

Puerto Rico

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ABSTRACT

The commonwealth of Puerto Rico is the smaller and eastern-most island of the Greater Antilles. It rests on the north-eastern corner of the Caribbean Plate facing the high energy Atlantic Ocean to the north and the Caribbean basin to the south. The islands have a large diversity of habitats along the coast and on the insular platform, and coral reef ecosystems cover around 5,010 Km². Coral reef communities and colonized hard bottom habitats comprise about 757 Km² (15.1 %), seagrass beds cover 625 Km² (12.8 %), hard bottoms dominated by macroalgae 97 Km² (1.9 %), and mangrove fringes and forests 73 Km² (%). The first major inventory of marine biodiversity was done during the expedition of the Sea Hawk in the late 1800s. This survey produced the first systematic lists of marine invertebrates and fish for Puerto Rico. A total of 1580 species from nine marine phyla were identified, of these, 192 species and 8 genera were new to science. Other smaller surveys sponsored by the New York Academy of Sciences in the early 1900s produced new taxa and brought about a revision of some of the Sea Hawk collections and species lists. In general, there are big gaps in our knowledge of number and distribution of species for many important marine invertebrate groups that inhabit the coastal marine communities around the islands. With the exception of the marine algae, scleractinian corals, mollusks, chitons and fish, no major taxonomic revisions of any other marine taxa has been done in the last 70 years. Current systematic lists of the marine biodiversity of Puerto Rico include 492 species of algae, 5 of mangrove, 4 of seagrasses, 61 sponges, 171 cnidarians, 8 nemerteans, 1,176 mollusks, 129 polychaetes, 342 crustaceans, 165 echinoderms, 131 bryozoans, 677 fish, 5 reptiles and 18 mammals. These lists include minor, localized inventories in few areas around the islands. Collections of specimens from the older expeditions are in the US National Museum and the National Museum of Natural

History. There are only few collections of preserved specimens stored in the Department of Marine Sciences of the University of Puerto Rico and one private collection of mollusks. Collections in the *Herbario Marino Puertorriqueño* include 36,000 specimens of algae, 3,500 specimens of fish, and over 4,000 specimens of invertebrates. After the government of Puerto Rico realized that the use and demand for marine products (fisheries) and recreational areas on the coast will increase significantly due to an ever increasing population and tourist industry, a series of marine (and terrestrial) reserves and protected areas have been established around Puerto Rico in the last 20 years. With input from the government environmental agencies, the Planning Board has the responsibility for overall policymaking and developmental control of the maritime jurisdiction, which extends 16.7 Km off-shore. Territorial Marine Protected Areas (MPA's) include eight Special Planning Areas and 24 Coastal Marine Natural Reserves. The presence of well developed coral reefs has been one of the main criteria used to designate the natural reserves in coastal areas. There are currently 12 such natural reserves around Puerto Rico, but only two are designated as No-Take zones, the Luis Peña Marine Reserve (4.8 Km²) in Culebra island and the Desecheo Marine Reserve (6.2 Km²) on the west coast. New and revised laws have been implemented for the protection of fisheries, coral reefs and associated habitats. Most of these reserves, however, do not have a management structure and lack personnel and equipment for law enforcement. Therefore, they are in reality "paper parks" that do not work.

INTRODUCTION

Physical setting

The commonwealth of Puerto Rico is an island complex located on the north-eastern corner of the Caribbean sea. The complex is formed by the main island of Puerto Rico, the smaller and eastern-most island of the Greater Antilles (17° 54' - 18° 31' N and 65° 16' - 67° 16' W), and five other smaller islands located on the eastern and western coasts (Vieques, Culebra, Desecheo, Mona and Monito) (Figure 1). Together, they have a linear coast line of about 620 Km encompassing approximately 8,900 Km² of land area. Many other smaller islands and coral keys are distributed near the coast line in the eastern, southern and western coasts. The main island of Puerto Rico is almost rectangular (161 Km long and 56.3 Km wide) with a central mountain chain running from east to west across the island. Twenty eight major rivers originating in the high central mountain range discharge their sediment-loaded waters around the island. The island group rests on top of the north-eastern edge of the Caribbean Plate with the northern shore facing the high energy Atlantic Ocean and the southern shore facing the Caribbean basin. Puerto Rico lies within the hurricane belt of the northern Caribbean and hurricanes frequently hit the island or pass nearby during the summer months.

The climate in Puerto Rico is mostly tropical, dominated by a dry season during the fall-winter and a rainy season during spring-summer. Rainfall varies



Figure 1. Geographic location of Puerto Rico in the Caribbean basin and distribution of the other small islands and major marine communities around Puerto Rico.

significantly across the island, with most of it falling on the central mountain chain and the north-east and north-west slopes of the island. The south and southwest coast receive significantly lower rainfall and is mostly dry-arid terrain. Trade winds from the east and south east blow most of the year and marine water currents usually move from east to west with several eddies forming along it. There is little variability in average surface water temperatures during the year, with maximum averages around 29 °C and minimum averages around 26 °C. The average annual surface water temperature is around 27.5 °C (NOAA). Environmental data collected at La Parguera, off the south west coast, during the last 10 years by the CARICOMP program (Caribbean Coastal Marine Productivity) show average surface and sub-surface (10 m) water temperatures of 28.2 (\pm 1.6) and 27.9 (\pm 1.6) °C respectively, average visibility in the reef site (Secchi disk) of 14.3 (\pm 4.8) m in reef areas, and average salinity around 36.0 ‰ [1]. Orinoco river plumes reach the east and south coasts of the island almost every year, and African dust fallout has become more frequent in the last decade. These events influence the coastal nutrient dynamics and water visibility.

