COASTAL MYCOLOGY OF PUERTO RICO: A SURVEY AND BIOLOGICAL ASPECTS OF MARINE, ESTUARINE, AND MANGROVE FUNGI

by
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ABSTRACT

This study was subdivided into the chapters listed below, which treated a number of biological aspects of the coastal mycology of Puerto Rico (PR): (1) A review chapter on mangroves and mangrove-associated plants was included for PR. (2) A checklist that contains 604 taxa of fungi is provided. There were 13 new records for PR generated as a result of the studies described herein. (3) Samples of sea foam and senescent leaves of *Avicennia germinans* and *Rhizophora mangle* from two communities in an estuary known as Rincón Lagoon in SW PR were assessed for the frequency of occurrence of 8 selected filamentous fungi. Among 12 bags of sea foam and 1296 leaves screened (from February 2002 through January 2003), the samples consist of sporulating fungi and propagules, respectively. A two-way ANOVA performed on 8 filamentous fungi (propagules and spore counts, N = 432) in sea foam and ones isolated from mangrove leaves (colonies in *A. germinans*, N = 576; in *R. mangle*, N = 576) showed that variability was significant ($p > 0.05$). Statistical analysis suggested that date/site and site were significant ($p > 0.05$), although the date was insignificant ($p < 0.05$), rejecting the nule hypothesis. (4) *Cladosporium oxysporum* and *C. sphaerospermum* were isolated from seawater based on their ability to use the polyaromatic hydrocarbons naphthalene ($C_{10}H_8$) and phenanthrene ($C_{14}H_{10}$) as a sole carbon and energy source. (5) The planthopper *Petrusa marginata* excretes a sugary honeydew upon which the fungus *Asteridiella sepulta* grows in the leaves of *A. germinans*. The association of *A. sepulta* and *P. marginata* had not been noted. (6) Field surveys in SW PR, and SW Florida (U.S.A.) from July 2001 throughout 2003, yielded

14 spp. of manglicolous basidiomycetes of which 4 were new records. (7) *Stemonitis splendens* is reported on *R. mangle*. This was the first report of this myxomycete on mangroves in the Caribbean and the fifth report from *R. mangle*. (8) Aquatic fungi were isolated from several subtrates from a river mouth estuary Manatí River, N of PR. Finally, (9) a bibliography on coastal and marine biology primarily mycological in orientation is presented.

RESUMEN

Este estudio fue subdividido en los capítulos listados debajo y trató varios aspectos biológicos de la micología costera de Puerto Rico (PR): (1) Se incluye un capítulo de revisión en mangles y plantas asociadas a los mangles para PR. (2) Se provee una lista que contiene 604 taxones de hongos. Se encontraron 13 nuevos registros para PR generados como resultado de los estudios aquí descritos. (3) Muestras de espuma marina y hojas seniles de *Avicennia germinans* y *Rhizophora mangle* de dos comunidades en un estuario conocido como la Laguna Rincón en el SO de PR fueron evaluados en frecuencia de ocurrencia de 8 hongos filamentosos selectos. De entre las 12 bolsas de espuma marina y 1296 hojas muestreadas (desde febrero 2002 hasta enero 2003), las muestras consisten de hongos esporulantes y propágalos, respectivamente. Una ANOVA de dos vías que se hizo a los 8 hongos filamentosos (conteo de propágulos y esporas, $N = 432$) en espuma marina y para los aislados de hojas de mangle (colonias en *A. germinans*, $N = 576$; en *R. mangle*, $N = 576$) mostró que la variabilidad fue significativa ($p > 0.05$). El análisis estadístico sugirió que la fecha/lugar y el lugar fueron significativos ($p > 0.05$), aunque la fecha fue insignificante ($p < 0.05$), rechazando la hipótesis nula. (4) *Cladosporium oxysporum* y *C. sphaerospermum* fueron aislados de agua de mar basándose en su habilidad de usar los hidrocarburos poliaromáticos nafataleno ($C_{10}H_8$) y fenantreno ($C_{14}H_{10}$) como fuentes de carbono y de energía. (5) El saltahojas *Petrusa marginata* excreta una secreción azucarada sobre la cual crece el hongo *Asteridiella sepulta* en la superficie de las hojas de *A. germinans*. La asociación de *A. sepulta* con *P. marginata* es poco conocida. (6) Los

reconocimientos de campo en el SO de PR, y el SO de la Florida (U.S.A.) durante julio de 2001 y a través de 2003, produjeron 14 spp. de basidiomicetos manglícolas de los cuales 4 son nuevos registros. (7) Se informa a *Stemonitis splendens* en *R. mangle*. Este es el primer informe de este mixomiceto en mangles en el Caribe y el quinto informe en *R. mangle*. (8) Se aislaron hongos acuáticos de varios sustratos de la boca de río del estuario Río Manatí, al N de PR. Finalmente, (9) se presenta una bibliografía sobre la biología costera y marina con una orientación principalmente micológica.

"Chance makes a plaything of a man's life."

– Seneca
(First Century A. D.)

"*Recognosce notum*, *ignotum inspice*."

– Motto of the British Mycological Society

"The most beautiful thing we can experience is the mysterious. It is the source of all true art and science."

– Albert Einstein
(Physicist)

"The dream of man is to become God… The reasoning that taught man that he was clever than the animals made him also aware of his own deficiencies."

– John M. Allegro
(Biblical Scholar)

"Skepticism is an attitude towards life, an ethical position. The heart of this position is not to accept, but neither to reject anything a priori. No subject should be above discussion. Every extraordinary claim requires extraordinary evidence."

– Motto of the Skeptical Society of Puerto Rico

DEDICATION

I would like to dedicate this dissertation to my father, Víctor M. Nieves Seda, who passed away on April 9, 2004, and to my mother, Adela Rivera Quiles, whose love and friendship are truly an inspiration to continue graduate studies. Finally, to my stepfather, Don Hiram Monteverde Rivera, who always taught me how to keep up with the good work against all odds.

For the love of my life, my Isis, to my immortal beloved.

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LIST OF SYMBOLS AND ABBREVIATIONS

alt.	=	altitude
ANOVA	=	Analysis of variance
AMNR	=	Ángel M. Nieves-Rivera
APSF	=	Aquatic Preserves of Southwest Florida, Florida
ATCC	=	American Type Culture Collection, Rockville, Maryland
BBI	=	Boquerón Beach Inlet
BCF	=	Boquerón Commonwealth Forest
BPI	=	U.S. National Fungus Collections, Maryland
BS	=	Bahía Sucia, Boquerón Commonwealth Forest
BWR	=	Boquerón Wildlife Refuge
°C	=	Celsius scale, Celsius degree or centigrade scale
CD-ROM	=	Compact disk-read only memory
cf.	=	(*confer*), compare with
CFMR	=	Center for Forest Mycology Research, U.S. Department of Agriculture, Sabana Field Station, Puerto Rico
cm	=	centimeter(-s)
Co	=	coastal beaches (geologic nomenclature)
diam.	=	diameter
DNA	=	Deoxyribonucleic acid
DO	=	Dissolved oxygen
E	=	east
e.g.	=	(*exempli gratia*), for example
ENE	=	East-north-east
Fig(-s)., fig(-s).	=	Figure(-s) (in citations)
FL	=	Florida (U.S.A.)
g/L	=	grams per liter or g/1000 ml (= parts per thousand or ppt)

GB	=	Guayanilla Bay, Guayanilla, Puerto Rico
G.P.S.	=	Global Positioning System
H_0	=	Null hypothesis
HPLC	=	High Pressure Liquid Chromatograph
hr(-s)	=	hour(-s)
ibid.	=	(*Ibidem*), at the same place
MS	=	Institute of Marine Sciences, The University of North Carolina, Chapel Hill
km	=	kilometer(-s) per hour
km^2	=	square kilometer(-s)
KOH	=	5.0% aqueous solution of potassium hydroxide
LACMIP	=	Natural History Museum of Los Ángeles County, Department of Invertebrate Paleontology, Los Ángeles, California
LM	=	Los Morrillos, Boquerón Commonwealth Forest
LPCF	=	La Parguera Commonwealth Forest
Lr	=	limestone rock lands (soil nomenclature)
LTER	=	Long Term Ecological Research
m	=	meter(-s)
Ma	=	million year(-s)
MAPR	=	Tropical Mycology Collection, University of Puerto Rico Herbarium, Mayagüez
MEA	=	Malt extract agar
$mg \cdot ha^{-1} \cdot yr^{-1}$	=	milligrams per hectares per year
mg/L	=	milligrams per liter or 10^{-3} g/1000 ml (= parts per million or ppm)
MIML	=	Magueyes Island Marine Laboratories or Magueyes Island Field Station, La Parguera
ml	=	milliliter(-s)
mm^2	=	square milimeter(-s)

MO	=	Herbarium, Missouri Botanical Garden, Saint Louis, Missouri
N	=	north
NJRR	=	Nydia J. Rodríguez-Rodríguez
NOAA	=	National Oceanographic and Atmospheric Administration (U.S. Department of Commerce)
NY	=	Cryptogamic Herbarium, The New York Botanical Garden, Bronx
O	=	The Mycological Herbarium, The Botanical Garden, University of Oslo, Norway
op. cit.	=	(*opere citato*), in the work mentioned
PAHs	=	Polyaromatic hydrocarbons or polycyclic aromatic hydrocarbons
PC	=	La Parguera Channels
PDA	=	potato dextrose agar
pl.	=	plate(-s) (in citations)
Pp., pp.	=	page(-s) (in citations)
PR	=	Puerto Rico
PRDNR	=	Puerto Rico Department of Natural Resources (old name of PRDNER)
PRDNER	=	Puerto Rico Department of Natural and Environmental Resources
Qb	=	beach deposits (geologic nomenclature)
QLE	=	Coefficient of light extinction
Qm	=	Holocene's mangrove swamps (geologic nomenclature)
RL	=	Rincón Lagoon or "Laguna Rincón", southwestern Puerto Rico
S	=	south
sp., spp.	=	species (singular and plural, respectively)
s. str.	=	(*sensu stricto*), in the strict sense; narrowly
SSE	=	South-south east
SSF	=	San Sebastián Formation
SWM	=	Sea water medium
Tf	=	tidal flats (soil nomenclature)

Ts	=	tidal swamps (Ts) (soil nomenclature)
UARK	=	Herbarium, University of Arkansas, Fayetteville, Arkansas
UPRMP	=	Geological Museum, Department of Geology, University of Puerto Rico, Mayagüez Campus
UPRRP	=	Herbarium, University of Puerto Rico, Río Piedras Campus
USDA	=	United States Department of Agriculture
UTMC	=	University of Texas Myxomycete Collection, Texas
Vol(-s)., vol(-s).		
	=	volume(-s) (in citations)
W	=	west
YPM	=	Yale Peabody Museum Herbarium, Yale University, Cincinnati
yy, yr, yrs	=	year(-s)
µm	=	micrometer(-s)

CHAPTER 1

PREFACE

"In the sea around the Pillars of Hercules where there is much water, fungi are produced close to the sea, which people say have been turned to stone by the sun."

–Theophratus (circa 372-287 B.C.)

INTRODUCTION

Aquatic fungi and fungal-like organisms, especially freshwater forms have been studied for many years. The oomycetes, the most important group in early studies, taxonomically speaking are a group derived phylogenetically from algae and with which they were often confused (Ainsworth, 1976). The first representatives are zoosporic-like, although zoospores were first reported in 1807 by Prévost in the terrestrial *Albugo* (Peronosporales: Oomycota) (Ainsworth, 1976). Many important nineteenth-century works were consolidated within the contribution "Kryptogamenflora der Mark Brandenburg" by M. von Minden between 1911 to 1915, the latter being the forerunner of the later works of Frederick K. Sparrow (1923) on Saprolegniaceae and Pythiaceae, also treated by William C. Coker (1923) and Velma D. Matthews (1931) (Ainsworth, 1976). Since these early studies, many details of their complicated life cycles have been revealed and been added to the knowledge of the sexuality and cytology of the Oomycota. In the 1940's, Cecil T. Ingold described a series of mitosporic fungi today known as aquatic hyphomycetes (or Ingoldian fungi) growing on decaying leaves in a British stream (Ingold, 1942; Ainsworth, 1976). These fungi (mostly asexual forms of Ascomycota and Basidiomycota) are cosmopolitan in distribution, and therefore can be isolated from temperate regions and tropics, including estuaries (Kirk, 1969). However, our knowledge of these groups in general is increasing in the coastal environment.

