	D	I
Machaerium lunatum (L. f.) Ducke	NA	Escambrón	YR	YR	E	N
Machaonia portoricensis Baill	NA	Alfilerillo	YR	YR	D	NE
Mangifera indica L.	Mango	Mango	WI-SP	MA-SE	E	I
Manilkara bidentata (A. DC.) Chev.	Balata	Ausubo	YR	YR	E	N
Manilkara pleeana (Pierre) Cronq.	NA	Zapote de costa	YR	YR	E	N
Melia azedarach L.	Chinaberry	Alelaila	YR	YR	D	I
Melicoccus bijugatus Jacq.	Kinep	Quenepa	AP-JU	JU-SE	E	I
Metopium toxiferum (L.) Krug & Urban	Florida poisontree	Papayo	FE	SU-FA	E	N
Myrcia citrifolia (Aubelet) Urban	NA	Limoncillo del monte	SP-FA	SU-WI	E	N

continued

Appendix A (continued)

Alphabetical listing by scientific name of all tree species that were mentioned in the text or tables, and of other plant species mentioned only in text. Ecological information is provided only for tree species [a]

Scientific name	Common names		Ecological information		Habit [c]	Origin [d]
	English	Spanish	Flower [b]	Fruit [b]		
			months			
Neea buxifolia (Hook. f.) Heimerl	NA	NA	SP-SU	SU	E	N
Ottoschulzia rhodoxylon (Urban) Urban	NA	NA	?	?	E	NE
Ouratea littoralis Urban	NA	Abey amarillo	YR	YR	E	N
Oxandra lanceolata (Sw.) Baill.	Lancewood	Haya prieto	?	?	?	N
Parkinsonia aculeata L.	Jerusalem-thorn	Palo de rayo	YR	YR	D	N
Pectitia domingensis Jacq.	Fiddlewood	Capa blanco	YR	YR	E	N
Persea americana Mill.	Avocado	Aguacate	JA-AP	AP-MA	D	I
Pictetia aculeata (Vahl.) Urban	Fustic	Tachuelo	YR	YR	D	N
Pilosocereus royenii (L.) Byles & Rowley	Pipe-organ cactus	Sebucán	YR	?	E	N
Pimenta racemosa (Mill.) J.W. Moore	Bay-rum-tree	Malagueta	AP-AU	AU-OC	E	N
Piscidia carthagenesis Jacq.	Dogwood	Ventura	FE-JU	SU	D	N
Pisonia albida (Heimer) Britton & Standley	Corcho bobo	Corcho bobo	FE-MA	SP (late)	D	N
Pisonia subcordata Sw.	Water mampoo	Corcho blanco	SP-SU	SP	D	N
Pithcellobium dulce (Roxb.) Benth	Ape's earring	Guamá americano	JA-MA	FE-JL	E	I
Pithcellobium unguis-cati (L.) Mart.	Catclaw	Una de gato	YR	YR	D	N
Plumeria alba L.	Milktree	Alelí	YR	YR	E	N
Polygala cowellii (Britton) Blake	Violet-tree	Violeta	WI	MA-AP	D	NE
Polygala penaea L.	NA	NA	YR	YR	E	N
Prockia crusis R. Brown ex L.	NA	NA	?	SU	E/D	N
Prosopis juliflora (Sw.) DC.	Mesquite	Bayahonda	SU-FA	SU-FA	D	I
Pterocarpis officinalis Jacq.	Swamp bloodwood	Palo de pollo	FE-SE	AP-NO	E	N
Randia aculeata L.	Box briar	Tintillo	YR	YR	D	N
Rauvolfia nitida Jacq.	Bitter ash	Palo amargo	YR	YR	E	N
Reynosia uncinata Urban	NA	Cascarolla	YR	YR?	E	N
Rhizophora mangle L.	Red mangrove	Mangle rojo	YR	YR	E	N
Ricinus communis L.	Castorbean	Higüerito	YR	YR	E	I
Rochefortia acanthophora (DC.) Griseb.	Juso	Juso	SP-SU	SP-SU	D	N
Rondeletia inermis (Spreng) Krug & Urban	NA	Cardobancillo	YR	YR	E	NE
Roystonea borinquena O.F. Cook	Royal palm	Palma royal	YR?	YR?	E	N
Sabal casuarium (O.F. Cook) Beccari	Puerto Rico palmetto	Palma de sombrero	YR	YR	E	NE
Samanea saman (Willd.) Merril	Raintree	Samán	SP-FA	FA-WI	E	I
Sapindus saponaria L.	Wingleaf soapberry	Jaboncillo	?	?	E	N
Savia sessiliflora (Sw.) Willd.	NA	Amansa guapa	YR	YR	D	N
Schaefferia frutescens Jacq.	Florida boxwood	Jiba	YR	YR	E	N
Securinga acidoton (L.) Rawcett & Randle	NA	NA	SP-SU	SP-SU	D	N

continued

Alphabetical listing by scientific name of all tree species that were mentioned in the text or tables, and of other plant species mentioned only in text. Ecological information is provided only for tree species[a]

Scientific name	Common names		Ecological information			
	English	Spanish	Flower[b]	Fruit[b]	Habit[c]	Origin[d]
			months			
Senna polyphylla (Jacq.) Irwin & Barneby	Desert cassia	Ratama prieta	YR	YR	D	N
Sideroxylon foetidissum Jacq.	False mastic	Tortugo amarillo	YR	YR	E	N
Sideroxylum obovatum Lam.	Breakbill	Lechecillo	YR?	YR?	E	N
Solanum drymophilum O.E. Schultz	NA	Erubia	YR	YR	?	NE
Spondias mombin L.	Hogplum	Jobo	WI-SU	SU-WI	D	N
Stahlia monosperma (Tul.) Urban	NA	Cobana negra	FE-JU	SU-FA	E	N
Stenocereus hystrix (Mill.) R. Kiesling	Organpipe cactus	Pitahaya	SP-SU	SU	E	N
Sterculia apetala (Jacq.) Karst	Panama tree	Anacaguita	SP-FA	?	E	I
Swietenia mahagoni Jacq.	Small leaf mahogany	Caoba dominicana	MA-JL	WI	D	I
Tabebuia heterophylla (DC.) Britton	White-cedar	Roble blanco	SP+YR	YR	D	N
Tamarindus indica L.	Tamarind	Tamarindo	SP-FA	WI-SP	E	I
Tecoma stans (L.) Juss.	Ginger-thomas	Roble amarillo	YR	YR	E	N
Tectona grandis L. f.	Teak	Teca	AU-DE	YR	D	I
Terminalia catappa L.	Indian almond	Almendro	YR	YR	E/D	I
Thespesia populnea (L.) Solander	Seaside mahoe	Emajagüilla	SP-FA	SP-FA	E	I
Thouinia striata Radlk.	NA	Ceboruquillo	SP-FA	SP-FA	E	NE
Thouinia striata var. portoricensis (Radlk) Voltava & Alain	Serrasuela	Serrasuela	YR	YR	D	NE
Trichilia hirta L.	Broomstick	Tinacio	YR	YR	D	N
Trichilia triacantha Urban	NA	Bariaco	FE	?	E	NE
Vitex divaricata Swartz	White fiddlewood	Higüerillo	FE-JL	JU-NO	D	N
Zanthoxylum flavum Vahl	Yellow sanders	Aceitillo	WI-SU	SP-FA	D	N
Zanthoxylum martinicense (Lam.) DC.	White prickle	Espino rubial	SP-FA	SP-FA	E	N
Zanthoxylum monophyllum (Lam.) P. Wilson	Yellow prickle	Palo rubio	?	?	D	N
Ziziphus reticulata (Vahl) DC.	Cascarroya	Cascarroya	SU	SU	E	N
Other Plant Species (text only)						
Aristida chaseae A.S. Hitchc.	NA (grass)	NA (graminea)				
Aristida portoricensis Pilger	NA (grass)	NA (graminea)				
Batis maritima L.	Saltwort, pickleweed					
Bromelia penguin L.	Penguin bromelia	Piña de ratón				
Bulbostylis pauciflora (Liebm.) C.B. Clarke	Fewflower hairsedge					
Catesbaea melanocarpa Krug & Urban	Tropical lilythorn					
Cenchrus ciliaris L.	African foxtail					

continued

Appendix A (continued)