During the winter, northern and western shores are frequently hit by large swells produced by cold fronts moving down from the north, which add to the usual high energy seas of the Atlantic. These high energy conditions, the exposed shorelines and the sediment loaded waters from river discharges, have played an important role over time in structuring the marine and coastal communities, with many organisms showing specific adaptations to withstand the rough conditions [2]. The northern shores of Puerto Rico and Culebra have a

narrow insular platform and there are no well developed reefs along this coast (Figure 2), only a few small fringing reefs along and around a series of small rocks and submarine platforms (La Cordillera) between Puerto Rico and Culebra, and small patches in protected bays along the coast. Consolidated hard bottoms and rocky subtidal habitats dominate the northern coast and harbor coral communities with scattered colonies of corals, octocorals, sponges, zoanthids and other reef organisms down to 20 m depth.

Rocky shores and sandy beaches are found all along the north coast line and mangrove forests are mostly located towards the north-east shore, fringing the estuary and lagoons of the San Juan area (Figure 2). Long extensions of sandy beaches in small bays are filled by several rivers that discharge their sediment-loaded waters along the north coast. This also affects the development of coral reefs and other benthic communities.

The southern shore of Puerto Rico faces the Caribbean sea and has a wide (up to 20 Km) insular platform from the mid to the west end (with an average depth of 18 m) that supports extensive seagrass, coral reef, sandy and algal communities. From Ponce to Cabo Rojo, the southern edge of the insular platform is fringed by well developed and diverse bank reefs that remain in good conditions (Figure 2). Scattered mangrove forests fringe the coast and coralline keys in protected areas, and are well developed in small bay areas along the coast (i.e. Jobos Bay, Ponce, Guánica and La Parguera). Dry conditions and lack of large rivers have been a key factor in the development of some of the best coral reef formations of Puerto Rico in La Parguera, on the southwest coast (Figure 2). Coral reefs, sea grass beds, sandy beaches and mangrove fringes are distributed along the southwest coast and on the wide insular platform on the south section of the west coast (Figures 2 and 3). The Mona Passage, one of the main deep channels connecting the Caribbean and the Atlantic Ocean, separates Puerto Rico from the Dominican Republic on the west. Currents in the passage usually flow to the north out of the Caribbean, but the temporal patterns are complex [3, 4]. Three islands are found in this passage: Desecheo, near the main island, and the islands of Mona and Monito about 75 Km west of the main island. The area is an important wintering ground for humpback whales, and Mona is an important nesting site and juvenile grazing area for the hawksbill turtle (*Eretmochelys imbricata*) [5]. Desecheo and Mona harbor very well developed and diverse coral reefs along their south and west coasts. The fish fauna in the islands of the passage includes 260 species [6].

The east coast of the main island faces the islands of Culebra and Vieques, separated by a narrow, shallow (< 50 m) passage [7]. The Natural Reserve of La Cordillera is a string of small islets and rocky areas that run from the north east coast of Puerto Rico to the north west coast of Culebra, breaking the surge and wave energy of the Atlantic. Several important coral reef formations are found along this chain. Culebra has one of the only No-Take natural reserves in the Luis Peña channel along the south-west coast. The island has suffered from increasing and sometimes uncontrolled development, which has affected the coastal communities, including the Natural Reserve [8]. Viequez, on the other hand, is a long island to the south. It used to be the US Navy's main training

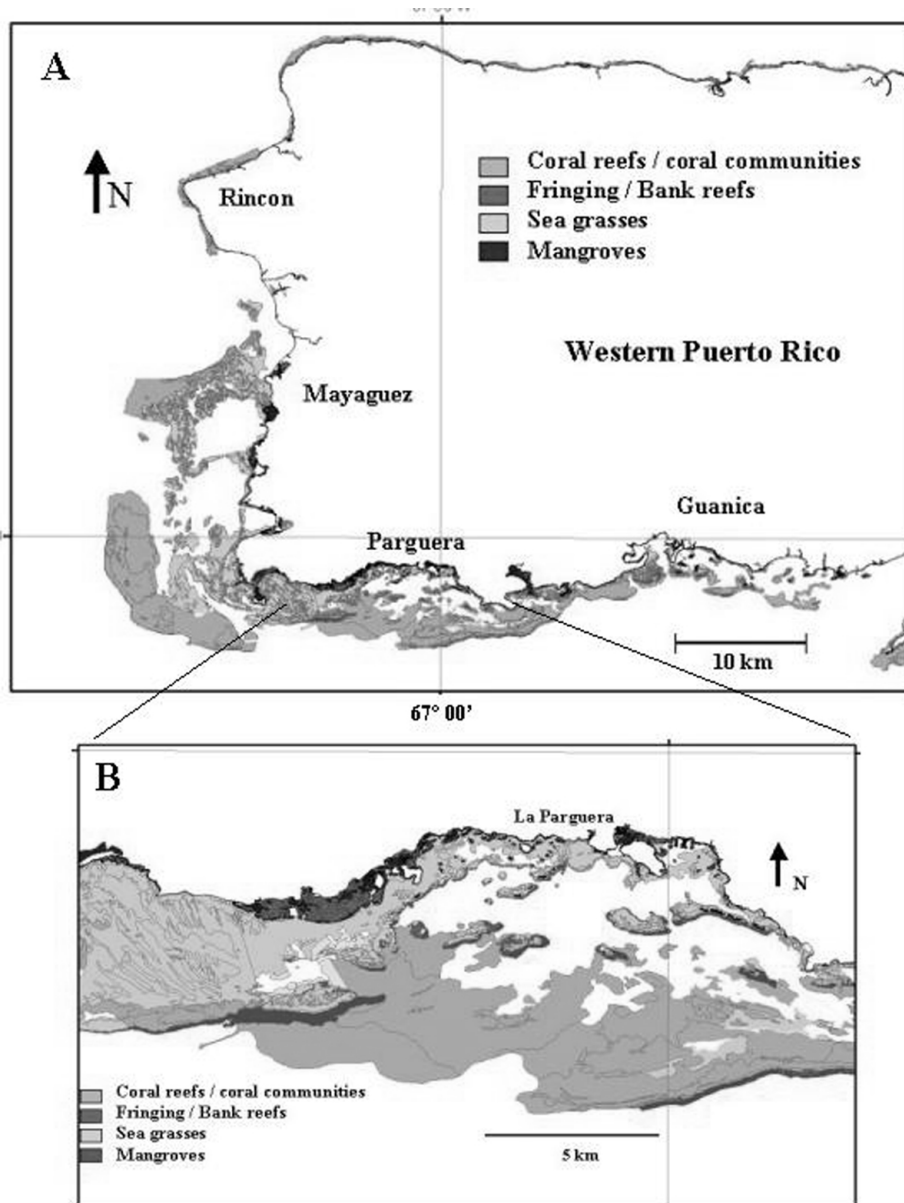


Figure 2. Western coast of Puerto Rico showing distribution and area of the main coastal and shelf marine communities (A). Area of La Parguera showing the extension of the insular platform and distribution of main communities (B).