The study of marine fungi [obligate and facultative as defined by Kohlmeyer (1974)] and marine mycology began early in the twentieth century with the report of some species by Arthur D. Cotton in 1909 (Ainsworth, 1976). The first reports dealing with marine pyrenomycetes were published by George K. Sutherland in 1915 and 1916 (Ainsworth, 1976). However, the report that caused major interest to the scientific community was the paper on the marine fungi of New England and California by Elso S. Barghoorn and David H. Linder in 1944 (Barghoorn and Linder, 1944). As a direct consequence, an expansion of mycological studies has been carried out since the 1950's, mostly due to popularity among scientists from whom originated such monographs as "Fungi in oceans and estuaries" (Johnson and Sparrow, 1961), "Recent advances in aquatic mycology" (Jones, 1976), "Marine mycology: the higher fungi" (Kohlmeyer and Kohlmeyer, 1979), and "Marine mycology: a practical approach" (Hyde and Pointing, 2000). Also, the "International marine and freshwater mycology symposium" which occurs every 4 to 5 years and attracts an increasing number of participants around the world is the source of new research on marine fungi (Hyde and Pointing, 2000). Certainly, those new investigations, especially those on biotechnological potentialities of marine fungal metabolites are of great interest to pharmaceutical companies.

Traditionally, terrestrial and freshwater fungi have been the main subject for study by Puerto Rican mycologists. Recently, coastal fungi (e.g., marine, estuarine, and manglicolous fungi) have received some attention in Puerto Rico (Acevedo, 2001; Nieves-Rivera et al., 2002). Human concern with oceanographic issues also account for the increased interest in coastal organisms. Pollution in mangroves, estuaries, and local shores is common, thus the roles of macro- and micromycetes in coastal environments are relevant. The topics reviewed in this thesis included fungal nomenclature, taxonomy and morphology, and ecology. In keeping with the growing concern over environmental issues, a chapter dealt with two locally isolated microfungi (*Cladosporium oxysporum* and *C. sphaerospermum*) that have the capability of degrading polyaromatic hydrocarbons (PAHs). It is therefore, my intention of summarizing all available works, either published or unpublished, that dealt with coastal fungi (obligate and facultative marine and terrestrial fungi) from Puerto Rico. This work might be considered a supplement to the Caribbean mycological survey of Minter et al. (2001). Most coast fungi collections are in some cases sporadic and interrupted by many years. This study reported the incidence of fungi in coasts from Puerto Rico, a subtropical island located between 18°00'–18°30' N, 65°35'–67°15' W, in the northeastern Caribbean Sea (Figure 1A-C). The maps of southwestern Puerto Rico showing the general collection sites (Cabo Rojo, La Parguera, and Guayanilla quadrangles) are included in Figures 2-4.

OBJECTIVES

The proposed study relies on the hypothesis that fungal communities from mangroves and estuarine ecosystems in Puerto Rico are relevant as saprophytes and decomposers. Obligate and facultative marine fungi (s. str. Kohlmeyer, 1974) are important to the degradation of plant debris and have been found to be more diverse than previously suspected. Although many ecological studies on manglicolous and estuarine fungi have been accomplished in various parts of the globe, their ecology has been poorly documented by previous researchers in Puerto Rico. The null hypothesis (H_0) proposed is that sampling time (mm-yy), site or location, and the combination of both sources (intersect) will not affect significatively ($p < 0.05$) two filamentous fungal communities in a tropical estuary.

Specific objectives include:

1. To survey and report the taxonomic composition of marine, estuarine, and terrestrial costal fungi (Ascomycota, Basidiomycota, Zygomycota, Chytridiomycota, and Mitosporic fungi) and fungal-like organisms (Oomycota, Myxomycota, Plasmodiophoromycota) associated with mangroves species (e.g., *Rhizophora mangle*, *Avicennia germinans*, *Laguncularia racemosa*, and *Conocarpus erectus*) in marine, estuarine, and terrestrial ecosystems of southwestern Puerto Rico (e.g., see Figures 5A-I and 6A-C);
2. To compare the ecological aspects (e.g., taxonomic composition y distribution patterns) of the fungal communities that will be surveyed (see objective 1) with previous reports

from other subtropical and tropical mangal regions of the globe especially the Caribbean.

3. Characterization by morphology of two species of *Cladosporium* (*C. oxysporum* and *C. sphaerospermum*) isolated from coastal seawater and have the ability to use polyaromatic hydrocarbons (PAHs) naphthalene and phenanthrene.

4. To contrast two filamentous fungal communities in a nutrient- and organic matter rich brackwater lagoon bordered by mangroves versus the environmental parameters (e.g., water temperature, pH, salinity, dissolved oxygen, etc.).

5. Prepare a bibliography on coastal mycology of Puerto Rico with a particular emphasis on tropical and subtropical marine, estuarine, and mangrove-associated fungi.

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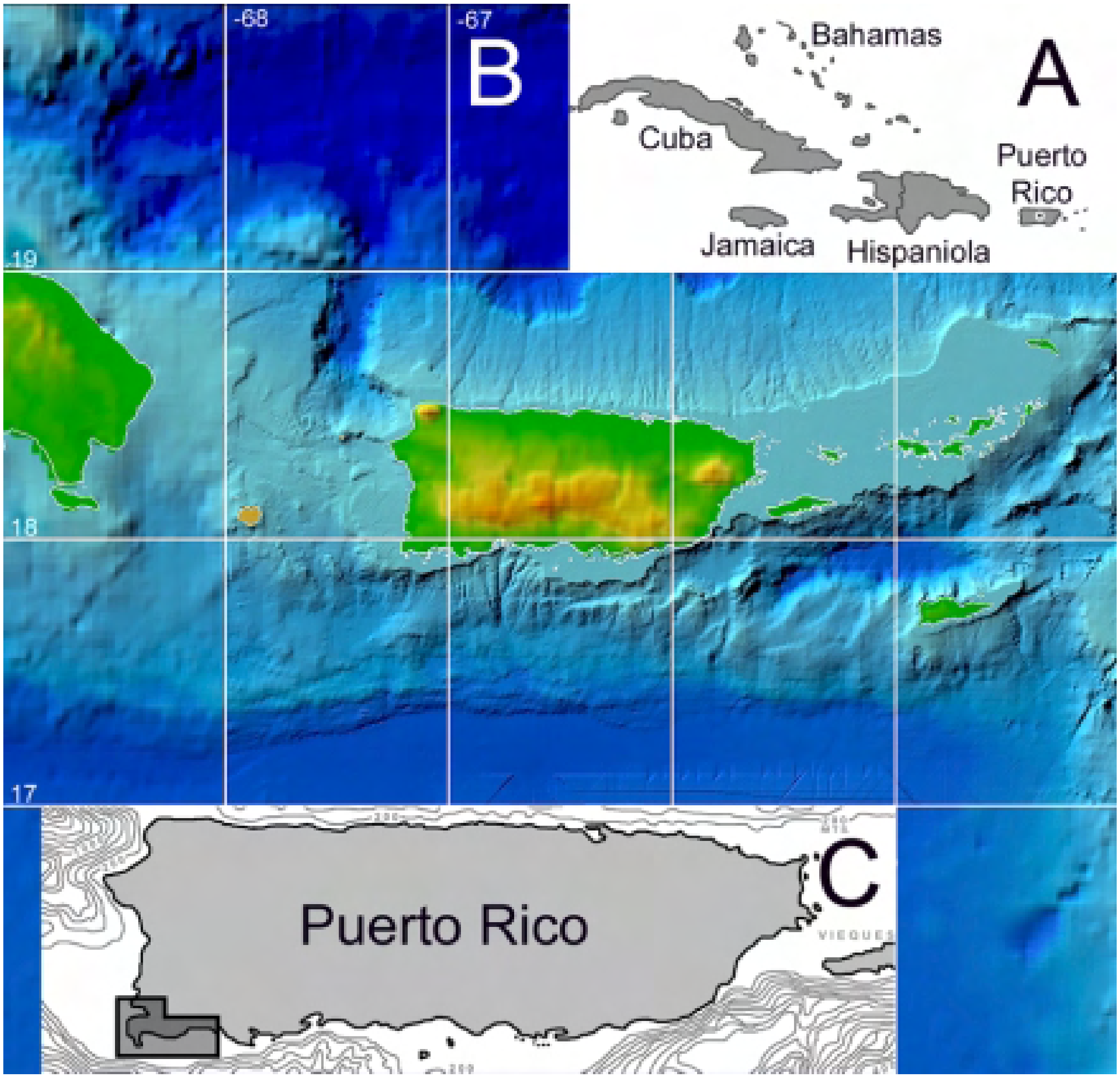


Figures 1A-C. A. Location of Puerto Rico in regards to the Greater Antilles. B. Bathymetry of Puerto Rico (map courtesy of Aurelio Mercado and Harry Justiniano). C. Map of southwestern Puerto Rico, showing the general collection area.

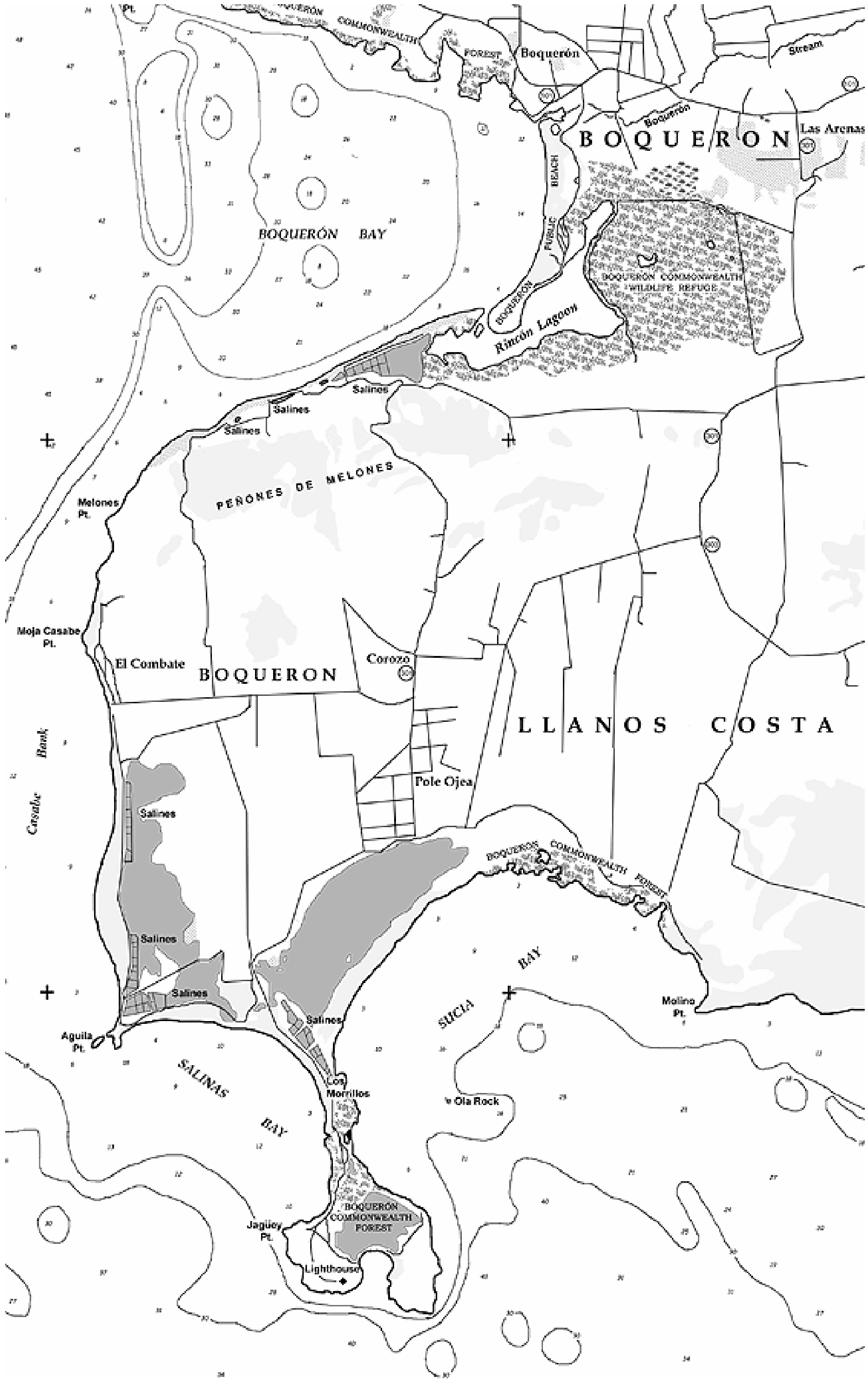


Figure 2. Studied sites in southwestern Puerto Rico, Cabo Rojo quadrangle.