Alphabetical listing by scientific name of all tree species that were mentioned in the text or tables, and of other plant species mentioned only in text. Ecological information is provided only for tree species [a]

Scientific name	Common names		Ecological information			
	English	Spanish	Flower [b]	Fruit [b]	Habit [c]	Origin [d]
			months			
Cynometra portoricensis Krug & Urban	False oregano	Oreganillo falso				
Dendrophthora bermejae Kuijt, Carlo & Aukema	Mistletoe	Muérdago				
Heliotropium curassavicum L.	Seaside heliotrope					
Hohenbergia antillana Mez.	Antilles lacebark					
Leptocereus quadricostatus Bello (Britt & Rose)		Pitahaya				
Lyonia truncata Urban var. proctorii	Proctor's staggerbush					
Panicum maximum Jacq. P.Q.	Guinea grass					
Polygala hecatantha Urban	West Indian milkwort					
Psychilis krugii (Bello) Sauleda	Krug's peacock orchid					NE
Sesuvium portulacastrum L.	Shoreline purslane					
Tephrosia cinerea (L.) Pers.	Asshen hoarypea					
Tillandsia recurvata (L.) L.	Small ballmoss					
Veronia proctorii L.E. Urbatsch	NA	NA				
Waltheria calcicola Urban	Raichie					
Wedelia lanceolata DC.	Riverbank creeping oxeye					N
Zamia portoricensis Urban	?	Marungüey	?	?	E	NE

[a] Scientific names for plants were used in text to avoid confusion. Many species have several common names in both languages and some species have no common name.

[b] Months in flower or fruit, as follows: JA, FE, MA, AP, MM, JU, JL, AU, SE, OC, NO, DE; YR = entire year, or intermittently during the year; seasonal (i.e., SP = spring, SU = summer, FA = fall, WI = winter); ? = uncertain or data not provided; O = not fruit bearing in Puerto Rico. Sources; Little and Wadsworth 1964; Little and others 1974.

[c] Habit: D = deciduous; E = evergreen; E/D = evergreen, except in pronounced drought.

[d] Origin: N = native; NE = endemic to Puerto Rico; I = introduced; ? = uncertain.

Appendix B

Plant species at the Cabo Rojo and Laguna Cartagena National Wildlife Refuges

Family and species	Refuges [a]			
	Cabo Rojo		Laguna Cartagena	
	H	S	L	T
Pteridophyta				
Polypodiaceae				
Azolla caroliniana Wild.	–	–	X	–
Acrostichum danaeifolium Langsd. & Fisher	–	–	–	X
Cheilanthes microphylla (Sw.) Sw.	–	–	–	X
C. trichomanolides (L.) Mett.	–	–	–	X
Marsilea ancylopoda A. Braun	–	–	X	–
Memionitis palmata L.	–	–	–	X
Nephrolepis biserrata (Sw.) Schott	–	–	X	–
N. multiflora (Roxb.) Jarret ex Morton	–	–	–	X
Polypodium heterophyllum L.	–	–	–	X
P. polypodioides (L.) Watt	–	–	–	X
Gynospermae (Cycadophyta)				
Zamiaceae				
Zamia portoricensis Urban	–	–	–	X
Monocotyledonae				
Alismataceae				
Echinodorus berteroi (Spreng.) Fassett	X	–	X	–
Sagittaria intermedia M. Micheli	–	–	X	–
S. lancifolia L.	X	–	X	–
Araceae				
Anthurium crenatum (L.) Kunth	–	–	–	X
Philodendron scandens Koch & Sello	–	–	X	–
Pistia stratiotes L.	–	–	X	–
Xanthosoma brasiliense (Desf.) Engl.	–	–	–	X
Arecaceae				
Acrocomia media O.F. Cook	X	–	X	–
Cocos nucifera L.	X	X	X	–
Roystonea borinquena O.F. Cook	X	–	X	–
Sabel morrissi H. Wendl.	X	–	–	–
Thrinax morrissi H. Wendl.	–	–	–	X
Commelinaceae				
Commelina diffusa Burm. f	–	–	X	–
C. elegans HBK.	–	–	X	X
Cyperaceae				
Bulbostylis capillaris (L.) Kunth ssp. *antillana* (Britton) T. Koyama	X	–	–	X
Cyperus articulatus L.	–	–	X	–
C. compressus L.	–	–	X	–
C. esculentus L.	–	–	X	–
C. giganteus Vahl	–	–	X	–
C. laevigatus L.	–	–	X	–
C. lingularis L.	–	–	X	–
C. ochraceus Vahl	X	–	X	–
C. odoratus (Presl.) Mattf. & Kuk	–	–	X	–
C. rotundus L.	X	–	X	X
C. surinamensis Rottb.	X	–	X	–
Eleocharis cellulosa Torrey	–	–	X	–