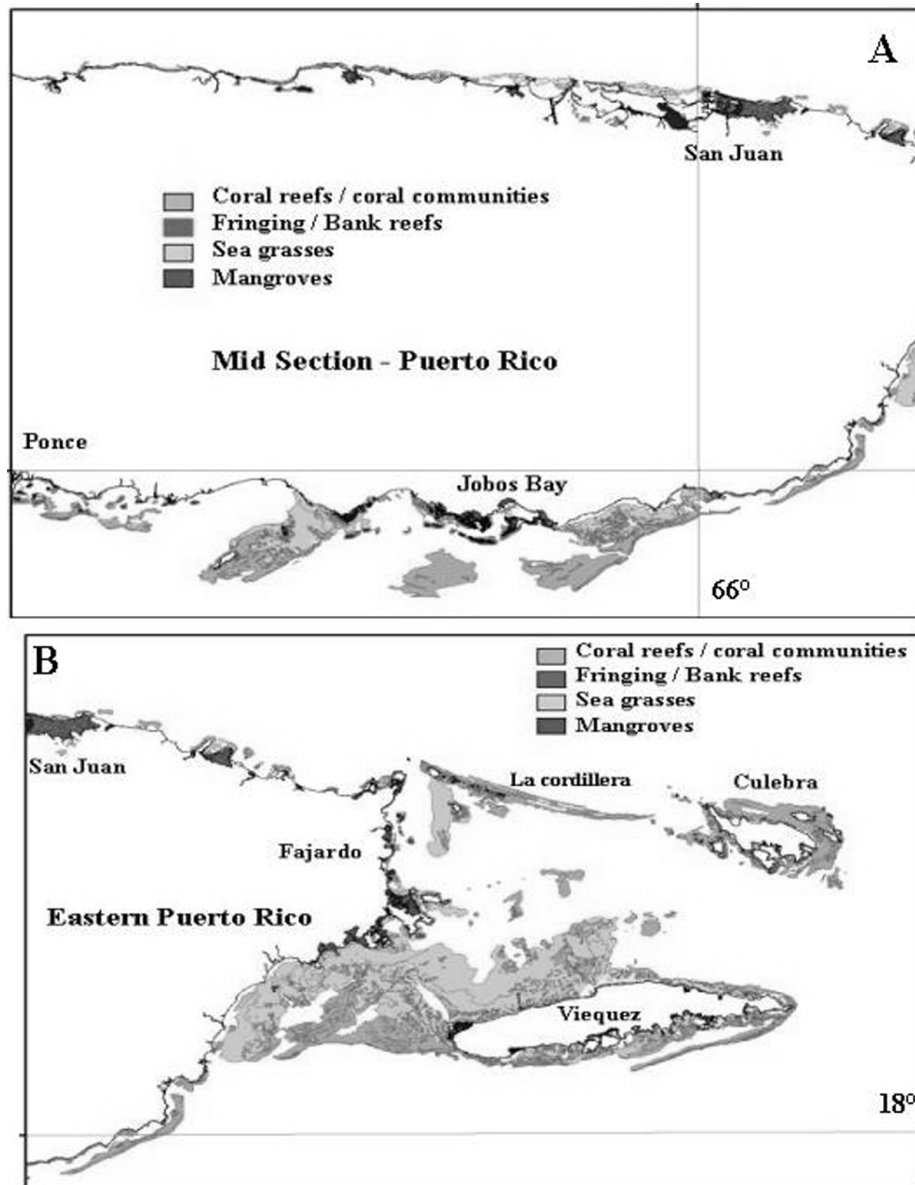


Figure 3. (A) Central section of Puerto Rico with narrow north coast with few extensive marine communities compared with the south coast. (B) The eastern coast of Puerto Rico and the islands of Vieques and Culebra.

area in the region. The island is surrounded by important coral reef, seagrass, mangrove, rocky and sandy shores. There is little information on the community structure and biodiversity of most of these important coastal communities [7] due to the restricted access imposed by the US Navy until recently.

Puerto Rico has one of the highest population densities (approximately 475 ind/Km²) in the Caribbean. Nearly 4 million people live in three major coastal cities (San Juan, Ponce, and Mayagüez) and other small cities and towns located along the coast and inland. Only two of the other smaller islands, Vieques and Culebra, are permanently inhabited, but with significantly lower population densities. The island receives over 4 million tourists every year, increasing the pressure on the coastal ecosystems.

Physiographic diversity

With an estimated perimeter length of coast line for the island complex of 1,383.5 Km, significantly more than the linear estimation of 620 Km, Puerto Rico harbors a large diversity of habitats along the coast and on the insular platform. Estimates from recent mapping of the coral reef ecosystems and associated communities and habitats along the coast and the insular platform by NOAA, indicated a total area of coral reef ecosystem and associated communities of 5,010 Km² [9]. Of these, 757 Km² were covered by coral reefs and colonized hard bottom habitats (15.1 % of the total area), 625 Km² by seagrass beds (12.8 %), 97 Km² by hard bottoms dominated by macroalgae (1.9 %), and 73 Km² (%) by mangrove fringes and forests (1.4 %) (Table I, Figures 2 and 3). Very few estuaries are found along the coast. The most important estuarine areas are San Juan and Jobos Bay (Figure 3) where the most extensive mangrove forest is also found. There are 468 Km of sandy beaches and 220 Km of rocky shores around the islands.