Figure 3. Studied sites in southwestern Puerto Rico, La Parguera quadrangle.

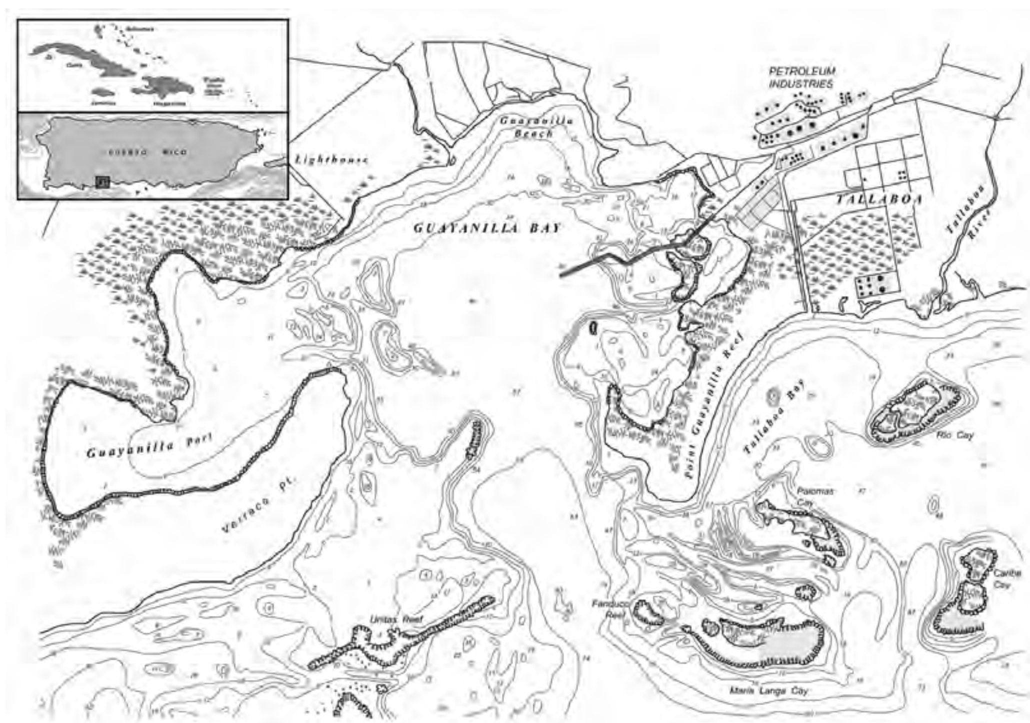
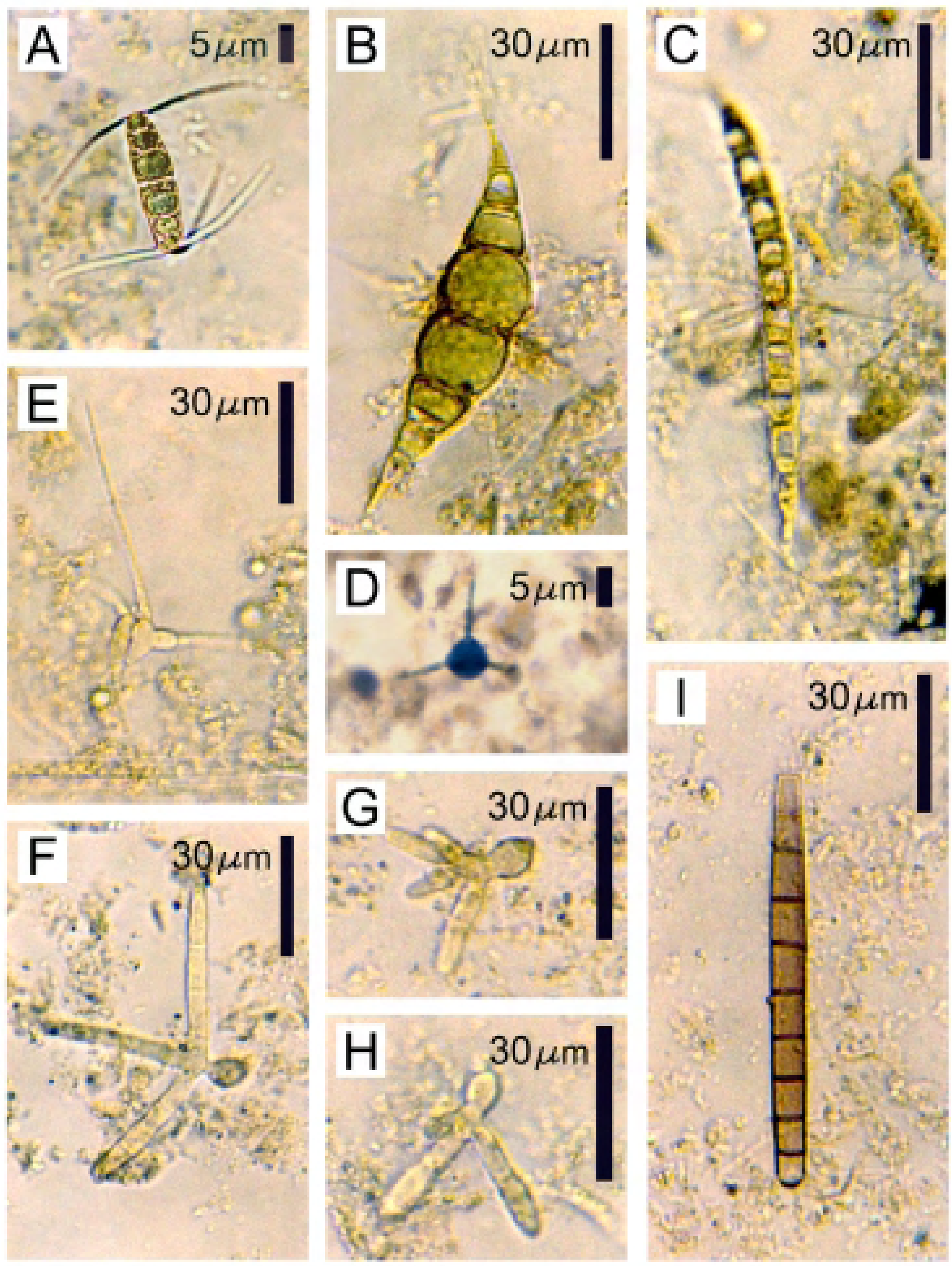
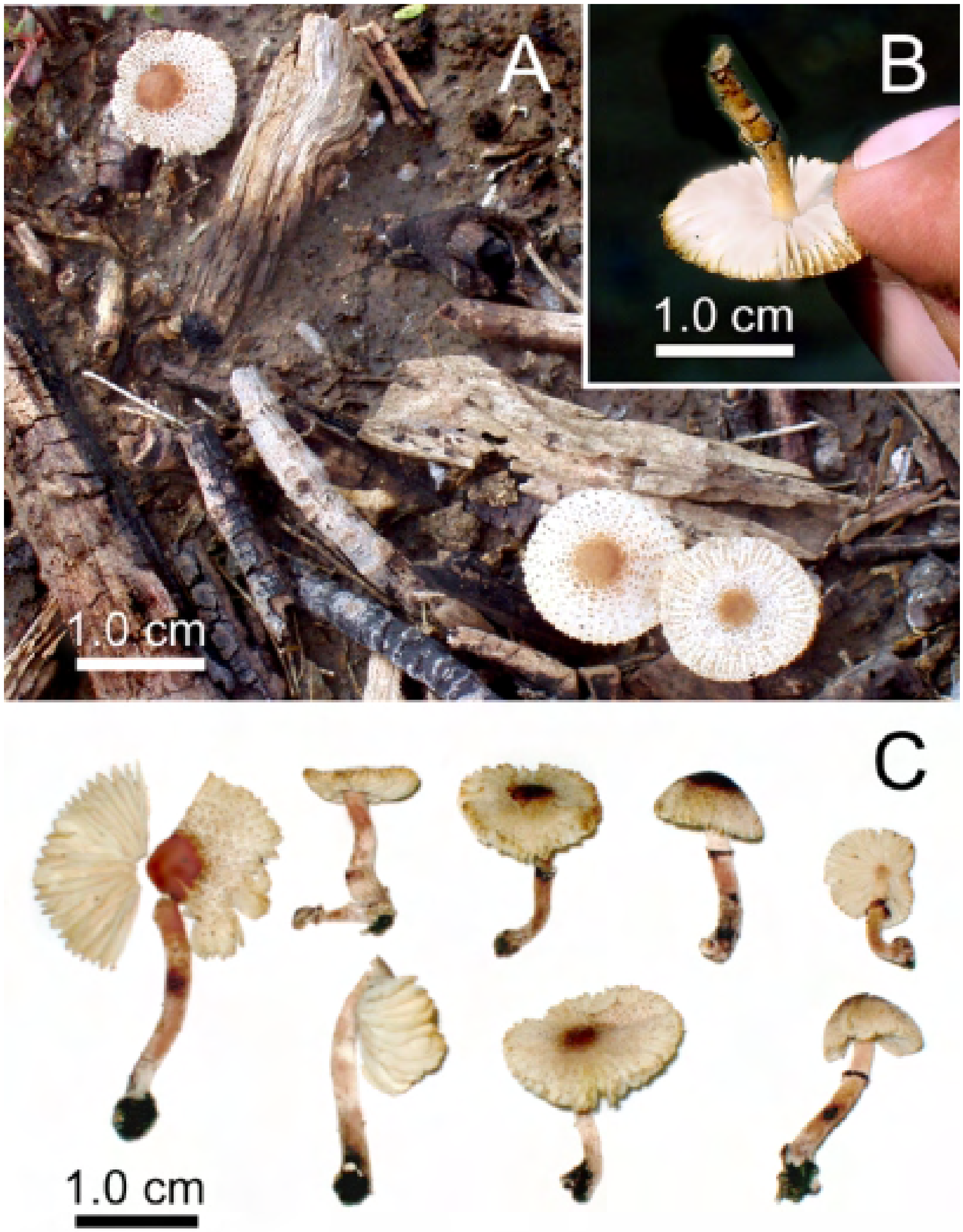


Figure 4. Guayanilla Bay area, southwestern Puerto Rico, Guayanilla quadrangle.



Figures 5A-I. Examples of marine and estuarine microfungi isolated from Puerto Rico. Ascospores: A. *Arenariomyces triseptatus*. B. *Corollospora* cf. *colossa*. C. *Corollospora filiformis*. Conidia: D. *Brachiosphaera tropicalis*. E. *Campylospora* sp. F-H. *Clavatospora bulbosa*. I. *Camposporidium* sp.



Figures 6A-C. Example of a mushroom (*Lepiota* cf. *erinana*) recently collected from buried wood in a saltpeter next to the Phosphorescent Bay, Lajas, Puerto Rico A. In situ. B. Checking the lamellae. C. Basidiocarps in different stages of development.

CHAPTER 2

NEW RECORDS OF AN EXOTIC VARIETY, FOSSIL, AND UNUSUAL STRUCTURE IN MANGROVES OF PUERTO RICO

ABSTRACT

A compilation of 125 plants routinely found in mangrove forests, the introduction of a new variety of the mangrove-associated plant, *Conocarpus erectus* var. *sericeus* (Combretaceae), unusual aerial roots in *Avicennia germinans* (Avicenniaceae), and several new trace fossils (ichnofossils) of mangroves are reported for Puerto Rico. An actualized checklist of scientific and common botanical names (English/Spanish), including 3 true mangroves (*A. germinans*, *Laguncularia racemosa*, and *Rhizophora mangle*) and 122 mangrove-associates are herein reported for Puerto Rico.

RESUMEN

Un resumen de 125 plantas rutinariamente encontradas en los bosques de mangle, la introducción de una nueva variedad de planta asociada al mangle, *Conocarpus erectus* var. *sericeus* (Combretaceae), unas raíces aéreas inusuales en *Avicennia germinans* (Avicenniaceae) y varios nuevos fósiles trazas (icnofósiles) de mangles son informados para Puerto Rico. Se informa una lista actualizada de nombres científicos y comunes botánicos (inglés/español), incluyendo 3 mangles verdaderos (*A. germinans*, *Laguncularia racemosa* y *Rhizophora mangle*) y 122 asociados al mangle para Puerto Rico.