continued

Plant species at the Cabo Rojo and Laguna Cartagena National Wildlife Refuges

Family and species	Refuges [a]			
	Cabo Rojo		Laguna Cartagena	
	H	S	L	T
Cyperaceae (continued)				
E. fallax Weath.	–	–	X	–
E. geniculata (L.) R. & S.	–	X	X	–
E. interstincta (Vahl) R. & S.	–	–	X	–
E. mutata (L.) R. & S.	–	–	X	–
Kyllinga brevifolia Rottb.	–	–	–	X
Pycreus poystachyos (Rottb.) P. Beauv.	–	–	–	X
Rhynchosphora nervosa (Vahl) Boeck. ssp. ciliata (Vahl) T. Koyama	–	–	–	X
R. holochoenoides (L.C. Rich.) Herter	–	–	–	X
Scleria lithosperma (L.) Sw.	–	–	–	X
S. pterota Presl.	–	–	–	X
Graminae (or Poaceae)				
Anthephora hermaprodita (L.) Kuntze	X	–	–	–
Aristida adscensionis L.	X	–	–	–
A. chaseae Hitchc.	X	–	–	–
A.portoricensis Pilger	–	–	–	X
Bambusa vulgaris Schrad. ex Wendl.	–	–	X	–
Bothriochloa pertusa (L.) A. Camus	X	–	X	X
Bouteloua americana (L.f) Scribn.	X	–	X	–
B. repens (HBK.) Scribn. & Merr.	–	–	–	X
Brachiaria adspersa (Trin.) Parodi	X	–	–	–
B. fasciculata (Sw.) S.T. Blake	X	–	–	–
B. purpurascens (Raddi) Henr.	–	–	X	–
B. subquadripara (Trin.) Hitchc.	X	–	–	X
Cenchrus ciliris L.	X	X	X	X
C. echinatus L.	X	X	X	–
Cheloris ciliata Sw.	X	–	–	–
C. inflata Link	X	–	X	–
Cynodon dactylon (L.) Pers.	X	–	X	–
Dactyloctenium aegyptium (L.) Beauv.	X	–	X	–
Dichanthium annulatum (Forssk.) Stapf.	X	X	X	X
Digitaria bicornus (Lam.) R. & S.	–	–	X	X
D. decumbens Stent	X	–	–	–
D. eggersii (Hack.) Menr.	–	–	–	X
D. insularis (L.) Mez	–	–	X	–
D. sanguianalis (L.) Scop.	X	–	–	–
Echinochloa colona (L.) Link	X	–	X	–
Eleusine indica (L.) Gaertn.	–	–	X	–
Eragrostis ciliaris (L.) R. Br.	X	–	X	–
E. tenella (L.) Beauv. ex R. & S.	X	–	–	–
Eriochloa polystachya HBK.	–	–	X	–
E. punctata (L.) Desv.	–	–	X	–
Heteropogon contortus (L.) Beauv. ex R. & S.	X	–	–	–
Hymenachne amplexicaulis (Rudge) Hees	–	–	X	–
Lasiacis divaricata (L.) Hitchc.	–	–	–	X
Leersia monandra Sw.	–	–	–	X
Leptochloa filiformis (Lam.) Beauv.	X	–	–	–
Olyra latifolia L.	–	–	–	X
Panicum maximum Jacq.	X	X	X	X
Paspalidium geminatum (Forssk.) Stapf	X	–	X	–

continued

Plant species at the Cabo Rojo and Laguna Cartagena National Wildlife Refuges

Family and species	Refuges[a]			
	Cabo Rojo		Laguna Cartagena	
	H	S	L	T
Graminae (or Poaceae) (continued)				
Paspalum conjugatum Berg.	–	–	X	–
P. distichum L.	–	–	X	–
P. laxum Lam.	X	–	–	–
P. notatum Flugge	–	–	X	–
P. setaceum Michx. var. *ciliatifolium* (Michx.) Vasey	X	–	–	–
Pharus glaber HBK.	–	–	–	X
Rottboellia cochinchinensis (Lour.) Clayton	–	–	X	–
Saccharum officinarum L.	–	–	X	–
Setaria barbata (Lam.) Kunth	–	–	X	–
S. rariflora Mikan	–	–	X	–
S. setosa (Sw.) Scribn. var. *leiophylla* (Nees) Arechavaleta	X	–	–	–
Sporobolus indicus (L.) R. Br.	–	–	–	X
S. jacquemontii Kunth	X	–	X	–
S. pyramidatus (Lam.) Hitchc.	X	–	–	–
S. virginicus (L.) Kunth	X	–	–	–
Tragus berteronianus Schult.	X	–	–	–
Tricholaena repens (Willd.) Hitchc.	X	–	–	X
Urochloa maxima (Jacq.) R.D. Webster	X	–	–	–
Liliaceae				
Aloe vera (L.) Burn. f.	X	–	–	–
Sansevieria trifasciata Prain	X	X	X	–
Yucca aloifolia L.	X	X	–	–
Najadaceae				
Najas guadalupensis (Spreng.) Morong	–	–	X	–
Orchidaceae				
Epidendrum krugii Bello	–	–	–	X
Oecceoclades maculata (Lindl.) Lindl.	X	–	–	X
*Psychilis krug*i (Bello) Sauleda	–	–	–	X
Tetramicra canaliculata (Aubl.) Urban	–	–	–	X
Vanilla claviculata (W. Wr.) Swartz	–	–	–	X
Pontederiaceae				
Eichhornia crassipes (Mart.) Solms in DC.	–	–	X	–
Smilaceae				
Smilax coriacea Spreng.	–	–	–	X
Typhaceae				
Typha domingensis Pers.	–	–	X	–
Dicotyledonae				
Acanthaceae				
Blechum pyramidatum (Lam.) Urban	–	–	X	–
Justica comata (L.) Lam.	–	–	X	–
Ruellia tuberosa L.	X	X	X	–
Siphonoglossa sessilis (Jacq.) Gibson	X	–	–	–
Thunbergia alata Bojer ex Sims	–	–	X	–

continued

Plant species at the Cabo Rojo and Laguna Cartagena National Wildlife Refuges

Family and species	Refuges[a]			
	Cabo Rojo		Laguna Cartagena	
	H	S	L	T
Aizoaceae				
Mollugo verticillata L.	X	–	–	–
Sesuvium portulacastrum L.	X	X	–	–
Trianthema portulacastrum (L.) L.	–	–	–	X
Amaranthaceae				
Achyanthes aspera L.	X	X	–	X
Alternanthera paronychioides St. Hil.	–	–	X	–
Amaranthus crassipes Schlecht	X	X	–	–
A. dubius Mart.	X	–	X	–
A spinosus L.	–	–	X	–
A. viridis L.	–	–	X	X
Gomphrena serrata L.	X	–	–	X
Iresine angustifolia Euphrasén	–	–	–	X
Amaryllidaceae				
Hymenocallis caribaea (L.) Herb.	X	–	X	–
Anacardiaceae				
Comocladia dodonaea (L.) Urban	X	–	–	X
Mangifera indica L.	X	–	X	X
Metopium toxiferum (L.) Krug & Urban	X	X	–	–
Spondias mombin L.	X	–	X	X
Annonceae				
Annona glabra L.	–	–	X	–
A. muricata L.	X	–	X	–
A. reticulata L.	–	–	X	–
A. squamosa L.	X	X	X	–
Oxandra lanceolata (L.) Urban	–	–	–	X
Apocynaceae				
Catharanthus roseus (L.) G. Don	X	X	–	–
Pentalinon luteum (L.) Hansen & Wunderlin	–	X	–	–
Plumaria alba L.	X	X	–	X
P. obtusa L.	X	–	–	–
Rauvolfia nitida Jacq.	X	X	X	X
R. viridis Willd. Ex. Roem. & Schult.	X	–	X	–
Aquifoliaceae				
Ilex sp.	–	–	X	–
Asclepidaceae				
Asclepias curassavica L.	–	–	X	–
Calotropis procera (Ait.) Ait.f.	X	X	X	X
Cryptostegia grandiflora R. Brown	–	–	X	–
Matelea maritima (Jacq.) Woodson	X	–	–	–
Metastelma linearae Bello	–	–	–	X
M. fallax Schltr.	X	–	–	–
Basellaceae				
Anredera leptostachys (Moq.) v. Stennis	X	–	–	X
Bataceae				
Batis maritima L.	X	X	–	–