Table I. Approximate coast line perimeter length (Km) including most bays, inlets, etc. for the island complex of Puerto Rico, sandy beaches and rocky shores. Area (Km²) of major coastal marine communities. Reef areas include coral reefs (fringing reefs, bank and patch reefs, back reef areas, and shelf reefs) and colonized hard bottoms (Source: ESI sensitivity index from NOAA coastal mapping of Puerto Rico, 2000).

Island	Coast line length (Km)	Marine coastal community	Area (Km ²)
Puerto Rico Complex	1,383.5		
Puerto Rico	1,165.0	Mangrove	73.8
Vieques	133.0	Seagrass	624.8
Culebra	46.0	Sandy bottom	27.8
Mona	32.0	Reefal areas	21.8
Monito	2.0	Estuaries	756.2
Desecheo	5.5	Macroalgae	31.7
Sandy beaches	468.0	Coral reefs	96.7
Rocky shores	220.0		5,010.0

Table II. Summary table of the total number of species, new genera and new species surveyed by the Fish Hawk expedition.

Taxon	# species	New genera	New species
Foraminifera	36		
Porifera	49		20
Corals	32		2
Alcyonaria	26		5
Actinaria	13		1
Nemertea	8		3
Mollusca	653		42
Annelida	85		32
Brachyura and Macrura	221	2	27
Anomurans	53	1	9
Isopoda	17	2	8
Stomatopoda	5		2
Cirripedia	4		
Echinodermata	87		8
Fish	291	3	33

CURRENT STATUS OF THE MARINE BIODIVERSITY

The marine flora and fauna of Puerto Rico has been studied for over 100 years. Intensive and extensive surveys and collections to characterize the component species of the most important benthic groups and fish started at the end of 1800s with the expedition of the steamer Sea Hawk, sponsored by the US Fish Commission. Reports were published in a series of monographs in two parts of volume XX of the US Fish Commission Bulletin in 1902. Most of the reports had revised systematic lists of the taxonomic groups studied, and many new genera and species were described for most of the major phyla. The first part of volume XX included fishes [10] and mollusks [11] of Puerto Rico. The second part included Foraminiferan [12] and the invertebrate groups Porifera [13], Actinaria [14], scleractinian corals [15], Alcyonaria [16], Nemertea [17], Polychaeta [18], Cirripedia [19], Isopoda [20], Stomatopoda [21], Brachyura and Macrura [22], Anomura [23], and Echinodermata [24]. Most of the specimens collected and identified were deposited in the US National Museum. A summary with the number of species in each major biological groups surveyed is presented in Table II.

A second survey effort was sponsored by the New York Academy of Sciences several years later. It brought revisions of the old lists by many of the same taxonomists, the study of other taxa, and descriptions of new species. Results and revisions were published in a series of volumes of the New York Academy of Sciences Scientific Surveys of Porto Rico and the Virgin Islands. The major groups that were revised included the brachyuran crabs [25], echinoderms [26], macruran and anomuran crustaceans [27], and the polychaetes [28]. A new phylum included in this survey was the Bryozoa, for which very few information

Table III. Example of the biodiversity of species of different Biological groups inhabiting sub-tidal mangrove habitats (aerial roots, sandy-muddy bottom, nearby seagrass beds) around Puerto Rico. Source: Cerame-Vivas [40]. Number in parenthesis are the total number of species for the major group.

Taxon	# species	Taxon	# species
Mangrove	4	Sipunculida	2
Algae	(105)	Annelida	(28)
Cyanophyta	3	Polychaeta	28
Clorophyta	35	Crustacea	(89)
Phaeophyta	11	Anostraca	1
Rodophyta	56	Cirripeda	5
Protozoa	3	Stomatopoda	2
Porifera	25	Mysidasea	4
Cnidarians	(36)	Isopoda	9
Hydrozoa	11	Amphipoda	3
Scyphozoa	8	Decapoda	65
Anthozoa	17	Echinodermata	(29)
Ctenophora	1	Asteroidea	5
Platyhelminthes	6	Echinoidea	4
Nemertea	2	Ophiuroidea	13
Nematoda	1	Holoturoidea	7
Entoprocta	2	Chordata	(110)
Ectoprocta	11	Ascidasea	30
Mollusca	(123)	Fish	78
Amphyneura	3	Mammals	2
Gastropoda	79		
Pelecipoda	40		
Cephalopoda	1		

existed in some reports, and a comprehensive systematic list of this group was published [29]. Very few new revisions or systematic lists have been published since these series. Some include a revised list of the shallow-water (< 10 m) scleractinian corals of Puerto Rico [30] and a number of isopod species sampled in 14 localities around Puerto Rico [31]. The most recent comprehensive systematic reviews of marine organisms include mollusks [32], algae [33–35], and chitons [36]. Other publications of educational-informative material and government reports include lists of organisms associated with the different shallow marine tropical communities around the island [37–42], or systematic lists for some of the invertebrate groups [39, 41, 43] in a single or very few localities (Table III). Recent and ongoing research and extensive surveys around the island have increased the total number of reported species for several invertebrate groups such as scleractinian corals, octocorals, sponges, hydrozoans ([44]). More systematic inventories are needed.

The major marine invertebrate collection is stored in the Department of Marine Sciences (> 4,000 specimens). Some working collections are in other

Table IV. Summary table of the number of currently reported species in each of the major marine taxa for Puerto Rico.