INTRODUCTION

A mangrove forest is considered a dynamic ecotone (or transition zone) between terrestrial and marine habitats. In its simplest sense, “mangrove” as used herein, encompasses a group of woody, halophylic plants that occurs along sheltered tropical and subtropical coastlines. Mangroves are derived from a variety of plant families and vary in their dependence upon littoral habitats. Mangrove forests are also referred to as mangrove swamps, tidal forests, tidal swamp forests or mangals. Caribbean mangroves range from 30° N latitude (northern Florida) to 8° N latitude (northwest Colombia) and from 59° W longitude (north of Guiana) to 89° W longitude (eastern Guatemala) (Tomlinson, 1986). Until recently, four mangrove species were known to occur in Puerto Rico, the most widely distributed of which are the red mangrove (*Rhizophora mangle*), black mangrove (*Avicennia germinans*), white mangrove (*Laguncularia racemosa*), and buttonwood (*Conocarpus erectus*) (Lugo and Snedaker, 1974; Cintrón et al., 1978) (Figures 7A-B, 8 A-C, and 9A-D). Following Tomlinson (1986), only three species should be considered as "true mangroves" (*A. germinans*, *R. mangle*, and *L. racemosa*) in Puerto Rico. *Conocarpus erectus* is frequently considered a "true mangrove", but Tomlinson (1986) suggested that is better regarded as a mangrove associate because it lacks any of the biological features (pneumatophores and vivipary) which characterize true mangroves; furthermore, it occurs in inland communities. A number of other plants characteristically occur in association with mangroves in Puerto Rico (Table I).

Table I. List of mangroves and mangrove-associated plants of Puerto Rico. Taxonomy and nomenclature according to García-Molinari (1952), Schubert (1979), Little and Woodbury (1980), Martorell et al. (1981), Tomlinson (1986), Más and García-Molinari (1990), Francis and Lowe (2000), Little et al. (2001), Anonymous (2001), Acevedo-Rodríguez (2003), and U. S. Department of Agriculture (2004).

TAXA	COMMON NAMES
Family Aizoaceae	
Sesuvium maritimum (Walt.) B.S.P.	slender seapurslane; verdolaga de mar
S. portulacastrum (L.) L.	sea purslane, shoreline seapurslane; yerba de vidrio, verdolaga rosada
Family Alismataceae	
Echinodorus berteroi (Spreng.) Fassett	creeping burrhead; llantén de agua

Sagitaria lancifolia L.	bulltongue arrowhead, arroz leaf; flecha de agua, saeta de agua
Family Annonaceae	
Annona glabra L.	pond apple, alligator apple, cork wood, mangrove annona, bunta dog apple, bunya, dog apple, monkey apple; cayur, cayure, corazón cimarrón, corcho, coyur
Family Apiaceae	
Hydrocotyle bonariensis Comm.: Lam.	largeleaf pennyworth
H. hirsuta Sw.	yerba de clavo
H. prolifera Kellogg	whorled marshpennyworth
H. pusilla A. Rich.	tropical marshpennyworth
H. umbellata L.	marsh pennyworth, manyflower marshpennyworth; ombligo de Venus, sombrerillo de agua, yerba de cuarto
Family Apocynaceae	
Rhabdadenia biflora (Jacq.) Muell.-Arg.	mangrove rubber vine, mangrovevine; enredadera de mangle
Family Aquifoliaceae	
Ilex vomitoria Soland. in Ait.*	cassena, yaupon; yaupón
Family Avicenniaceae	
Avicennia germinans (L.) Stearn	black mangrove, black-mangrove, olive mangrove, salt pond, honey mangrove, saltbush; mangle negro, mangle prieto, mangle bobo, chifle de vaca, prieto, salado, siete cueros, mangle blanco
Family Batidaceae	
Batis maritima L.	pickleweed, saltwort, turtleweed; barilla, planta de sal
Family Boraginaceae	
Argusia gnaphalodes (L.) Heine	sea rosemary, sea lavender, bay lavender; nigua de playa,

	té de mar, temporana, yerba cotorra
Heliotropium curassavicum L.	seaside heliotrope, salt heliotrope; cotorrera de playa
Heliotropium curassavicum L. var. *curassavicum*	seaside heliotrope, salt heliotrope; cotorrera de playa
Tournefortia filiflora (Ker-Gawl.) L. Benson	cold withe; nigua
Family Cactaceae	
Opuntia stricta (Haw.) Haw.	erect pricklypear, prickly pear, cactus; tuna, tuna brava, higo de mar
Opuntia stricta (Haw.) Haw. var. *dillenii* (Ker-Gawl.) L. Benson	erect pricklypear, prickly pear, cactus; tuna, tuna brava, higo de mar
Family Casuarinaceae	
Casuarina equisetifolia L.*	Australian pine, Australian beefwood, beef wood, beach sheoak; pino australiano, casuarina, pino
Family Combretaceae	
Conocarpus erectus L.	button mangrove, buttonwood, buttontree, button-tree; mangle botón, mangle de botón, botoncillo
C. erectus var. *sericeus* Griseb.*, ***	silver buttonwood, northern buttonwood; mangle botón plateado; botoncillo plateado
Laguncularia racemosa (L.) Gaertn. f.	white mangrove; mangle blanco, mangle bobo
Terminalia catappa L.*	Indian almond, Indian-almond, tropical almond, Malabar almond; almendra, almendro
Family Compositae	
Helianthus annuus L.*	common sunflower, sunflower; girasol, mirasol
Family Convolvulaceae	
Ipomoea imperati (Vahl) Griseb.	fiddle-leaf morningglory, beach morning glory, beach morning-glory; batatilla,

	bejuco de costa, bejuco de puerco de costa
I. pes-caprae (L.) R. Brown	beach morningglory, beach morning glory, bayhops, bay hops, goat foot; bejuco de playa
I. pes-caprae (L.) R. Brown ssp. *brasiliensis* (L.) van Ooststr.*	Brazilian bayhops, Brazilian bay hops; bejuco de playa brasiliense
Family Cyperaceae	
Cyperus imbricatus Retz.	shingle flatsedge; junco
C. unioloides R. Brown	uniola flatsedge
Eleocharis mutata (L.) Roem. & J.A. Schult.	scallion grass, scalion grass, angled spikerush
Remirea maritima Aubl.	beachstar, beach sedge; junco de playa
Scirpus tabernaemontani (K.C. Gmel.) Palla	softstem bulrush, bulrush; junco
Torulinum filiforme (Sw.) C.B. Clarke	pajón de costa
Family Euphorbiaceae	
Caperonia palustris (L.) St.-Hil.	sacatrapo
Croton astroites Ait.	wild marrow; maná, marán
C. betulinus Vahl	beechleaf croton
C. discolor Willd.	lechecillo
C. glandulosus L.	vente conmigo
C. humilis L.	pepper bush, pepperbush, yerba bellaca
C. impressus Urb.	Puerto Rico croton
C. lobatus L.	lobed croton; croton lobulado
C. lucidus L.	firebush
C. microcarpus Ham.	money croton
C. poecilanthus Urb.**	saninon; sabilón
C. rigidus (Muell.-Arg.) Britton	yellow balsam; adormidera, guayacanillo
C. stenophyllus Griseb.	West Indian croton
Hippomane mancinella L.	manchioneel, manchineel; manzanillo
Family Goodeniaceae	
Scaevola plumieri (L.) Vahl	inkberry, gullfeed; borbón, borborón, coralillo
Family Gramineae (Poaceae)	

Cenchrus brownii Roem. & J.A. Schult.	slimbristle sandbur; abrojito
C. echinatus L.	bur grass, southern sandbur; abrojo, cadillo
C. gracillimus Nash	slender sandbur; abrojo de playa
C. incerus M.A. Curtis	sand burgrass; abrojo de playa
C. myosuroides Kunth	big sandbur, spiked-bur-grass; abrojo de espigas
C. pauciflorum Benth.	sand burgrass, mat sandbur, field sandbur; abrojo de dunas, abrojo de playa
Cynodon dactylon (L.) Pers.	common Bermudagrass, Bermuda grass; yerba Bermuda, Bermuda común, hala que te quedas, palo de brujas, lao de brujas, Pepe Ortiz
Dactyloctenium aegypticum (L.) Willd.	Egyptian grass, goose foot grass, crowfoot grass, durban crowfoot grass; yerba egipcia, yerba de Egipto
Eustachys petraea (Sw.) Desv.	pinewoods fingergrass; stiffleaf eustachys; yerba de dedo
Paspalidium geminatum (Forsk.) Stapf	water panicum, Egyptian panicgrass; yerba de pantano
Paspalum vaginatum Sw.	seashore paspalum, stiltgrass; paspalum playero, cortadera
Phragmites australis (Cav.) Trin.: Steud.	common reed, reed grass; caña de indio, caña de pantano
Spartina patens (Ait.) Muhl.	saltmeadow cordgrass, salt grass; yerba de sal
Sporobolus virginicus (L.) Kunth	seashore dropseed, sea-shore rush grass, seashore rush grass, sandcoach, beachgrass, saltwater smutgrass; matojo de burro, matojo de playa, salaillo
Stenotaphrum secundatum (Walt.) Kuntze	Saint Augustine grass, St. Augustine grass, St.

augustinegrass, running crab-grass; yerba San Agustín, cinta, cinto, cintillo, grama, grama blanca, grama dulce

Family Guttiferae

Calophyllum inophyllum L.* — Alexandrian laurel, ball nut, kamani; María grande

Family Hydrocharitaceae

Thalassia testudinum Banks & Soland.: Koeing — turtlegrass, thalassia; thalassia, yerba tortuga, palma de mar

Family Lecythidaceae

Barringtonia asiatica (L.) Kurz* — fish poison tree; almendrota, bonete de arzobispo, coco de mar, mudilla

Family Leguminosaceae (Fabaceae)

Subfamily Caesalpinioideae

Caesalpinia bonduc (L.) Roxb. — gray nickers, yellow nicker; mato de playa, mato azul, haba de San Antonio

C. ciliata (Bergius: Wikstr.) Urb. — mato de playa, mato

C. culebrae (Britton & P. Wilson) Alain** — smooth yellow nicker; mato de playa culebrense

C. monensis Britton — black nicker; mato negro

C. portoricensis (Britton & P. Wilson) Alain** — brown nicker; mato marrón, mato negro

Chamaecrista nictitans (L.) Moench — partridge pea; matojo de playa

C. nictitans (L.) Moench ssp. *nictitans* — partridge pea; matojo de playa

C. nictitans (L.) Moench ssp. *nictitans* var. *aspera* (Muhl.: Ell.) Irwin & Barneby — partridge pea; matojo de playa

C. nictitans (L.) Moench ssp. *nictitans* var. *diffusa* (DC.) Irwin & Barneby — partridge pea; matojo de playa

C. nictitans (L.) Moench ssp. *patellaria* (DC.: Colladon) Irwin & Barneby

	partridge pea; matojo de playa
C. nictitans (L.) Moench ssp. *patellaria* (DC.: Colladon) Irwin & Barneby var. *glabrata* (Vogel) Irwin & Barneby	partridge pea; matojo de playa
Pterocarpus officinalis Jacq.	swamp bloodwood, dragonsblood tree; palo de pollo, pterocarpus
Senna bicapsularis (L.) Roxb.	Christmas-bush, Christmasbush, stiver bush, styver-bush; hoja de sen, sen del país
S. nitida (L.C. Rich.) H.S. Irwin & Barneby	hediondilla
Stahlia monosperma (Tul.) Urb.**	cóbana, cóbana negra, polisandro
Subfamily Papilionoideae	
Canavalia rosea (Sw.) DC.	baybean, beach bean, bay bean, seaside bean; haba de playa, canavalia, habichuela playera, mato de playa
Dalbergia ecastophyllum (L.) Taub.	coin vine, maraymaray; palo de pollo, maraimaray, siso
Machaerium lunatum (L. f.) Ducke	escambrón, palo de hoz
Family Lemnaceae	
Lemna aequinoctialis Welw.	lesser duckweed, duck weed; yerba de pato, lentejilla de agua
Wolffiella lingulata (Hegelm.) Hegelm.	tongueshape bogmat; wolffiella
Family Lentibulariaceae	
Utricularia gibba L.	humped bladderwort; grasilla
Family Liliaceae	
Yucca aloifolia L.*	aloe yucca, Spanish-bayonet; aguja de Adán, bayoneta española, mata de hueso
Family Malvaceae	
Hibiscus tiliaceus L.	beach hibiscus; emajagua, majagua