continued

Plant species at the Cabo Rojo and Laguna Cartagena National Wildlife Refuges

Family and species	Refuges [a]			
	Cabo Rojo		Laguna Cartagena	
	H	S	L	T
Bignoniaceae				
Crescentia cujete L.	X	–	X	X
C. linearifolia Miers.	X	–	X	–
C. portoricensis Britton	X	–	–	–
Disticus lactifolia (Vahl) DC.	X	–	X	X
Macfadyena unguis-cati (L.) A. Gentry	X	–	X	X
Spathodea campanulata Beauv.	–	–	X	–
Tabebuia donnell-smithii Rose	X	–	–	–
T. haemantha (Bert.) DC.	–	–	–	X
T. heterophylla (DC.) Britton	X	X	X	X
Tecoma stans (L.) Kunth in HBK.	X	–	–	–
Bombacaceae				
Ceiba pentandra (L.) Gaertner	X	–	X	X
Boraginaceae				
Bourreria succulenta Jacq. var. succulenta	X	X	X	X
B. virgata (Sw.) G. Don	–	–	–	X
Cordia alliodora (R. & P.) Oken	–	–	X	X
C. collococca L.	X	–	X	X
C. curassavica (Jacq.) R.	–	–	–	X
C. globosa (Jacq.) Kunth var. *humilis* (Jacq.) I.M. Johnst.	X	–	–	X
C. laevigata Lam.	X	–	X	X
C. polycephala (Lam.) I.M. Johnst.	–	–	X	–
C. rickseckeri Millsp.	X	–	–	–
C. stenophylla Alain	X	–	X	X
C. sulcata DC.	X	–	X	X
Heliotropium angiospermum Murray	X	X	X	X
H. curvassavicum L.	X	X	X	–
H. fruticosum L.	X	–	–	X
H. indicum L.	X	–	–	–
H. procumbens Mill.	X	–	–	–
H. ternatum Vahl	–	–	–	X
Rochefortia acanthophora (DC.) Griseb.	X	X	–	X
Tournefortia hirsutissima L.	–	–	X	X
T. volubilis L.	X	X	X	–
Brassicaceae				
Brassica sp.	X	–	–	–
Cakile lanceolata (Wild.) O.E. Schultz	X	–	–	–
Lepidum virginicum L.	–	–	–	X
Bromeliaceae				
Bromelia pinguin L.	X	–	X	X
Hohenbergia portoricensis Mez	–	–	X	–
Pitcairnia angustifolia Aiton	–	–	–	X
Tillandsia polystachya (L.) L.	–	–	X	–
T. recurvata (L.) L.	X	X	X	X
Burseraceae				
Bursera simaruba (L.) Sarg.	X	X	X	X
Tetragastris balsamifera (Sw.) Kuntze	–	–	–	X
Cactaceae				
Harrissia portoricensis Britton	X	–	–	–
Hylocereus trigonus (Haw.) Safford	–	–	X	X

continued

Plant species at the Cabo Rojo and Laguna Cartagena National Wildlife Refuges

Family and species	Refuges			[a]
	Cabo Rojo		Laguna Cartagena	
	H	S	L	T
Cactaceae (continued)				
Leptocereus quadricostatus (Bello) Britton & Rose	X	X	X	X
Melocactus intortus (Mill.) Urban	X	X	–	X
Opuntia borinquensis Britton & Rose	X	–	–	–
O. cochenillifera (L.) Miller	–	–	X	–
O. dillenii (Ker-Gawl.) Haw.	X	–	X	X
O. repens Bello	X	X	X	X
O. tricantha (Willd.) Sweet	X	–	–	–
Pilosocereus royenii (L.) Byles & Rowley	X	X	X	X
Campanulaceae				
Sphenoclea zeylanica Gaertn.	–	–	X	–
Canellaceae				
Canella winterana (L.) Gaertner	–	X	–	–
Capparaceae				
Capparis amplissima Lam. ssp. portoricensis	–	–	X	X
C. baducca L.	X	–	–	X
C. cyanophallophora L.	–	–	–	X
C. flexuosa (L.) L.	X	–	X	X
C. hastada Jacq.	X	X	X	X
C. indica (L.) Fawc. & Rendle	X	X	X	X
Cleome gynandra L.	–	–	X	–
C. spinosa Jacq.	X	–	–	–
C. stenophylla Klotzsch	–	–	–	X
C. viscosa L.	X	–	–	–
Celastraceae				
Crosopetalum rhacoma Crantz	X	–	X	X
Elaeodendrum xylocarpum (Vent.) DC.	X	–	–	X
Gyminda latifolia (Sw.) Urban	–	–	–	X
Schaefferia frutescens Jacq.	–	–	–	X
Ceratophyllaceae				
Ceratophyllum demersum L.	–	–	X	–
Chrysobalanaceae				
Chrysobalanus icaco L.	–	X	–	X
Clusiaceae				
Clusia gundlachii Stahl	–	–	–	X
C. rosea Jacq.	X	–	X	X
Garcinia hessi (Britton) Alain	–	–	–	X
Combretaceae				
Bucida buceras L.	X	X	X	X
Conocarpus erectus L.	X	X	–	–
Laguncularia racemosa (L.) Gaertn.	–	X	–	–
Quisqualis indica L.	X	–	–	–
Terminalia catappa L.	–	X	X	X
Commelinaceae				
Callisia repens (Jacq.) L.	–	–	–	X
Commelina diffusa Burn. F.	–	–	–	X
C. elegans Kunth in HBK.	X	–	X	–

continued

Plant species at the Cabo Rojo and Laguna Cartagena National Wildlife Refuges

Family and species	Refuges [a]			
	Cabo Rojo		Laguna Cartagena	
	H	S	L	T
Compositae				
Acanthospermum hispidum DC.	X	–	X	X
Bidens alba (L.) DC.var. *radiata* (Sch.Bip.) Ballard in Melchert	–	–	X	–
B. cyanpiifolia Kunth	–	–	–	X
Borrichia arborescens (L.) DC.	–	X	–	–
Eclipta prostada (L.) L.	X	X	X	–
Emilia fosbergii Nicolson	X	–	–	–
Eupatorium odoratum L.	X	–	–	–
Gnaphalium indicum L.	–	X	–	–
Lagasoea mollis Cav.	X	–	–	X
Mikania micrantha HBK.	X	–	X	X
Partherium hysterophorus L.	X	–	X	X
Pectis cilaris L.	X	–	–	–
P. carthusianorum Less.	X	–	–	–
P. linifolia L.	X	–	–	–
Pluchea carolinensis (Jacq.) G. Don	X	–	–	–
P. odorata (L.) Cass.	–	–	X	–
Pterocaulon virgatum (L.) DC.	–	–	–	X
Synedrella nodiflora (L.) Gaertn.	–	–	X	X
Tridax procumbens L.	X	X	X	X
Verbesina encelioides (Cav.) Benth. & Hook.	X	–	–	–
Vernonia cinerea (L.) Less.	X	–	X	X
V. proctorii Urbatsch	–	–	–	X
Wedelia lanceolata DC.	X	X	–	X
Convolvulaceae				
Convolvulus nodiflorus Desr.	X	–	–	X
Cuscuta americana L.	–	–	–	X
C. indecora Choisey	X	–	X	–
Evovulus alsinoides (L.) L. var. *grisebachianus* Meissn.	X	–	–	–
E. convolvuloides (Wild. Ex Schultes) Stern	–	–	X	–
E. nummularius (L.) L.	–	–	X	–
Ipomoea alba L.	–	–	–	X
I. guamoclit L.	–	–	X	–
I. indica (Burm.f) Merr. var. *acuminata* (Vahl) Fosb.	X	–	–	X
I. nil (L.) Roth	X	–	–	–
I. ochracea (Lindl.) G. Don	X	–	–	–
I. steudelii Millsp.	X	–	–	X
I. triloba L.	X	–	–	X
Jacquemontia pentanthos (Jacq.) G. Don	–	–	X	–
J. tamnifolia (L.) Griseb.	X	–	–	–
Merremia aegyptia (L.) Urban	X	–	–	–
M. dissecta (Jacq.) Hall.f.	X	–	–	–
M. quinquefolia (L.) Hall.f	X	–	–	X
M. umbellata (L.) Hall.f.	X	–	X	X
Turbina corymbosa L. Raf.	–	–	–	X
Crassulaceae				
Bryophyllum pinnatum (Lam.) Oken	X	X	X	X
Cruciferae				
Rorippa portoricensis (Speng.) Stehle	–	–	X	–