Taxon	# species	Source
Algae	492	[33–35]
Mangroves	5	[45]
Phanerogams	4	[46, 47]
Porifera	61	[13, 48]
Cnidaria	171	[15, 16, 30, 44, 49]
Nemertea	8	[17]
Mollusca	1176	[11, 32, 36, 43]
Annelida	129	[18, 28, 50]
Crustacea	342	[20–23, 31]
Echinodermata	165	[24, 26]
Bryozoa	131	[29]
Fish	677	[6, 51]
Reptiles	5	[52]
Mammals	18	[53]

universities (Rio Piedras and Humacao). The most complete collection of Mollusca for Puerto Rico has about 1,200 species and belongs to Dr. Edgardo Ortíz, Department of Biology, UPRH. In the next sections the current status of knowledge of the taxa (species numbers) for the most important marine flora and fauna of Puerto Rico is presented. A summary of the recent biodiversity for major groups of marine organisms is presented in Table IV.

Algae, Seagrasses and Mangroves

The marine algal flora of Puerto Rico has been intensively collected and is presently the best known of any island or island group in the region. Studies of Puerto Rican algae date to the latter part of the last century. Hauck's report of 90 species of algae was the first published algae account of Puerto Rico [54]. Many of these records were subsequently treated as "uncertain records" [55], and several of these reported species have not been collected again in Puerto Rico. Subsequent collecting by University of Puerto Rico professors Luis R. Almodóvar and Manuel Díaz-Piferrer substantially increased the number of species and algal records for the island, and the substantial contributions of the island's benthic marine flora made by several authors has been discussed [56]. The first comprehensive systematic list of the marine benthic algae of Puerto Rico was compiled in 1983 [57], and revised in 1997, when many nomenclatural changes were incorporated [33, 34, 58]. Recently, the list was updated [35] and it can be now accessed from the Internet. It is an extremely useful tool in digital form http://128.32.109.44/fest_PRCL/checklist.html. Four hundred ninety-two species of algae, including macroscopic Chrysophyceae and Xanthophyceae, but excluding Cyanophyta, are now listed from Puerto Rico. The list

Table V. Number of species of algae (excluding Cyanophyta), seagrass and mangrove reported for Puerto Rico.

Taxon	# species	Source
Algae	492	[33–35]
Chlorophyta	135	
Phaeophyta	67	
Rhodophyta	290	
Seagrass	4	[46, 47]
Mangrooves	5	[40]

includes 290 species (59 %) of Rhodophyta, 67 species (13 %) of Phaeophyta, and 135 species (28 %) of Chlorophyta (Table V).

Collections of Puerto Rican marine algae have historically been housed in two herbaria on the island. The first of these, the *Ficoteca Puertorriqueña* was established in 1958 and was directed by Manuel Díaz-Piferrer. The second was also founded in 1958 by Luis R. Almodóvar. Both herbaria were holdings within the Department of Marine Sciences of the University of Puerto Rico at Mayagüez. The two were officially combined into a single herbarium, MSM in 1990 and the collection of over 36,000 specimens is now known as the *Herbario Marino Puertorriqueño*. One hundred fifty-three genera or species are currently linked to underwater natural habitat images, photomicrographs, herbarium specimen scans, or paintings.

Four species of sea grasses [46, 47] and five species of mangroves are currently recognized for Puerto Rico [40, 45] (Table IV).

Marine Invertebrates

PORIFERA (SPONGES)

The first and only published systematic list of the sponges of Puerto Rico has 51 species in 32 genera and 15 families [13]. Currently, a systematic revision of the group is underway and the current information, which includes only coral reef areas from 2 to 20 m depth, and some mangrove root habitats, has approximately 61 species in 36 genera [40, 48]. These are still low numbers compared to northern localities of the Caribbean [59]. Ongoing research will increase the knowledge on the biodiversity and local distribution of sponge species in for Puerto Rico and nearby islands.

CNIDARIANS

The phylum Cnidaria is composed of three major classes, the Anthozoa (corals, octocorals, zoanthids and anemones), the Hydrozoa (hydras and hydrocorals) and the Scyphozoa (true jellyfish). Limited taxonomic reviews of the diversity of the Hydrozoa and Scyphozoa are available. A total of 32 species (4 new) in 27 genera of hydrozoans, and 16 species in 12 genera of scyphozoans were

Table VI. Number of species of Porifera (sponges) and Cnidarians reported for Puerto Rico.

Taxon	# species (genera)	Source
Porifera	51 (32)	[13, 40, 48]
Cnidarians	175 (98)	
Hydrozoa	43 (32)	[39]
Scyphozoa	16 (12)	[39]
Anthozoa	116 (54)	
Alcyonaria	44 (14)	[16, 44]
Anthipatharia	4 (4)	[49]
Actinaria	12 (10)	[14]
Scleractinia	56 (26)	[15, 30, 44, 49]

listed after a survey of the coastal zone of Puerto Rico [39]. In a more recent revision of the hydrozoans, the total number of species increased to 43 (24 species in 20 genera and 12 families of athecate hydroids and 18 species in 12 genera and 3 families of thecate hydrozoans) [41]. The earliest systematic list of anthozoans for Puerto Rico was published after the Sea Hawk expedition in 1902. Twenty six species distributed among 17 genera of Alcyonaria (= octocorallia) were described [16]. Collections were done from shallow water to 75 fathoms around the island of Puerto Rico. The number of species is clearly an underestimation of the octocoralline fauna of Puerto Rico. The authors stated that compared to other collections from the Caribbean, the survey of the Fish Hawk expedition showed a lower number of species and genera. Nevertheless, two genera and six species were new reports. More recent reports [49], and extensive surveys and personal observations made by the author over several years, have produced a list of 44 species in 14 genera of octocorals (Table VI). This list will probably increase as further research and inventories are carried out. The first systematic list of scleractinian corals for Puerto Rico included 26 species in 15 genera (8 non-zooxanthellate species from 4 genera, and 18 zooxanthellate species from 11 genera) (Vaughan, 1902), a gross underestimate of the coral fauna in the area at that time. The second systematic list was concentrated mostly on the shallow water coral species (< 10 m) and included only 36 species (33 zooxanthellate and 3 non-zooxanthellate) in 22 genera and 11 families [30]. More recent inventories (Garcia et al., 2003) listed a total of 44 species distributed in 27 genera (41 zooxanthellate species in 25 genera and 3 non-zooxanthellate in 3 genera). Extensive surveys and ongoing research in many localities around the island include a total of 56 species of shallow water (< 40 m) scleractinian corals (46 zooxanthellate spp. in 26 genera and 10 non-zooxanthellate in 8 genera and 12 families) for the island complex of Puerto Rico (Table VI) [44]. This coral biodiversity is similar to that reported for most of the northern Caribbean islands [44, 59–61] but lower than localities further south, like Venezuela [62].