H. pernambucensis Arruda	sea hibiscus; emajagua, majagua
Pavonia paludicola D.H. Nicols.: Fryxell	swampbush; cadillo de ciénaga
Thespesia populnea (L.) Soland.: Correa*	seaside mahoe, portia tree, Spanish cork, portiatree, otaheita; emajagüilla
Family Mimosaceae	
Prosopis pallida (Humb. & Bonpl.: Willd.) Kunth*	mesquite; bayahonda, mesquite, algarroba del Hawaii, kiawe
Neptunia plena (L.) Benth	water dead and awake, water neptunia; desmanto amarillo
Family Myoporaceae	
Bontia daphnoides L.	white alling; manzanilla, mangle bobo
Family Myricaceae	
Morella cerifera (L.) Small*	wax myrtle, southern waxmyrtle, bay-berry, wax-berry; arrayán, cerero
Family Najadaceae	
Najas guadalupensis (Spreng.) Magnus	southern waternymph, Guadalupe waternymph, southern naiad, common water nymph
Najas guadalupensis (Spreng.) Magnus ssp. *guadalupensis*	southern waternymph
N. marina L.	holly-leaf waternymph, holly-leaved waternymph, spiny naiad, bushy pondweed
Family Orchidaceae	
Psychilis krugii (Bello) Sauleda**	Krug's butterfly orchid, Krug's peacock orchid Remarks.—This endemic orchid was common in the mangroves and dry forests of southwestern Puerto Rico, but it has been almost collected out of the mangroves. Specimens deposited in The New York

	Botanical Garden herbarium (NY) with accession numbers 59135 to 59149.
Family Palmaceae	
Cocos nucifera L.*	coconut palm, coconut; palma de coco(-s), cocotero, coco
Sabal causiarum (O.F. Cook) Becc.**	Puerto Rican palmetto, Puerto Rico palmetto, hat palm, hat palmetto, straw-hat palm; palma de sombrero, yarey
Family Polygonaceae	
Coccoloba uvifera (L.) L.	seagrape, sea grape; uvero, uvera, uva de playa, uvas
Family Pteridaceae	
Acrostichum aureum L.	golden leatherfern; helecho de río, helecho de pantano, palmita del río
A. danaeifolium Langsd. & Fisch.	giant leatherfern, giant fern, swamp fern, inland leatherfern; helecho de pantano, helecho gigante de pantano
Marsiela polycarpa Hook. & Grev.	water fern, Guayanan waterclover; helecho de agua
Family Rhizophoraceae	
Rhizophora mangle L.	red mangrove, American mangrove, mangrove; mangle rojo, mangle colorado, mangle zapatero, mangle de chifle
Family Rosaceae	
Chrysobalanus icaco L.	coco-plum, cocoplum coco plum; icaco, hicaco, jicaco
Family Rubiaceae	
Ernodea littoralis Sw.	beach creeper, coughbush
Family Ruppiaceae	
Ruppia cirrhosa (Petag.) Grande	spiral ditch-grass; yerba de zanja espiral
R. maritima L.	widgeongrass, ditch-grass; yerba de zanja

Family Scrophulariaceae	
Bacopa monnieri (L.) Pennell	coastal water-hyssop, herb of grace; yerba de culebra
Family Simaroubaceae	
Suriana maritima L.	bay cedar, baycedar; guitarrán, quitarán, temporana
Family Typhaceae	
Typha domingensis Pers.	southern cattail, cat tail; eneas, enea, aeneas, yerba de eneas
Family Umbelliferaceae	
Centella erecta (L. f.) Fern	erect centella; yerba de clavo
Hydrocotyle bonariensis Lam.	largeleaf pennywort
H. hirsuta Sw.	yerba de clavo
H. umbellata L.	marsh pennywort; ombligo de Venus, sombrerillo de agua, yerba de cuarto
Family Verbenaceae	
Lantana camara L.	yellow sage; cariaquillo
L. camara var. *aculeata* (L.) Mold.	pink sage, prickly sage; cariaquillo espinoso
L. involucrata L.	button sage, wild sage; cariaquillo Santa María, Santa María
L. montevidensis (Spreng.) Briq.	trailing lantana, trailing shrubverbena; cariaquillo rastrero, cariaquillo de canastas
Lippia nodiflora (L.) Michx.	common fog fruit, common fiddlewood, northern fog-fruit, cape-turkeytangle, cape-weed, Turkey tangle fogfruit, Turkey-tangle, fog fruit, weed; cidrón, yerba de Sapo; hierba de la Virgen María

* Exotic species; ** Endemic species; *** New record for Puerto Rico.

Mangroves are exceptionally adaptable and therefore can survive under a relatively wide range of environmental conditions. Some species have been found in freshwater ponds well above sea level. Environments suitable for mangrove growth occur where temperatures are warm and frosts are infrequent, where the shoreline is protected from wave action and pounding surf, or behind protective natural formations such as dunes (Martínez, 1988) and on coastal plains where the influence of seawater occurs. They develop best where they also receive terrestrial runoff and periodic flooding by river discharge (e.g., estuaries). Where the tides are large and the coast is of low relief, salt water can intrude inland for long distances, and mangrove coverage may be very extensive (Cintrón et al., 1978; Vázquez, 1983). One major biological characteristic of mangrove forests is their homogeneity. Often, a single tree species is monodominant over large areas.

The purpose of this study is to offer further information on the introduced species *Conocarpus erectus* var. *sericeus* (Combretaceae), the unusual aerial roots formation in *A. germinans*, and paleobotanical notes on mangrove-like plants in Puerto Rico.

CONOCARPUS ERECTUS VAR. *SERICEUS*: AN INTRODUCED MANGROVE-ASSOCIATED PLANT

The buttonwood mangrove (*C. erectus*) grows along the coast of west tropical Africa, the tropic and subtropical coasts of the Atlantic, including the West Indies and the Pacific coast of North and South America. A pubescent-leaf variety of *C. erectus* known as the silver buttonwood, *C. erectus* var. *sericeus*, was reported originally from the Bahamas, southern Florida, and northern Central America (Stemple, 1970; Miller and McRitchie, 1973; Schubert, 1979). In recent times, *C. erectus* var. *sericeus* has been introduced into the Greater and Lesser Antilles (Stearn, 1958; Stemple, 1970; Nieves-Rivera, unpubl. data). This report is a new record for Puerto Rico and the mangrove habitat.

The study areas for the data herein reported were Boquerón Beach Inlet (BBI) (18°00’95.7”N, 67°10’24.9”W), located west of the Boquerón Wildlife Refuge, Boquerón Commonwealth Forest (BCF) and Magueyes Island Marine Laboratories (MIML) (17°58’24.3”N, 67°02’71.8”W), located in La Parguera Commonwealth Forest), both in southwestern Puerto Rico, at mean sea level. The general environment of BBI and MIML is classified as a subtropical dry forest (Ewel and Whitmore, 1973). Further details on climatology, ecology, geology, and edaphic formations of BBI and MIML are available in Vázquez (1983), Volckmann (1984), Toro and Colón (1986), Torres-Figueroa (1993), Vázquez and Kolterman (1998), Winter et al. (1998), and Nieves-Rivera et al. (2002). *Rhizophora mangle* and *A. germinans* occasionally form thick coastal forests in BCF, as well as on the rest of the southwestern coast of Puerto Rico (Cintrón et al., 1978; Lugo, 1989; Vázquez and Kolterman, 1998) (Figures 7A-B and 8A-C).

Conocarpus erectus var. *sericeus* is frequently a shrub with alternate leaves which generally lives on the landward side of the tidal mangrove swamps. The leaves are leathery or pubescent, fleshy, lance-shaped or elliptical 3.0 to 7.6 cm long x 0.6 to 3.2 cm wide, long-pointed at both ends, and yellow green on both sides. This species characteristically forms small evergreen trees up to 6.0 m in height and 20 cm in trunk diameter, sometimes reaching a larger size or occurring only as a low shrub, with a spreading crown. Stemple (1970) reported three *C. erectus* morphotypes: one is pubescent or silky, sometimes with silvery hairy foliage (type 1), glabrous throughout (type 2), combination of both or 'cyclic' (type 3). The pattern formed by the hairs on the leaves in *C. erectus* var. *sericeus* is similar to that of the coastal plants *Spiraea ulmaria*, *Borrichia arborescens* (Stemple, 1970), and to that of the paramo-adapted plants *Espeletia* spp. and *Senecio* spp. (Rundel et al., 1994). In southern Florida the variety with pubescent or silvery hairy foliage is usually grown as an ornamental. This variety will grow on dry land well away from the seashores (Little et al., 2001).

Conocarpus erectus var. *sericeus* has been introduced in late 1970's into Puerto Rico as an ornamental and seedlings might be bought from commercial nurseries throughout the island (Figures 9A–D). Schubert (1979) recommended 46 trees species useful for shade and ornament in Puerto Rico and the Virgin Islands, including *C. erectus* var. *sericeus*. However, he (Schubert, op. cit.) did not reported *C. erectus* var. *sericeus* as a new record for Puerto Rico. Because of anthropogenic forces, such as plant commerce and human introductions, the pubescent morphotype may intermingle with native coastal vegetation and eventually become part of the landscape. In this way, *C. erectus* var. *sericeus* expands its distribution throughout the Caribbean. So far, there is no attempt to restrict, control, or eradicate this new variety in Puerto Rico. Phytopathogens, such as fungi (e.g., *Cylindrocladium scoparium*) might be introduced in Puerto Rico as a causal agent of a disease of silver buttonwood as in Florida (see Miller and McRitchie, 1973).

AERIAL ROOTS IN *AVICENNIA GERMINANS*

Avicennia germinans is a small evergreen tree or shrub 3 to 12 m high, attaining a trunk diameter of 30 cm in Puerto Rico, and characterized by a rounded crown of spreading branches (Little et al., 2001) (Figures 8A–C). This species seems hardier than the other mangroves, to which it is not related. It penetrates farther inland along rivers and in the United States ranges farther northward, beyond the tropical zone. In Puerto Rico it appears to withstand prolonged flooding better than white mangrove (*Laguncularia racemosa*) (Little et al., 2001). The advancing thickets of mangroves with networks of roots collect and hold silt, thus building up the shores.

In *A. germinans*, numerous pneumatophores often rise vertically from the long horizontal roots in the mud under a tree, perhaps aiding in bringing air to the roots. Little et al. (2001) reported masses of roots 7.6 to 46 cm long sometimes hanging in the air from the upper part of large trunks, while discussing *A. germinans* general morphology. They (Little et al., op. cit.) do not discussed location or quantity of these aerial root masses. A total of 15 pendulous aerial roots in two *A. germinans* trees were first noticed by oceanographer Jorge E. Corredor (pers. comm.) during a walk to his office located on MIML the afternoon of May 8, 2003. MIML aerial roots of *A. germinans* were photographed by the senior author afterwards (Figure 8C). These aerial roots were single or bifurcated, 1.4 to 16.0 cm long x 6.0 to 11.0 cm in diameter and protruded from large tree trunks. The morphology of aerial roots in *A. germinans* was treated by Snedaker et al. (1981) and Tomlinson (1986). *Avicennia germinans* aerial roots appear to occur only rarely. We could not determine what caused the development of these roots in the present case. Snedaker et al. (1981) considered that this development was a response to oil pollution.

PALEOBOTANICAL NOTES ON MANGROVE-LIKE PLANTS

The most common trace fossils (also known as ichnofossils or "Lebensspuren", 'living traces' in German) left by plant activity are root traces or casts (rhizoliths), which show the branching and irregularities of living root morphology. These casts also reveal plant behavior, by showing growth. Their preservation taphonomy was probably the result of early cementation around the original roots, followed by cementation of carbonate sand that filled the mold (Martin, 1996). The fossilized mangrove-like plants of Puerto Rico have been little studied. A total of 11 trace fossils (ichnofossils) of mangrove-associated plants are herein reported for Puerto Rico (Table II).