continued

Plant species at the Cabo Rojo and Laguna Cartagena National Wildlife Refuges

Family and species	Refuges [a]			
	Cabo Rojo		Laguna Cartagena	
	H	S	L	T
Cucurbitaceae				
Cucumis anguria L.	X	X	X	X
Doyerea emetocathartica Grossourdy	–	–	–	X
Melothria pendula L.	X	–	–	–
Momordica charantia L.	X	–	X	X
Ericaceae				
Lyonia truncata Urban var. *proctorii* Judd	–	–	–	X
Erythroxlaceae				
Erythroxylum areolatum L.	X	X	X	–
E. brevipes DC.	–	–	–	X
E. rotundifolium Lunan	–	–	–	X
E. urbanii O.E. Schulz in Urban	–	–	–	X
Euphorbiaceae				
Acalypha bisetosa Bert.	X	–	–	–
A. portoricensis Muell. Arg.	X	–	–	X
Adelia ricinella L.	–	–	X	X
Alteramnus lucidus (Sw.) Rothm.	–	–	–	X
Argythamnia candicans Sw.	X	–	–	X
Caperonia palustris (L.) St. Hil.	–	–	X	–
Chamaesyce articulata (Aublet) Britton	–	–	–	X
C. glomerifera Millsp.	X	–	–	–
C. hirta (L.) Millsp.	X	–	X	–
C. hypericifolia (L.) Millsp.	X	–	X	–
C. hyssopifolia (L.) Small	–	–	X	–
C. prostata (Ait.) Small	X	–	–	–
Cnidoscolus aconitifolius (Mill.) I. M. Johnston	X	–	–	–
Croton astriotes Dryander	–	–	–	X
C. betulinus Vahl	X	–	–	X
C. discolor Willd.	X	–	–	–
C. glandulosus L.	X	–	–	–
C. humilis L.	X	–	–	–
C. lobatus L.	X	–	X	–
Dalechampia scandens L.	X	–	–	X
Euphorbia herterophylla L.	X	–	–	–
E. lactea Haw.	X	X	–	–
Gymnanthes lucida Sw.	–	–	–	X
Hura crepitans L.	X	–	X	–
Jatropha curcas L.	–	–	X	X
J. gossypifolia L.	X	–	X	X
J. hernandifolia Vent.	X	–	–	–
Margaritaria nobilis L.f.	–	–	–	X
Pedilanthus tithymaloides (L. Poiteau) ssp. tithymaloides	–	–	–	X
Phyllanthus amarus Schumach.	X	–	X	X
Ricinus communis L.	X	–	X	X
Securinega acidoton (L.) Rawcett & Rendle	X	–	–	–
Savia sessiliflora (Sw.) Willd.	–	–	–	X
Tragia volubilis L.	X	–	X	X

continued

Plant species at the Cabo Rojo and Laguna Cartagena National Wildlife Refuges

Family and species	Refuges [a]			
	Cabo Rojo		Laguna Cartagena	
	H	S	L	T
Flacourtiaceae				
Casearia aculata Jacq.	–	–	X	X
C. decandra Jacq.	–	–	–	X
C. guianensis (Aublet) Urban	–	–	–	X
C. sylvestris Sw.	–	–	X	X
Prockia crucis L.	–	–	–	X
Samyda dodecandra Jacq.	–	–	–	X
Goodeniaceae				
Scaevola plumieri (L.) Vahl	–	X	–	–
Guttiferae				
Calophyllum calaba L.	X	–	–	X
Hippocrateaceae				
Hippocratea volubilis L.	–	–	–	X
Krameriaceae				
Krameria ixina L.	–	X	–	X
Labiatae				
Hyptis capitata Jacq.	–	–	X	–
H. suaveolens (L.) Poit.	X	–	–	–
Leonotis nepetifolia L.	X	X	X	–
Ocium sanctum L.	X	–	–	–
O. campechianum Mill.	–	–	–	X
Lauraceae				
Cassytha filiformis L.	–	–	X	X
Licaria parvifolia (Lam.) Kostern.	–	–	–	X
Nectrandra coriacea (Sw.) Griseb.	–	–	–	X
Lemnaceae				
Lemna aequinoctialis Welw.	–	–	X	–
L. perpusilla Torry	–	–	X	–
L. polyrhiza (L.) Schleiden	X	–	X	–
Leguminosae - Caesalpinioidae				
Bauhinia monandra Kurz	–	–	–	X
Caesalpinia bonduc (L.) Roxb.	–	X	–	–
Cassia chamaecrista L.	X	–	–	–
C. fistula L.	–	–	X	–
C. obtusifolia L.	X	–	–	–
Chamaecrista glandulosa var. *swartzii* (Wikstr.) Irwin & Barneby	–	–	X	–
C. nictitans (L.) Moench	–	–	–	X
Hymenaea courbaril L.	X	X	X	X
Parkisonia aculeata L.	X	X	X	–
Senna obtusifolia (L.) Irwin & Barneby	X	–	X	–
S. occidentalis (L.) Link	–	–	X	–
S. polyphylla (Jacq.) Irwin & Barneby	X	–	X	X
S. siamea (Lam.) Irwin & Barneby		–	X	–
Stahlia monosperma (Tul.) Urban	X	X	X	–
Tamarindus indica L.	X	X	X	X