The systematic list of actinians is also old and included 12 species in 10 genera and 7 families [14]. Little or no information is available for the ce-

Table VII. Recent marine Mollusca from Puerto Rico. The list is the most recent compilation from Ortiz [32] and the chitons from Garcia-Rios [36].

Taxon	Family	Genera	Species
Gastropoda	130	408	804
Bivalvia	55	141	274
Scaphopoda	5	8	34
Cephalopoda	10	16	32
Polyplacophorans	7	16	29
Caudofoveatans	2	2	2
Solenogastres	1	1	1

rianthipatharians, the antipatharians and other groups of cnidarians found in Puerto Rico. Recent revisions for most of the important classes of this group are lacking. Many specimens of cnidarians collected over the years by researchers and students are preserved and stored in the Marine Invertebrate Collection of the Department of Marine Sciences, at Isla Magueyes.

MOLLUSCA

Before the Fish Hawk expedition in the late 1800s, little attention was paid to the marine mollusks of Puerto Rico [63, 64]. Most of the early reports were from land and freshwater mollusks. After the survey and collection of the Fish Hawk expedition, the first comprehensive systematic list of marine mollusks for the island reported 535 species (42 were new) [11]. The report also included 16 fresh water species and 102 land species of mollusks. More recently, a total of 1,070 mollusk species have been reported for Puerto Rico, 1,016 of which were marine species, 109 were land species (including 18 endemics), and 45 were freshwater species (including 23 endemic species) [43]. The current expert in this group is Edgardo Ortíz, who increased the number of marine species to 1,168 in his Ph.D dissertation [32] (Table VII). In a recent communication this author indicated that the current biodiversity of mollusks for Puerto Rico is around 1,200 species. Regarding specifically the polyplacophoran (chitons), species lists have been published [63, 64], updated and reviewed [11], bringing the total number of species and subspecies to 21. Of these, only 17 were valid and new additions established the total number of species in 21 [65, 65]. The most recent revision reported a total of 29 species [36] (Table VII). Many specimens (3,531) of mollusks collected over the years by researchers and students are preserved and stored in the Marine Invertebrate Collection of the Department of Marine Sciences, Isla Magueyes.

NEMERTEANS

Nemerteans, or ribbon worms, are colorful ambush predators that harpoon or lasso their prey with a venomous penetrating or sticky proboscis. They are long, slender worms with several species exceeding 1 m. They burrow in sediment

Table VIII. Current number of species of Nemertean, Polychaete and Crustacea for Puerto Rico.

Taxon	# species (genera)	Source
Nemertean	8 (6)	[17]
Polychaeta	129 (62)	[18, 28, 50]
Crustacea	342 (199)	
Brachyura	173 (103)	[22, 25]
Macrura	52 (29)	[22, 27]
Anomura	53 (23)	[23, 27]
Stomatopoda	17 (15)	[21]
Isopoda	42 (25)	[20, 31]
Cirripedia	5 (4)	[19, 40]

bottoms or hide in crevices and holes in many different marine habitats. Very few species of this group have been found in Puerto Rico. A total of 8 species in 6 genera collected around the island of which 3 are new species have been reported [17] (Table VIII). No recent inventories or taxonomic work has been done with this group.

POLYCHAETES

The first systematic list of the polychaetes of Puerto Rico reported 85 species in 46 genera and 22 families. Of these, 32 were new species [18]. This collection was revised after a second survey several years later and the list increased to 123 species in 69 genera and 31 families [28]. In the most recent revision, the total number of species has increased to 129 in 69 genera and 32 families [50] (Table VIII).

CRUSTACEA

The first systematic list of the Puerto Rican decapods reported a total of 52 species. Of these, 37 were brachyurans (crabs) and 8 were macrurans (shrimps and lobsters) [66]. Not long after that, the most complete systematic list for these two groups of crustaceans at the time was compiled, with a total of 162 species in 85 genera and 14 families of brachyurans and 52 species in 29 genera and 16 families of macrurans [22]. One genus and 14 species of crabs, and one genus and 13 species of shrimps were new reports. Most of the specimens were collected from less than 183 m, but a few specimens came from deeper habitats. Most of the specimens were stored in the US National Museum. Several years later, the same author revised the list of brachyuran crabs in view of a new survey done by the New York Academy of Sciences. This revised list reported 173 species distributed among 103 genera and 16 families for Puerto Rico and the Virgin Islands. This is the most complete compilation so far (Table VIII).

The first systematic list of anomurans (hermit crabs) of Puerto Rico was compiled after the collections of the Fish Hawk expedition [23]. A total of 53

Table IX. Total number of species of Echinoderms and Bryozoa reported for Puerto Rico. Data source were Clark [24, 26] and Osburn [29] respectively.

Taxon	# species (genera)
Echinoderms	165 (71)
Crinoids	13 (7)
Asteroids	15 (9)
Ophiuroid	68 (24)
Echinoids	19 (15)
Holothurians	50 (16)
Bryozoa	131 (96)

species in 23 genera were found. Of these, nine species were new reports. A total of 5 species (one new) from 4 genera of Stomatopoda have been described [21], as well as 17 species from 15 genera in 11 families (two new genera and 8 new species) of Isopoda [20] from specimens collected during the Fish Hawk expedition. All of these were littoral and sub-littoral specimens collected at no deeper than 137 m. A more recent revision of the taxonomy of the Isopoda in Puerto Rico reported 42 species in 25 genera and 6 families. Of these, three new genera and 14 new species were described [31]. Four species of Cirripedia in 4 genera and 2 families were reported from the Fish Hawk collection [19]. More recently, 5 species in 4 genera have been reported in mangrove habitats [40] (Table II). Many specimens of crustaceans collected over the years by researchers and students are preserved and stored in the Marine Invertebrate Collection of the Department of Marine Sciences, Isla Maguëyes. No recent revisions for these groups have been done.