The earliest root casts in Puerto Rico were dated Late Cretaceous (probably Santonian, 85.8 to 83.5 Ma; Santos, 1990, 1999). These plant ichnofossils (Figures 10A–E), along with scattered large, near-vertical trace fossils (*Skolithos* s. str. Prothero and Schwab, 1996) are present on the top of bioturbated magnetite-rich units (magnetite lenses) of the oldest facies of the Cotuí Limestone, Cabo Rojo-San Germán, in southwestern Puerto Rico (Santos, 1990, 1999). The location of the Cotuí Limestone root casts is given at Table II and was at 25.3 m elevation. Cretaceous root casts, have been tentatively interpreted to have been caused by mangrove-like plants (e.g., *Deltoidospora* sp. [= *Acrostichum*] or the extinct *Brevitricolpites* sp.), although recent palynological studies reported the origin of these two candidates in the Eocene (Tomlinson, 1986; Rull, 1998). Another possible candidate is the mangrove-associated palm *Nypa* which nowadays is widely distributed through southwestern Asia and dates back to Late Cretaceous (Tomlinson, 1986; Rull, 1998). These casts (2 to 20 mm wide), which Santos suggested as were derived from some mangrove-like plants, possess many anatomical traits also found in modern mangrove-associated plants (e.g., *Acrostichum* spp.). The original wood material was decomposed and no longer exists; however, the spaces were filled with soft sediment, easily removed by physical and biogeochemical mechanisms (Figures 10C–E). These features are characteristic of intertidal to shallow subtidal marine environments with high energy (active waves and currents) (Santos, 1990, 1999).

In the 1920s, Hollick (1928) began a paleobotanical survey in Puerto Rico, which was summarized in his "Paleobotany of Porto Rico", based on his field collections of seeds, leaves, and wood macrofossils of various species (including mangrove species such as *Rhizophora*) in the gray shale walls of the Collazo and Guatemala Rivers of the San Sebastián Formation (SSF), of Oligocene in age (33.7 to 23.8 Ma). These plant species were also collected in other localities around the island (Hollick, 1928). Hollick (op. cit.) reported leaves of *Rhizophora* sp. (*Rhizophora* (?) *doctrinalis*) (Figure 5b, plate 82 of Hollick, 1928) from station B (at the base of the first falls below the bridge) in the gray shales of the Collazo River, SSF, northwestern Puerto Rico. A type (YPM 27218), paratype (YPM 27196), and figure (YPM 27199) of *R.* (?) *doctrinalis* were deposited in the Yale Peabody Museum (Table II).

Palynological studies in Puerto Rico were conducted by Graham and Jarzen (1969) and Graham (1996, 2003), collecting at many of Hollick's original Tertiary surveyed sites, and adding new ones. Palynomorphs (pollen) of these plant species were collected in the shales and organic-rich silty limestone layers of the San Sebastián and Lares Formations, northwestern Puerto Rico. In their study, Graham and Jarzen (1969) obtained 165 palynomorphs; 44 were identified and 15 are unknown. Graham (1996, 2003) summarized Hollick's works and demonstrated that there is further need for paleobotanical studies in the region on the diversity and importance of the fossil plant record of Puerto Rico. Graham (1995) carried out palynological studies in the Caribbean, with emphasis on the diversification of the Gulf/Caribbean mangrove communities, especially before and after the appearance of the Isthmus of Panama in the Pliocene (5.3 to 1.8 Ma) (s. str. Graham, 1992).

Although fossil pollen of *Avicennia* has not been collected in Puerto Rico, this mangrove was the first to be found in the Late Miocene (11.2 to 5.3 Ma) of the Caribbean (Graham, 1995), although Duke (1995) reported *Avicennia* in Early Miocene (23.8 to 16.4

Ma). *Avicennia* pollen is also common in the Quaternary (1.8 to 0.01 Ma) of Costa Rica, Panama, and in northern South America (Müller et al., 1987; Graham, 1995). Microfossils of *Rhizophora* first appeared in the Late Eocene (37.0 to 33.7 Ma), *Avicennia* in Late Miocene, *Laguncularia* in the Pliocene (5.3 to 3.6 Ma), and *Conocarpus* in the Quaternary (Graham, 1995).

More recent palynological surveys by Graham and Jarzen (1969) and Graham (1995, 1996, 2003), reported Puerto Rican Tertiary (Middle Oligocene) mangrove plant microfossils. Mangrove pollen included *Rhizophora* sp. and *Pelliciera* sp. (Graham and Jarzen, 1969; Graham, 1995, 1996, 2003). Palynomorphs of both mangrove species were collected in the light gray and gray shales of SSF. Both mangrove species are typical of coastal habitats with brackish or marine waters; however, *Pelliciera rhizophoreae* is now limited to the Pacific coasts of Costa Rica, Panama, and both Pacific and Atlantic coasts of Colombia (Tomlison, 1986).

Oligocene and Miocene lignitic rocks, traces of amber, and trace fossils (possibly mangrove rhizoliths) also have been found in several geological formations of northern and southern Puerto Rico (e.g., Juana Díaz Formation and Ponce Limestone s. str. Frost et al., 1983) (Iturralde-Vinent, 2001; MacPhee and Wyss, 1990; MacPhee and Iturralde-Vinent, 1995; Nieves-Rivera, unpublished data, 2002) (Table II). The biostratigraphy of the (Holiday Inn) outcrop, which is part of the Ponce Limestone, is Late Miocene in age is herein reported (María Ruiz-Yantín, pers. comm., 2004). During Late Miocene times, this area was active tectonically, whereas the northern part of Puerto Rico was passive. The outcrop has four units. The first unit (Unit 1) shows a lagoon environment and it is 1.2 m in thickness. It is a wackestone composed mainly of the foraminifer *Miosorites* cf. *americanus*, solitary corals, *Pecten* with original shells, and internal gastropod molds. Unit 2 represents a reef front environment and is 4.5 m thick. It is a massive unit (packstone) containing solitary corals in growth position, colonial corals such as *Diploria* and *Porites*, unidentified burrows, *Pecten*, crabs remains, *M.* cf. *americanus* foraminifers, rhizoliths of mangrove origin (LACMIP locality 17772), and internal gastropods molds. It shows a coral framework. Unit 3 represents a reef crest environment and is 4.5 m in thickness. The corals are out of place and are not as well cemented as in the underlying unit. There are solitary corals, *Montastrea annularis*, *Porites porites*, brain corals that are probably *Diploria*. Also there are few gastropods, bivalves, and crabs remains. There is an erosion surface between unit 3 and 4. Unit 4 is 8.05 m in thickness and shows a lagoon environment similar to Unit 1 (María Ruiz-Yantín, personal communication, 2004).

Pleistocene eolianite terraces (s. str. Taggart, 1992) that occur in southwestern Mona Island and northern Puerto Rico jut out from the coastline. The shoreline of Mona Island terraces sometime shows "dead mangrove roots" that protrude from crannies and fissures, and coral fossils (e.g., *M. annularis*, *M. cavernosa*, *Diploria* sp., *Acropora palmata*) are found everywhere (Hernández-Ávila, 1970; Taggart, 1992). Punta Jacinto, located in Playa Jobos in Isabela, northern Puerto Rico, is a typical example of aeolian fossilized dunes having plant root casts (rhizoliths). The Isabela rhizoliths were deposited in the Natural History Museum of Los Ángeles County, Department of Invertebrate Paleontology, Los Ángeles, California (LACMIP). Pleistocene Isabela rhizoliths (see LACMIP location 17768) are possibly from a mangrove-associated plant such as *Scaveola* sp. (Goodeniaceae) (Storrs L. Olson, pers. comm., 2005) (Figures 11A–F) (Table I and II). Similar rhizoliths have been found as reefs at Key Biscayne Bay in Florida (U.S.A.) (Hoffmeister and Multer, 1965), in aeolian dunes of Hawaii (Olson and James, 1982), and San Salvador Island in the Bahamas (Martin, 1996).

To date, the data on ichnofossils of mangrove-like plants are too poor to speculate on such subjects as dispersal and island biogeography, especially in Puerto Rico. Most of the taxonomic information presented herein was collected from fragmentary surveys from Puerto Rico. However, the data herein suggest that the composition of fossilized mangrove-like plants is more complex than previously suspected. Therefore, it would seem important to continue studying such paleoenvironments, in order to contribute to the conservation and knowledge of the paleoecology of mangrove-like plants of Puerto Rico.

In conclusion, a compilation of 125 plants routinely found in the mangrove forest, the introduction of a new variety of mangrove-associated plant, *Conocarpus erectus* var. *sericeus* (Combretaceae), unusual aerial roots in *Avicennia germinans* (Avicenniaceae), and several new trace fossils (ichnofossils) of mangroves are reported for Puerto Rico. An actualized checklist of scientific and common botanical names (English/Spanish), including 3 true mangroves (*A. germinans*, *L. racemosa*, and *R. mangle*) and 122 mangrove-associates are herein reported for Puerto Rico.

Table II. Location of mangroves and mangrove-associated plants palynomorphs (PL) or ichnofossils (IF) found in Puerto Rico. They are placed in order of geologic time.

Taxa	Accession Numbers[1]	Coordinates	Geological Formation[2]	Geologic Time[3]	References
Mangrove-like root casts (IF)	-------	18°04'72.0" N, 67°05'31.2" W	CM	LC	Santos (1990, 1999); Nieves-Rivera (Unpubl. data)
Ilex sp. (PL)	MO C-47, 15; ESF H-19	18°19'99.8" N, 66°56'91.8" W	SC	MO	Graham & Jarzen (1969)
Myrica sp. (PL)	MO C-42, 4; ESF N-43	18°19'99.8" N, 66°56'91.8" W	SC	MO	Graham & Jarzen (1969)
Pelliciera sp. (PL)	MO C-48, 1; ESF D-38, 2	18°19'99.8" N, 66°56'91.8" W	SC	MO	Graham & Jarzen (1969)
Rhizophora (?) *doctrinalis* Hollick (IF)	YPM 27218 (type) YPM 27196 (paratype) YPM 27199 (figured)	18°19'99.8" N, 66°56'91.8" W	SC	MO	Hollick (1928); Graham (1996)
Rhizophora sp. (PL)	MO C-47, 1; ESF L-21, 3				

		18°19'99.8" N, 66°56'91.8" W	SC	MO	Graham & Jarzen (1969)
Tournefortia sp. (PL)	MO A-12, 10; ESF U-34, 4	18°17'41.3" N, 66°53'41.1" W	SL	MO	Graham & Jarzen (1969)
Mangrove-like root casts (IF)*	-------	17°58'41.2" N, 66°53'73.0" W	BL	MO	Nieves-Rivera (Unpubl. data)
Mangrove-like root casts (IF)*	-------, LACMIP 17772	17°58'94.7" N, 66°40'02.8" W	PC	LM	Olson and James (1982); Nieves-Rivera (Unpubl. data)
Scaveola plumieri rhizoliths (IF)*	LACMIP 17768	18°30'87.3" N, 67°04'50.1" W	ED	PL	Nieves-Rivera (Unpubl. data)
Mangrove-like root casts (IF)	-------	18°04'85.4" N, 67°56'37.9" W	EF	QT	Hernández-Ávila (1970); Nieves-Rivera (Unpubl. data)

* = New records for Puerto Rico; ESF = England Slide Finder coordinates. [1]**Museum Abbreviations:** LACMIP = Natural History Museum of Los Ángeles County, Department of Invertebrate Paleontology, Los Ángeles, California; MO = Herbarium, Missouri Botanical Garden, Saint Louis, Missouri; YPM = Yale Peabody Museum Herbarium, Yale University, Cincinnati. [2]**Geological Formation**: BL = Barrio Luna, Juana Díaz Formation, Guánica; CM = Cotuí Mountains, Cotuí Formation, Cabo Rojo-San Germán; ED = Eolianite dunes, Punta Jacinto, Isabela; EF = Eolianite Formation, Carabinero, Mona Island; PC = Ponce Cement Quarry, Ponce Limestone, Ponce; SC = Salto Collazo, San Sebastián Formation, San Sebastián; SL = Slope, junction of Roads PR-111 and PR-124, San Sebastián Formation, Lares. [3]**Geologic Time:** LC = Late Cretaceous (Santonian, 85.8-83.5 Ma); LM = Late Miocene (11.2-5.3 Ma); MO = Middle Oligocene (28.5 Ma); PL = Pleistocene (1.8-0.01 Ma); QT = Quaternary (1.8 Ma to 10,000 yr).