continued

Plant species at the Cabo Rojo and Laguna Cartagena National Wildlife Refuges

Family and species	Refuges[a]			
	Cabo Rojo		Laguna Cartagena	
	H	S	L	T
Leguminosae - Faboidae				
Abrus precatorius L.	X	–	X	X
Aeschynomene americana L.	–	–	X	–
A. sensitiva Swartz	–	–	X	–
Alysicarpus vaginalis (L.) DC.	X	–	X	X
Andira inermis (W. Wright) Kunth	X	–	X	X
Centrosema virginianum (L.) Benth.	X	–	X	–
Clitoria ternatea L.	X	–	–	X
Coursetia caribaea (Jacq.) Lavin	–	–	–	X
Cracca caribaea (Jacq.) Benth	X	X	–	X
Crotalaria incana L.	–	–	X	–
C. falcata Vahl ex DC.	–	–	–	X
C. lotifolia L.	–	–	–	X
C. pallida Ait.	–	–	X	–
C. retusa L.	X	–	X	–
Desmodium glabram (Mill.) DC.	X	–	–	–
D. incanum DC.	–	–	–	X
D. procumbens (Mill.) Hitchc.	X	–	–	X
D. tortuosum (Sw.) DC.	X	–	–	–
Galactia dubia DC.	–	–	–	X
G. striata (Jacq.) Urban	X	–	–	–
Gliricidia sepium (Jacq.) Kunth ex Walp.	–	–	–	X
Indigofera suffruticosa Mill.	–	–	X	X
I. tinctoria L.	X	–	–	–
Lonchocarpus domingensis (Pers.) DC.	–	–	X	–
Macroptilium lathyroides (L.) Urban	X	–	X	–
Pictetia aculeata (Vahl) Urban	X	–	X	X
Piscidia carthagenensis Jacq.	X	X	–	–
Poitea paucifolia (DC.) Lavin	X	–	–	–
Pterocarpus officinalis Jacq.	–	–	X	–
Rhynchosia minima (L.) DC.	X	–	X	–
R. reticulata (Sw.) DC.	–	–	X	–
Sesbania emerus (Aubl.) Urban	–	–	X	–
Sesbania sericea (Willd). Link	X	X	X	–
Stylosanthes hamata (L.) Taub.	X	–	–	X
S. viscosa Sw.	–	–	–	X
Tephrosia cinerea (L.) Pers.	X	–	X	–
T. senna HBK.	X	–	–	–
Teramnus labialis (L.f.) Spreng.	X	–	–	–
Zornia reticulata J.E. Smith	X	–	–	X
Leguminosae - Mimosoideae				
Acacia farnesiana (L.) Willd.	X	–	X	X
A. retusa (Jacq.) Howard	–	–	X	X
A. tortuosa (L.) Willd.	–	–	–	X
Albizia lebbeck (L.) Benth.	X	X	X	X
A. procera (Roxb.) Benth.	–	–	–	X
Dasmanthus virgatus (L.) Willd.	X	–	X	X
Inga vera Willd.	–	X	X	–
Leucaena leucocephala (Lam.) de Wit	X	X	X	X

continued

Plant species at the Cabo Rojo and Laguna Cartagena National Wildlife Refuges

Family and species	Refuges [a]			
	Cabo Rojo		Laguna Cartagena	
	H	S	L	T
Leguminosae - Mimosoideae (continued)				
Minosa casta L.	–	–	–	X
M. ceratonia L.	–	–	X	–
M. pudica L.	–	X	X	X
Neptuna plena (L.) Benth. in Hook	–	–	X	–
Pithecellobium dulce (Roxb.) Benth.	X	X	X	X
P. ungis-cati (L.) Mart.	X	X	X	–
Prosopis juliflora (Sw.) DC.	X	X	X	X
Samanea saman (Willd.) Merr.	X	–	X	X
Loganiaceae				
Spigelia anthelmia L.	–	–	X	–
Loranthaceae				
Dendropemon purpureus (L.) Krug & Urban	–	–	X	–
Malphighiaceae				
Bunchosia glandulosa (Cav.) L.C. Rich	X	–	–	–
Byrsonima lucida (Mill.) L.C. Rich.	X	–	–	–
B. spicata (Cav.) HBK.	X	–	–	X
Heteropteris purpurea (L.) Kunth	X	–	–	X
H. laurifolia (L.) A. Juss.	X	–	–	X
Stigmaphyllon emarginatum (Cav.) A. Juss.	X	–	X	X
S. floribundum (DC.) C. Anders.	–	–	X	–
S. periplocofolium (Desf.) A. Juss.	–	–	X	X
S. tomentosum (Desf.) Ndz.	–	–	X	X
Malvaceae				
Abutilon umbellatum (L.) Sweet	X	–	–	–
Bastardia viscosa (L.) HBK.	X	–	–	X
Hibiscus phoeniceus Jacq.	X	–	–	X
Gossypium barbadense L. var. barbadense	–	X	–	X
Malachra capitata (L.) L.	–	–	X	–
M. alceifolia Jacquin	X	–	X	–
M. urens Poiteau ex Ledeb. & Aldestram	–	–	X	–
Malvastrum americanum (L.) Torrey	X	–	–	–
M. corchorifolium (L.) Garcke	–	–	X	X
M. coromandelianum (L.) Garcke	X	–	–	–
Pavonia spinifex (L.) Cavanilles	–	–	–	X
Sida abutilifolia Mill.	X	–	–	X
S. acuta Burm. f.	X	X	–	X
S. alba L.	X	–	X	–
S. ciliaris L.	–	–	X	–
S. cordifolia L.	X	–	–	–
S. glabra Mill.	X	–	–	–
S. glomerata Cav.	X	–	X	X
S. jamaicensis L.	X	–	–	X
S. pyramidata Desp. ex Cav.	–	–	–	X
S. rhombifolia L.	X	–	–	X
S. salviifolia Presl.	X	–	X	–
S. spinosa L.	X	–	X	–
S. stipularis Cav.	–	–	–	X
S. urens L.	–	–	X	–
Sidastrum multiflorum (Jacq.) Fryxell	X	–	X	–

continued

Plant species at the Cabo Rojo and Laguna Cartagena National Wildlife Refuges

Family and species	Refuges [a] Cabo Rojo H	Cabo Rojo S	Laguna Cartagena L	Laguna Cartagena T
Malvaceae (continued)				
Thespesia populnea (L.) Solander ex Correa	X	X	X	–
T. grandiflora DC.	–	–	X	–
Urena lobata L. ssp. lobata	–	–	X	X
Wissadula amplissima (L.) R.E. Fries	X	–	X	X
W. periplocifolia (L.) Presl.	–	–	X	X
Meliaceae				
Azadirachta indica A. Juss.	–	–	X	X
Cedrela odorata L.	X	–	–	–
Guarea guidonia (L.) Sleumer	–	–	X	–
Melia azedarach L.	X	–	X	–
Swietenia mahagoni (L.) Jacq.	X	X	–	X
Trichilia hirta L.	X	X	X	X
Menispermaceae				
Cissampelos pareira L.	–	–	–	X
Menyanthaceae				
Nymphoides indica (L.) Kuntze	–	–	X	–
Molluginaceae				
Mullugo verticulata L.	X	–	–	–
Moraceae				
Cecropia schreberiana Miq.	–	–	–	X
Ficus americana Aubl.	–	–	X	–
F. benjamina L.	X	–	–	–
F. citrifolia Mill.	X	–	X	X
Moringaceae				
Moringa oleifera Lamarck	–	–	X	–
Myrsinaceae				
Ardisia obovata Hamilt.	–	–	–	X
Myrtaceae				
Eugenia biflora (L.) DC.	–	–	–	X
E. foetida Pers.	–	X	–	–
E. lingustrina (Sw.) Willd.	–	–	–	X
E. monticola (Sw.) DC.	–	–	–	X
E. procera (Sw.) Poir.	–	–	–	X
E. pseudopsidium Jacq.	–	–	–	X
E. rhombea (Berg.) Krug & Urban	–	–	–	X
E. sessiliflora Vahl	X	X	–	X
E. woodburyana Alain	X	–	–	X
Myrcia citrifolia (Aublet) Urban	–	–	–	X
M. splendens (Sw.) DC.	–	–	–	X
Myrciaria floribunda (West ex Wild.) Berg	–	–	–	X
Pimenta recemosa (Miller) J.W. Moore var. *racemosa*	X	–	–	X
Psidium guajava L.	–	–	–	X
Nyctaginaceae				
Boerhavia coccinea Mill.	–	–	–	X
B. diffusa L.	X	–	–	X
B. erecta L.	–	–	–	X
Commicarpus scandens (L.) Standl.	X	–	X	X