ECHINODERMS

The echinoderms are one of the most conspicuous groups of invertebrates in shallow marine communities. The first systematic list of this group was compiled after the US Fish Commission expedition [24]. Clark stated that although some of the groups were represented by few species (probably due to difficulty in dredging in some habitats), the collection represented well the echinoderm fauna of Puerto Rico at the time. A total of 87 species identified from the surveys were distributed among the crinoids (3 species in 2 genera), asteroids (11 species from 8 genera and 7 families), ophiuroids (49 species), echinoids (13 species) and the holothurians (11 species). This early list was reviewed and completed in the early 1930's after a second expedition to Puerto Rico [26] (Table IX). This is another important invertebrate group that needs to be revised for Puerto Rico. Many specimens of echinoderms collected over the years by researchers and students are preserved and stored in the Marine Invertebrate Collection of the Department of Marine Sciences, Isla Maguëyes.

BRYOZOA

Before the expedition of the Fish Hawk in the late 1800s, no previous attempt had been made to compile a list of the Bryozoan fauna of Puerto Rico. One incidental report registered 5 species near Puerto Rico [67]. The most comprehensive systematic list reports 131 species distributed among 96 genera and 53 families [29] (Table IX).

Marine Vertebrates

PISCES

Prior to the expedition of the Fish Commission in 1899, only 99 marine fish species were known from Puerto Rican waters [10]. The systematic list produced after the expedition reported 291 species in 165 genera and 75 families, including 3 new genera and 33 new species. This figure is much lower than the number of fish species known for Cuba at the time (301 compared to 499 species). The most recent systematic list included 677 species [6, 51]. The list can be accessed through the internet in the following web page address: http://cars.er.usgs.gov/Marine_Puerto_Rico_Plateau/marine_puerto_rico_plateau.html. The most extensive collection of fishes in Puerto Rico is stored in the Fish Collection of the Department of Marine Sciences, Isla Maguëyes, Puerto Rico. The collection has 3,786 specimens.

REPTILIA AND MAMMALIA

Three species of sea turtles nest on the islands of Puerto Rico, the hawksbill (*Eretmochelys imbricate*), the green turtle (*Chelonia mydas*) and the leather turtle (*Dermochelys coreacea*). Two other species have been reported occasionally in different areas, the loggerhead (*Caretta caretta*) and the olive Ridley sea turtle (*Lepidochelys olivacea*). Of these, the hawksbill turtle is the most common and best studied [5, 52]. Eighteen species of whales, dolphins and manatees inhabit and/or pass through the waters of Puerto Rico [53].

MAJOR THREATS TO THE MARINE BIODIVERSITY

Overall, threats to the coastal marine biodiversity can be divided into natural and anthropogenic-based (Table X). However, the synergistic effects of many of these threats is complex and usually cause the major problems. Moreover, human impacts on a global scale (global warming, high [CO₂]) are indirect and confounding effects in what are considered to be "natural" threats nowadays (i.e. global warming increases water temperature which is linked with higher hurricane frequency and intensity, disease epizootics, bleaching, etc.). The major threat to the natural coastal ecosystems of Puerto Rico is human population growth. The present human pressure on coral reefs and other coastal marine communities is one of the most critical in the Caribbean [68]. The population of the island was 3.81 million in 2002 (approximately 475 ind/km²), an increase of

Table X. Natural and anthropogenic threats to marine biodiversity in Puerto Rico.

Natural Threats	Anthropogenic Threats
Hurricanes and storms	Population growth
Bleaching	Over fishing
Diseases	Deforestation - sediment load
Population blooms	Coastal development
Exotic species	Dredging
(Global warming)	Sewage discharges
	Chemical contamination
	Agriculture
	Oil spills
	Chemical spills
	Ship groundings
	Thermal contamination
	Increase of atmospheric [CO ₂]
	Uncontrolled tourism
	Military activities
	Lack of regulations

8.1 % since 1992. Most of the population (65 %) lives on the coast. Furthermore, the island receives around 4.0 million tourists every year [69], increasing the pressure on coastal marine communities.

By the 1950s, massive deforestation of mangroves, dredging, runoff from large scale agricultural developments in the coastal plains, and building of thermoelectric plants among other activities, had an important impact on coastal natural communities. More recently, accelerated urban and industrial development in coastal areas and lack of effective implementation and enforcement of policies and laws to protect the ecological integrity of the coastal system have caused extensive degradation in many habitats. Controls and regulations of other human associated activities (over-fishing, agriculture, tourism, canneries, boating, marinas, etc) are lacking or are not enforced due to inadequate personnel and/or equipment. All these human activities pose the major threat to the marine environment of Puerto Rico and its associated biodiversity. Water quality problems have been a big concern. Lack of secondary and tertiary treatment plants and the high population density pose a clear threat to the health of the natural coastal and sub-tidal communities and the human population itself. The Environmental Quality Board (EQB) operates 88 permanent water quality (mostly for human use) stations around the islands. Several parameters affecting aquatic life have been linked to industrial and municipal contamination, sewage disposal, urban runoff, land fillings and marinas [70].