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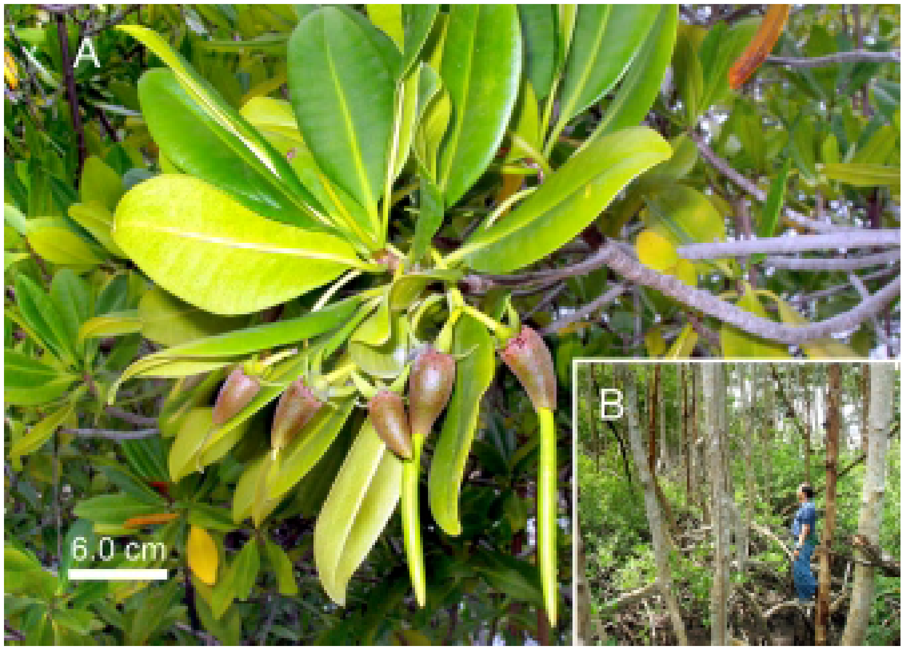
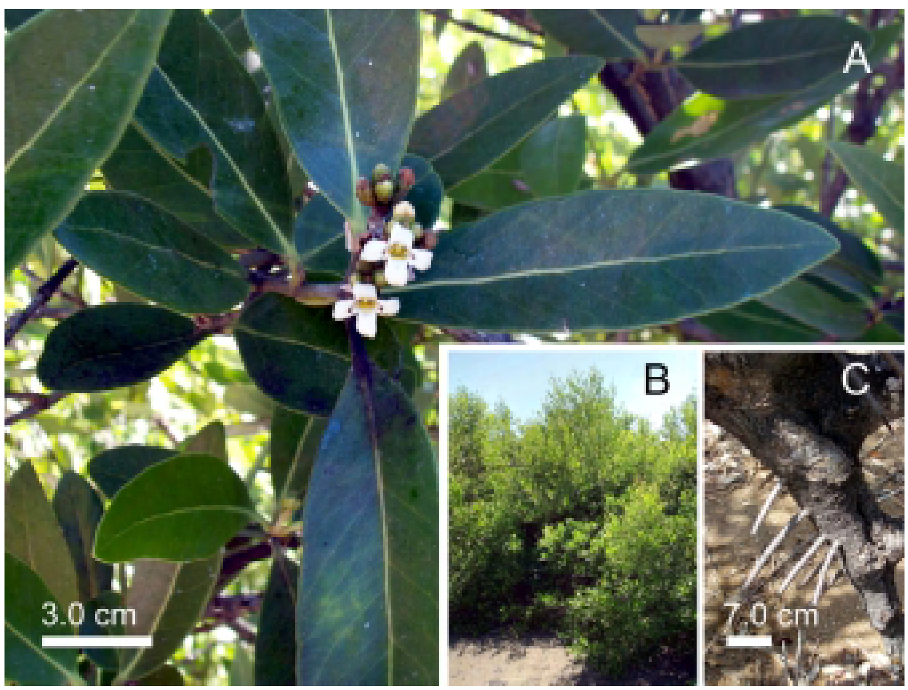
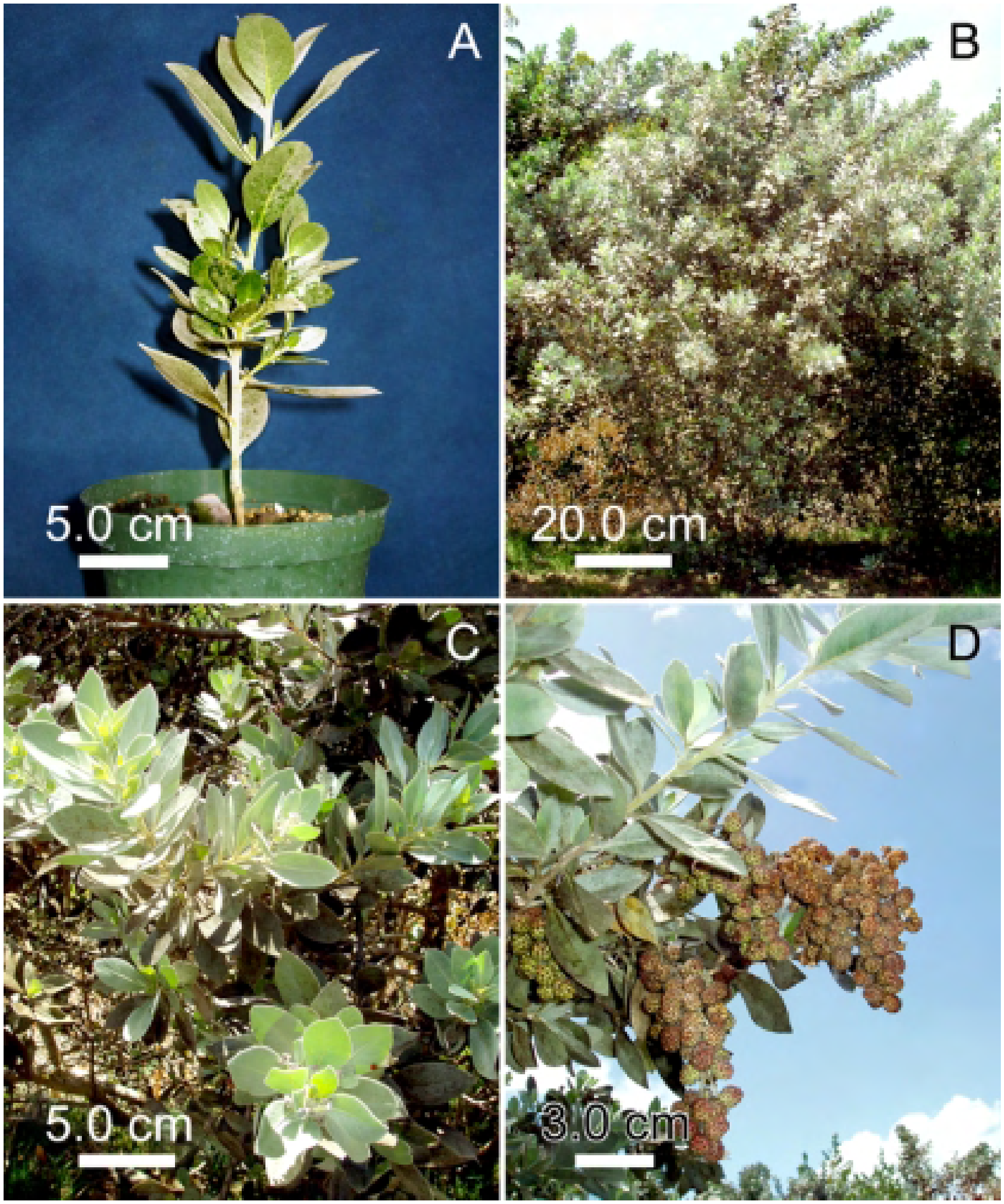


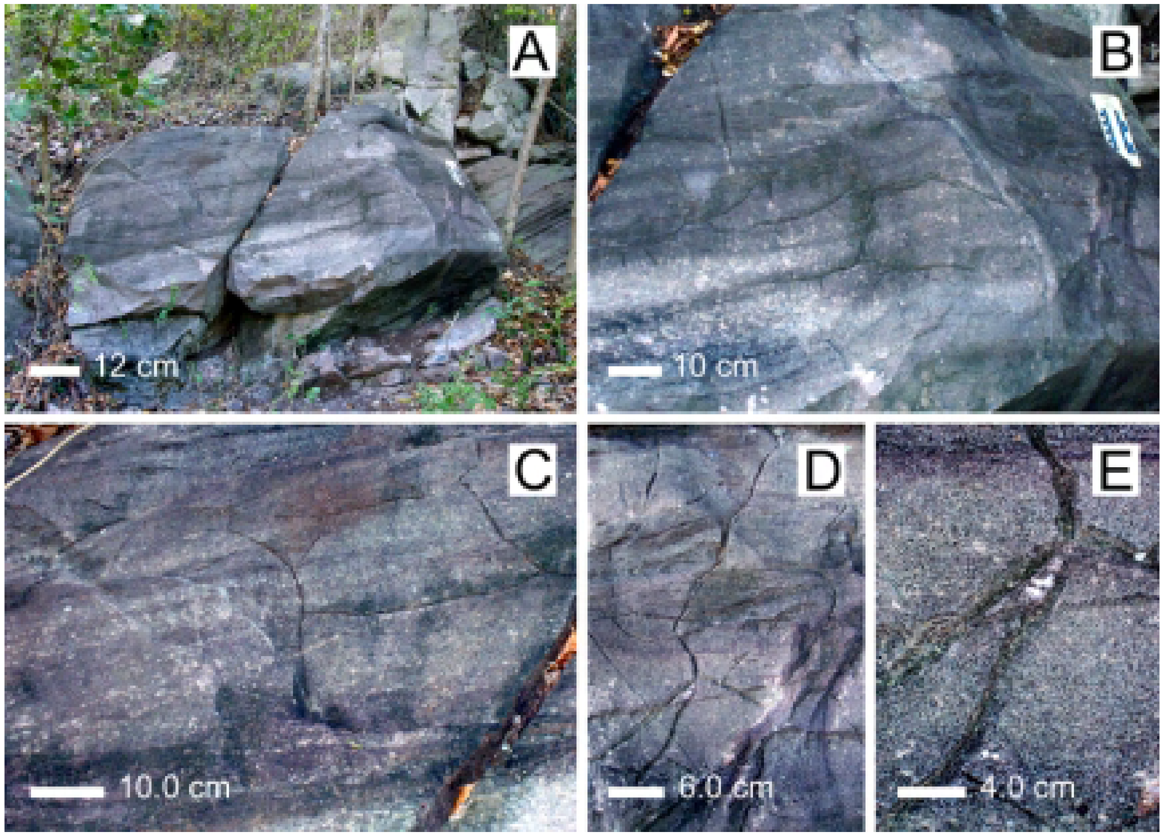
Figures 7A–B. *Rhizophora mangle* (Rhizophoraceae). A. Leaves and seedling (La Parguera, southwestern Puerto Rico) (Boquerón Commonwealth Forest, Cabo Rojo).