continued

Plant species at the Cabo Rojo and Laguna Cartagena National Wildlife Refuges

Family and species	Refuges[a]			
	Cabo Rojo		Laguna Cartagena	
	H	S	L	T
Nyctaginaceae (continued)				
Guapira fragrans (Dum.-Cours) Little	–	–	X	X
Neea buxifolia (Hook. f.) Heimerl	–	–	–	X
Pisonia aculeata L.	–	–	–	X
P. albida (Heimerl) Britton ex Standl.	X	–	–	–
P. subcordata Sw.	X	–	X	–
Nymphaeaceae				
Nymphaea ampla (Salisb.) DC.	–	–	X	–
N. odorata Dryand. in Ait.	–	–	X	–
N. pulchella DC.	–	–	X	–
Ochnaceae				
Ouratea littoralis Urban	–	–	–	X
Oleaceae				
Forestiera segregata (Jacq.) Krug & Urban	–	–	–	X
Jasminum fluminense Velloso	X	X	X	X
Onagraceae				
Ludwigia erecta (L.) H. Hara	X	–	X	–
L. leptocarpa (Nuttal) H. Hara	–	–	X	–
L. octovalvis (Jacquin) Raven	–	–	X	–
L. peploides (HBK.) Raven	–	–	X	–
Papaveraceae				
Argemone mexicana L.	–	–	X	X
Passifloraceae				
Passiflora edulis Sims	–	–	X	–
P. suberosa L.	X	–	–	X
Phytolaccaceae				
Petiveria alliacea L.	–	–	X	X
Rivina humilis L.	X	X	X	X
Trichostigma octandrum (L.) H. Walt.	–	–	X	X
Piperaceae				
Peperomia humilis A. Dietr.	–	–	–	X
P. obtusifolia (L.) A. Dietr.	–	–	–	X
Polygalaceae				
Polygala cowellii (Britton) S.F. Blake	X	–	–	–
P. penaea L.	–	–	–	X
Securidaca virgata Sw.	–	–	–	X
Polygonaceae				
Antigonon leptopus Hook. & Arn.	X	–	–	–
Coccoloba diversifolia Jacq.	X	–	–	X
C. microstachya Willd.	X	–	–	X
C. swartzii Meissn.	X	–	–	–
C. uvifera (L.) L.	X	X	–	–
C. venosa L.	–	–	–	X
Polygonum acuminatum HBK.	–	–	X	–
P. glabrum Willd. in L.	–	–	X	–
P. punctatum Ell.	–	–	X	–
P. segetum HBK.	–	–	X	–

continued

Plant species at the Cabo Rojo and Laguna Cartagena National Wildlife Refuges

Family and species	Refuges [a]			
	Cabo Rojo		Laguna Cartagena	
	H	S	L	T
Portulacaceae				
Portulaca grandiflora Hook.	–	–	–	X
P. halimoides L.	X	–	–	–
P. oleracea L.	X	X	X	X
P. pilosa L.	X	–	–	X
P. quadrifida L.	X	–	X	X
Talinum fruticosum (L.) A.L. Juss.	X	–	X	X
T. paniculatum (Jacq.) Gaerth.	–	–	–	X
T. triangulare (Jacq.) Willd.	X	–	–	–
Ranunculaceae				
Clematis dioica L.	–	–	–	X
Rhamnaceae				
Colubrina arborescens (Mill.) Sarg.	X	X	–	–
Gouania lupuloides (L.) Urban	–	–	–	X
Krugiodendron ferreum (Vahl) Urban	X	X	–	X
Reynosia uncinata Urban	X	–	–	–
Ziziphus reticulata (Vahl) DC.	X	–	–	X
Rhizophoraceae				
Rhizophora mangle L.	X	X	–	–
Rubiaceae				
Chiococca alba (L.) Hitchc.	–	–	–	X
Diodia apiculata (Willd.) K. Schum.	X	–	–	X
D. rigida Cham. & Schldl.	X	–	–	X
Erithalis fruticosa L.	–	X	–	X
Exostema caribaeum (Jacq.) Roem. & Schult.	X	–	–	X
Guettarda elliptica Sw.	X	–	–	–
G. scabra (L.) Vent	–	–	–	X
Hamelia patens Jacq.	–	–	X	X
Hedyotis corymbosa (L.) Lam. Tabl.	–	–	–	X
Machaonia portoricensis Baill.	–	–	–	X
Psychotria microdon (DC.) Urban	–	–	–	X
P. pubescens Sw.	–	–	–	X
Randia aculeata L.	X	X	X	X
Rondeletia inermis (Spreng.) Krug & Urban	–	–	–	X
Spermacoce assurgens Ruiz & Pavon	X	–	–	–
S. confusa Rendle & Gillis	X	–	–	–
S. prostrata Aubl.	X	–	–	–
S. repens (DC.) Fosberg & Powell	X	–	–	–
S. verticillata (L.) Meyer	X	–	X	–
Rutaceae				
Amyris elemifera L.	–	–	–	X
Citrus aurantifolia (Christm.) Swingle	X	–	X	–
C. limon (L.) Burm. f.	X	–	X	–
C. sinensis (L.) Osbeck	–	–	X	–
Zanthoxylum flavum Vahl	X	–	X	–
Z. martinicense (Lam.) DC.	X	–	–	X
Z. monophyllum (Lam.) P. Wilson	X	–	X	X

continued

Plant species at the Cabo Rojo and Laguna Cartagena National Wildlife Refuges

Family and species	Refuge[a]			
	Cabo Rojo		Laguna Cartagena	
	H	S	L	T
Sapindaceae				
Allophyllus racemosus (Sw.)	–	–	–	X
Cardiospermum corundum L.	X	–	–	–
Cupania americana L.	–	–	X	X
Dodonaea americana L.	–	X	–	–
Hypelate trifoliata Sw.	–	–	–	X
Melicoccus bijugatus Jacq.	X	–	X	X
Paullinia pinnata L.	–	–	X	X
Sapindus saponaria L.	–	–	X	X
Serjania polyphylla (L.) Badlk.	–	–	X	X
Thouinia striata Radlk. var. *portoricensis* (Radlk.) Votava & Alain	X	–	–	X
Triphasia trifolia (Burm.f) P. Wilson	X	–	–	–
Sapotaceae				
Bumelia obovata (Lam.) A. DC.	X	X	X	–
Chrysophyllum oliviforme L.	–	–	–	X
Manilkara pleeana (Pierre) Cronq.	–	–	–	X
Sideroxylon foetidissimum Jacq.	X	–	X	X
S. obovatum Lam.	–	X	–	X
Scrophulariaceae				
Bacopa monnieri (L.) Pennell	–	–	X	–
Capraria biflora L.	X	X	X	X
Scoparia dulcis L.	X	–	X	–
Solanaceae				
Capsicum frutescens L.	–	–	X	X
Datura inoxia Mill.	X	X	–	–
D. metel L.	–	–	–	X
D. stramonium L.	–	–	X	–
Goetzea elegans Wydler	X	–	–	–
Physalis angulata L.	X	–	X	–
Solanum americanum var. nodiflorum L.	–	–	X	–
S. campechiense L.	–	–	X	–
S. drymophilum O.K. Schultz	–	–	–	X
S. persicifolium Dunal	X	–	X	X
S. rugosum Dunal	–	–	–	X
S. torvum Sw.	–	–	X	X
Sterculiaceae				
Ayenia insulicola Cristóbal	X	–	–	–
Guazuma ulmifolia Lam.	X	–	X	X
Helicteres jamaicensis Jacq.	X	–	–	X
Melochia nodiflora Sw.	–	–	X	X
M. pyramidata L.	X	X	X	X
M. tomentosa L.	X	X	X	X
M. villosa (Mill.) Fawcett & Rendle	–	–	X	–
Sterculia apetala (Jacq.) Karst	X	–	–	–
Waltheria indica L.	X	X	–	X
Theophrastaceae				
Jacquinia arborea Vahl	X	X	–	–