High sedimentation, turbidity and nutrient loading have been associated with the degradation of coral reefs and other associated communities [49, 70–72]. Sedimentation problems are caused by inland and coastal deforestation and clear-cutting either to raise cattle or to develop the land (building). Rains and surface

waters move sediments and other chemicals into the rivers that carry them to the coast. Western, near-shore reef and hard bottom communities are subjected to high turbidity, sediment influx from three rivers, sewage and nutrient enrichment from agriculture, tuna canneries and the Mayagüez outfall. On the southeast coast, the Jobos Bay National Estuarine Reserve has been severely impacted by sedimentation associated to coastal erosion and long-shore transport from Guayama and Salinas [70]. Removal and filling of mangrove areas have been a problem in the past. Many coastal communities are now affected because the buffering role of the mangrove fringe is no longer there.

Reef fisheries have plummeted in Puerto Rico during the last two decades, showing the classic signs of over-fishing. From 1979 to 1990, fish landings fell 69 % [73]. A similar situation is happening for lobster and other invertebrate fisheries (queen conch, octopus, top-shells, etc). There is a cascade of detrimental effects when major predators and herbivores are removed from trophic-complex marine communities like coral reefs [74]. In recent years, diseases of coral reef organisms have become one of the most important factors influencing the loss of biodiversity and general decline of coral reef communities around the Caribbean [1, 75, 76]. Lack of herbivorous fish due to overfishing, coupled with the mass mortalities (epizootic events) of the black sea urchin *Diadema antillarum* in the early 1980s, and two of the most abundant and conspicuous species of coral (*Acropora palmata* and *A. cervicornis*) throughout the Caribbean [77–79], brought significant changes in structure, composition and in the biodiversity of coral reefs and other shallow water communities [74, 80, 81]. Mostly, macroalgae monopolized and overgrew most of the available space and in many instances, killed other important benthic components [74].

MARINE PROTECTED AREAS, LAWS AND REGULATIONS

Puerto Rico's maritime jurisdiction extends 16.7 Km off-shore. New and revised laws have been implemented for the protection of fisheries, coral reefs and associated habitats. With input from the government agencies, the Planning Board has the responsibility for overall policymaking and developmental control. Land use policies and regulations, including coastal management are proposed by the Board and approved by the Governor. The Department of Natural Resources, the Environment Quality Board, the Regulations and Permits Administration (RPA), and the National Marine Fisheries Service are the agencies responsible for the management and protection of the marine habitats and resources.

Over the last 20 years, after the government of Puerto Rico realized that the use and demand for marine products (fisheries) and recreational areas on the coast would increase significantly due to an ever increasing population and tourist industry, a series of marine (and terrestrial) reserves and protected areas were established around Puerto Rico. For example, La Parguera, in the south west coast, has been transformed from an undeveloped, quaint fishing village to a tourist resort town with several development projects. In order to halt ad hoc deforestation of the natural semi-arid forest and mangrove coastline, the Puerto

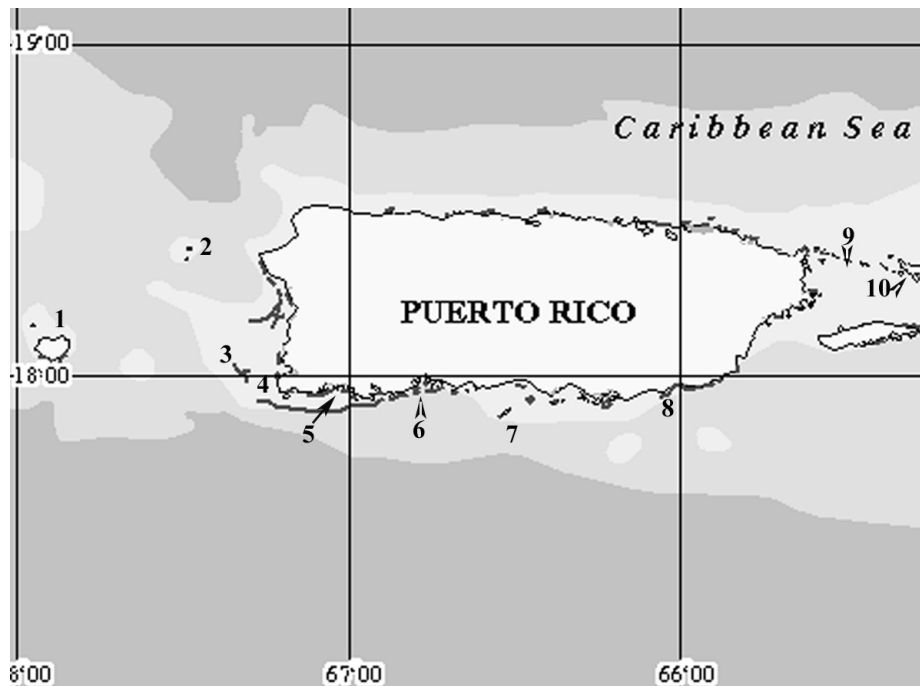


Figure 4. Map of Puerto Rico showing the current marine reserves (numbers) and the no-take zones.

Rico Planning Board classified La Parguera as a Zone of Special Planning. In further recognition of the ecological value of its marine resources, La Parguera was designated as a Natural Reserve by the Department of Natural Resources (DNR).

Territorial Marine Protected Areas (MPA's) include eight Special Planning Areas and 24 Coastal Marine Natural Reserves. The presence of well developed coral reefs has been one of the main criteria used by the DNR to designate "Natural Reserves" in coastal areas. There are currently 12 such natural reserves around Puerto Rico (Figure 4). Only two are designated as No-Take zones, the Luis Peña Marine Reserve (4.8 Km²) in Culebra island and the Desecheo Marine Reserve (6.2 Km²) on the west coast. The Jobos Bay Natural Reserve was established in 1981 and its management plan was approved in 2000. It is currently co-managed by NOAA and the DNR. This reserve protects Puerto Rico's second largest estuarine system and is home to several endangered species including the West Indian manatee and sea turtles.

In 2001 the DNR published a guide with all the laws and administrative orders related to coral reefs and associated communities for Puerto Rico. It is disappointing, however, that most of these protected areas are in reality "paper reserves". They do not have management plans or even a management structure. They lack infrastructure, vigilance or enforcement. Most importantly, there is a general lack of information for the public.

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