continued

Plant species at the Cabo Rojo and Laguna National Wildlife Refuges

Family and species	Refuges [a]			
	Cabo Rojo		Laguna Cartagena	
	H	S	L	T
Tiliaceae				
Corchorus aestuana L.	X	–	–	–
C. hirsutus L.	X	–	–	–
C. orinocensis Kunth in HBK.	X	–	–	–
C. siliquosus L.	X	–	–	–
Triumfetta semitriloba Jacquin	–	–	X	–
Turneraceae				
Piriqueta ovata (Bello) Urban	X	–	–	X
Turnera diffusa Willd.	X	–	–	X
T. ulmifolia L.	X	–	–	–
Umbelliferae				
Hydrocotyle verticillata Thunberg	–	–	X	–
Urticaceae				
Pilea microphylla (L.) Liebm.	–	–	X	–
Verbenaceae				
Bouchea prismatica (L.) Ktze	X	–	–	X
Citharexylum fruitcosum L.	X	–	X	X
Clerodendrum aculeatum (L.) Schlecht	X	–	–	–
Lantana camara L.	X	X	X	X
L. involucrata L.	X	X	X	–
L. reticulata Pers.	–	–	X	–
L. urticifolia Miller	–	–	X	–
Lippia micromera Schaer. var. *helleri* (Britton) Mold.	–	–	–	X
L. nodiflora (L.) Michx.	X	–	X	–
L. strigulosa Martens & Gal.	–	–	–	X
Petitia domingensis Jacquin	–	–	–	X
Priva lappulacea (L.) Pers.	–	–	X	–
Stachytarpheta jamaicensis (L.) Vahl	X	X	X	X
Tamonea boxiana (Mold.) Howard	–	–	X	X
T. spinosa Sw.	X	–	–	X
Vitex divaricata Sw.	–	–	–	X
Viscaceae				
Phoradendron anceps (Spenng.) Krug & Urb.	X	–	–	–
P. quarangulare (Kunth) Griseb.	X	–	X	X
P. randiae (Bello) Britton	–	–	–	X
P. tetrapterum Krug & Urban	–	–	X	–
Vitaceae				
Cissus trifoliata (L.) L.	X	–	–	X
C. verticillata (L.) Nicolson & Jarvis	–	–	–	X
Zygophyllaceae				
Guaiacum officinale L.	X	X	–	X
Kallstroemia maxima (L.) Hook. & Arn.	X	–	–	X
Tribulus cistoides L.	X	–	–	–

Sources: Cabo Rojo Refuge (McKenzie 1986, see endnotes); Laguna Cartagena Refuge (Breckon 1998; Diaz-Soltero 1990; Proctor 1996, see endnotes); both refuges (Joseph Schwagerl, personal observations).

[a] H = Headquarters tract, S = Salinas tract, L = Lagoon tract, and T = Tinafa tract.

Weaver, Peter L.; Schwagerl, Joseph J. 2009. U.S. Fish and Wildlife Service refuges and other nearby reserves in southwestern Puerto Rico. Gen. Tech. Rep. IITF-40. San Juan, PR: U.S. Department of Agriculture Forest Service, International Institute of Tropical Forestry. 110 p.

The main purpose of this paper is to summarize information about the Cabo Rojo and Laguna Cartagena National Wildlife Refuges in southwestern Puerto Rico. The Cabo Rojo (Headquarters and Salinas tracts) and Laguna Cartagena (Lagoon and Tinaja tracts) occupy 1174 ha and are part of the 10 231-ha Caribbean system of nine refuges. Their major geologic and physiographic features are Sierra Bermeja, the oldest mountain range in Puerto Rico, and the floodplains of the Lajas Valley. Together, the refuges combined contain 9 geologic features and 26 soils' types. Rainfall averages about 1000 mm/year and hurricanes occur periodically. Among the several vegetation types, including are mangroves, salt flats, littoral woodland, mesquite and semievergreen woodland, coastal shrub, deciduous woodland, and pasture. At least 644 plant species grow on the refuges. Eight of these species are considered rare and endangered, and have formal recovery plans. Refuge mammals include two species of native bats and six introduced species—two monkeys, a mongoose, two rats, and a mouse. Both the Cabo Rojo Salt Flats and Cartagena Lagoon are renowned as wintering habitat for migratory birds where >200 resident and migratory birds have been observed, including 12 island endemics. Moreover, several other species are listed as rare and endangered, or of conservation concern, or as target species for management. Among the reptiles are seven lizards, two geckos, and three turtles (one terrestrial and two marine). Five amphibians (one toad and four frogs) and 18 species of fish (fresh and brackish water) are also present. Six of the wildlife species have formal recovery plans.

The major management activities on the refuges include protection against fires, habitat restoration, public education, special uses, and water management at the Cartagena Lagoon and the Salinas salt flats. Habitat recovery has been stimulated through fire control, through livestock removal, and by planting >9,000 trees of nearly 80 species. Public education encompasses nearly 20,000 visits annually to interpretative centers at the Headquarters and Salinas tracts; moreover, another 2,600 visitors frequent the refuges to observe wildlife and take nature photographs, and nearly 4,900 others participate in educational and interpretative programs. Special use permits have been issued to 174 users since 1979, mostly for administrative matters or environmental research. Finally, water management at the Cartegena Lagoon remains a problem, partly because of historical events and partly due to current difficulties.

In addition to the U.S. Fish and Wildlife Service (F&WS) refuges, six other major protected areas occupy about 6800 ha along the southwestern coast: Punta Guaniquilla Natural Reserve, Boquerón Wildlife Refuge, Los Morrillos de Cabo Rojo, Boquerón Forest, Parguera Natural Reserve, and Guánica Forest. An additional 23 bird species not recorded on the refuges have been observed in these protected areas. The F&WS refuges and the protected areas provide critical wildlife habitat in Puerto Rico's southwest—an area that is experiencing a rapid increase in human population.

Keywords: Cabo Rojo Wildlife Refuge, Cartagena Lagoon Wildlife Refuge, fauna, flora, climate, geology, soils, management.

The Forest Service, U.S. Department of Agriculture (USDA), is dedicated to the principle of multiple use management of the Nation's forest resources for sustained yields of wood, water, forage, wildlife, and recreation. Through forestry research, cooperation with the States and private forest owners, and management of the National Forests and National Grasslands, it strives—as directed by Congress—to provide increasingly greater service to a growing Nation.