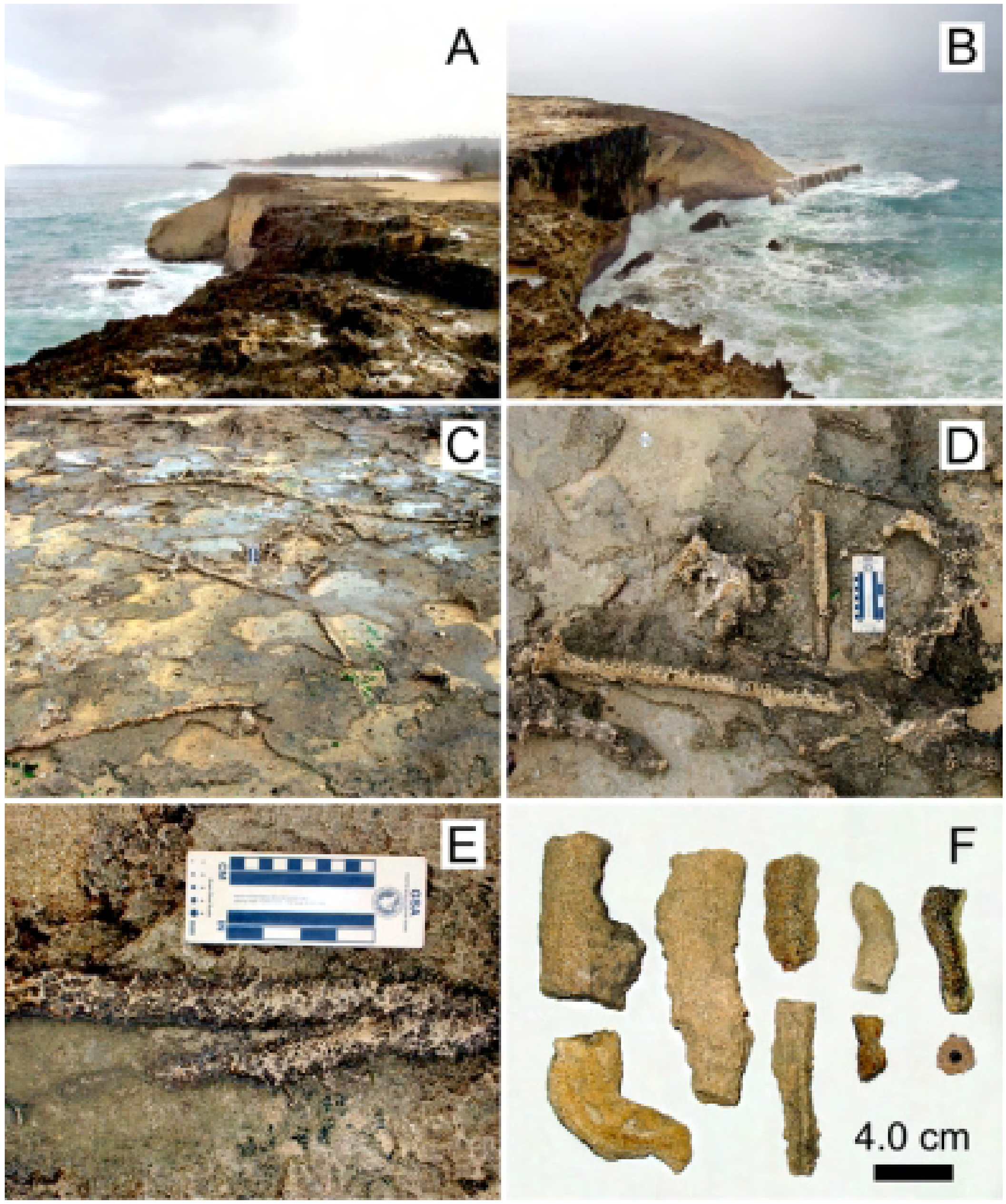
Figures 8A–C. *Avicennia germinans* (Avicenniaceae) (La Parguera, southwestern Puerto Rico). A. Flowers and leaves. B. Adult trees. C. Aerial roots). A. Leaves and seedling (La Parguera, southwestern Puerto Rico) (Boquerón Commonwealth Forest, Cabo Rojo).



Figures 9A–D. *Conocarpus erectus* var. *sericeus* (Combretaceae) from southwestern Puerto Rico. A. Seedling from a commercial nursery from San Germán, Puerto Rico). B. Used as ornamental in the Boquerón Beach-Cabin Complex, Cabo Rojo. C. Pubescent leaves. D. Fruiting.



Figures 10A–E. Santonian (Late Cretaceous) mangrove-like root casts reported by Santos (1990, 1999) from the Cotuí Formation, Cabo Rojo-San Germán, southwestern Puerto Rico. A–B. Magnetite bioturbated facies (lenses) where the roots are located. C–E. Enlargement of the root casts.



Figures 11A–F. Pleistocene (Late Quaternary) rhizoliths (LACMIP location 17768), possibly root casts from the mangrove-associated plant *Scaveola plumieri* (Goodeniaceae) in the aeolian fossilized dunes of Punta Jacinto, Playa Jobos, Isabela, in northern Puerto Rico. A–B. Aeolian dune views. C–E. Rhizoliths *in situ*. F. Profile and sectioned views of weathered rhizoliths.

CHAPTER 3

HISTORY OF MARINE MYCOLOGY IN PUERTO RICO, INCLUDING A CHECKLIST OF COASTAL AND MANGROVE-ASSOCIATED FUNGI

ABSTRACT

The history of marine mycology in Puerto Rico is described in general, but with particular emphasis on coastal and mangrove-associated fungi. Until recently, there have been few formal studies of the subject due to the lack of expertise, since there are few local marine biologists interested in marine mycology. Published and unpublished studies in marine mycology for Puerto Rico are summarized. A checklist that contains 604 taxa of fungi, including 65 fungal-like organisms (oomycetes and myxomycetes) is provided. These are divided among the principal divisions of fungi as follows: 23.7% Ascomycota, 40.7% Mitosporic fungi, 21.7% Basidiomycota, 2.5% Zygomycota, 5.1% Oomycota, 0.5% Chytridiomycota, 0.2% Plasmodiophoromycota, and 5.6% Myxomycota. The present study found some potentially new species. Some of these fungi have not yet been identified to species, thus there is a possibility that they might or not represent new species. There were 13 new records for Puerto Rico generated as a result of the studies described herein (*Aigialus* cf. *grandis*, *Asteromassaria* sp., *Calonectria morganii*, *Cochliobolus pallescens*, *Hysterium* sp., *Leptosphaeria australiensis*, *Strigula* sp. (Ascomycota), *Curvularia robusta*, *Exserohilum* sp., *Koorchaloma* sp., *Stemphylium* cf. *gracilariae*, *Trimmatostroma* sp. (Mitosporic fungi), and *Halophytophthora* sp. (Oomycota)). Ascomycetes found in the intertidal and submerged parts of mangroves are undoubtedly the best known marine fungi because of their wide geographic distribution. It was also found that there is a preponderance of mitosporic fungi to be found in the sediments, and apparently this is not due to sampling error. Most of the coastal and mangrove associated fungi in Puerto Rico are mitosporic fungi. This might be caused by sampling bias. This bias may due that throughout the years,

most of the Puerto Rican mycologists are better trained in mitosporic fungi taxonomy than in any other fungal or fungal-like organism taxa.

RESUMEN

Se describe la historia de la micología en Puerto Rico en general, con un particular énfasis en los hongos costeros y asociados al manglar. Hasta recientemente, ha habido pocos estudios formales en el tema debido a la falta de interés, ya que son pocos los biólogos marinos locales que se interesan en la micología marina. Se resumen los estudios en micología marina tanto publicados como inéditos para Puerto Rico. Se provee una lista que contiene 604 especies de hongos, incluyendo 65 organismos parecidos a los hongos (oomycetes y myxomycetes). Estos están divididos de acuerdo a las divisiones principales de los hongos como sigue: 23.7% Ascomycota, 40.7% Hongos mitospóricos, 21.7% Basidiomycota, 2.5% Zygomycota, 5.1% Oomycota, 0.5% Chytridiomycota, 0.2% Plasmodiophoromycota y 5.6% Myxomycota, 25.7%. En el presente estudio se encontró algunas nuevas especies potenciales. Algunos de estos hongos no han sido identificados hasta especie, por lo tanto cabe la posibilidad de que pudieran o no ser nuevas especies. Se encontraron 13 nuevos registros para Puerto Rico generados como resultado de los estudios aquí descritos (*Aigialus* cf. *grandis*, *Asteromassaria* sp., *Calonectria morganii*, *Cochliobolus pallescens*, *Hysterium* sp., *Leptosphaeria australiensis*, *Strigula* sp. (Ascomycota), *Curvularia robusta*, *Exserohilum* sp., *Koorchaloma* sp., *Stemphylium* cf. *gracilariae*, *Trimmatostroma* sp. (Hongos mitospóricos) y *Halophytophthora* sp. (Oomycota)). Indudablemente, los ascomicetos encontrados en las partes intermareales y sumergidas de los mangles son los hongos marinos mejor conocidos debido a su amplia distribución geográfica. Se encontró que hay una preponderancia de encontrar hongos mitospóricos en los sedimentos y aparentemente esto no se debe a errores de muestreo. La mayoría de los hongos costeros y asociados al manglar en Puerto Rico son hongos mitospóricos. Esto puede ser causado por parcialidad en los muestreos. Esta parcialidad puede deberse a que a través de los años, la mayoría de los micólogos puertorriqueños han sido mejor entrenados en la

taxonomía de los hongos mitospóricos que en otros taxones fúngicos u organismos parecidos a los hongos.

INTRODUCTION

Fungal distribution in coastal environments in the Caribbean is still poorly known, although a considerable number of published reports exist. For example, summaries of previous works in the Caribbean were included in Stevenson (1975), Nishida (1989), Lodge (1996a, b), Minter et al. (2001), and Schmit and Shearer (2003). Puerto Rican fungal collections from coastal habitats are in some cases sporadic and interrupted by many years. The purpose of this study is to develop a better understanding of the history of marine mycology, including saprophytic fungal communities, collected in sea foam, leaf litter, and wood from mangroves and mangrove-associated plant species in marine, estuarine, and terrestrial (coastal) ecosystems in Puerto Rico, a subtropical island located between the coordinates 18°00'–18°30' N and 65°35'–67°15' W, in the northeastern Caribbean Sea. Also, a partial checklist of marine, estuarine, and terrestrial fungi (with special interest for coastal and mangrove-associated fungi) for Puerto Rico is provided.

MANGROVES

A mangrove forest is considered a dynamic ecotone (or transition zone) between terrestrial and marine habitats. In its simplest sense, "mangrove" is used as a generic term referring to a group of woody, halophylic plants that occur along sheltered tropical and subtropical coastlines. Mangroves are derived from a variety of plant taxa and vary in their dependence upon littoral habitats. Mangrove forests are also referred to as mangrove swamps, tidal forests, tidal swamp forests or mangals. Caribbean mangroves range from 30° N latitude (northern Florida) to 8° N latitude (northwest Colombia) and from 59° W longitude (north of Guiana) to 89° W longitude (eastern Guatemala) (Tomlinson, 1986). Only four mangrove species occur in the Caribbean; the most widely distributed are the red mangrove (*Rhizophora mangle*), black mangrove (*Avicennia germinans*), white mangrove

(*Laguncularia racemosa*), and the buttonwood (*Conocarpus erectus*) (Lugo and Snedaker, 1974; Cintrón and Schaeffer-Novell, 1988).

Mangroves are exceptionally adaptable and therefore can survive under a relatively wide range of environmental conditions. Some species have been found in freshwater ponds well above sea level. Environments suitable for mangrove growth occur where temperatures are warm and frosts are infrequent, where the shoreline is protected from wave action and pounding surf, or behind protective natural formations like dunes (Martínez, 1988) and on coastal plains where the influence of sea water is felt. They develop best where they also receive terrestrial runoff and periodic flooding by river discharge (e.g., estuaries). Where the tides are large and the coast is of low relief, salt water can intrude inland for long distances, and mangrove coverage may be very extensive (Cintrón et al., 1978; Vázquez, 1983). One major biological characteristic of mangrove forests is their homogeneity. Often, a single tree species is monodominant over large areas.

Mangrove plants generate a large amount of litter in the form of branches, inflorescences, leaves, twigs, and other debris. The estimated annual litter production for a mangrove forest was somewhat similar for Puerto Rico (9.45 $mg \cdot ha^{-1} \cdot yr^{-1}$) and Florida (8.10 $mg \cdot ha^{-1} yr^{-1}$) (Pool et al., 1975; Twilley et al., 1986). The contribution of mangroves debris is the input of organic matter that which enriches the coastal ecosystem and in turn the fisheries in what would be stagnant oligotrophic tropical waters.

FUNGI

Fungi are the most important microbes in the food web. They are defined as non-photosynthetic microbes with nuclei, usually composed of threadlike hyphae, but sometimes budding as in yeasts (Lodge, 1996a). According to Hyde et al. (2000), there are 444 marine species described; however, Kirk et al. (2001) reported that fungi have a widespread occurrence in the sea, with 800 to 1000 species known to be marine. The higher numbers in Kirk et al. (ibid.) may include also the undescribed species (*Ignoti*). Species are parasites or commensals of marine algae or animals; they are also saprophytes, species found on diverse marine substrata. They have been found growing on seagrasses, protozoans, driftwood, corals, and many other substrata. Although fungal spores accumulate in sea foam, the fungi do not actually grow there. Fungal communities also occur in brackish water, salt marshes, mangrove swamps, saltpeter beds, sand, dunes, and in coastal plains. Many marine fungal spores have special appendages for attachment to substrata (Kohlmeyer and Volkmann-Kohlmeyer, 1991).

Marine fungi have been ecologically classified by Kohlmeyer (1974) into two major groups, the obligate (type 1) and facultative marine fungi (type 2). He defined them as: "obligate marine fungi are those that grow and sporulate exclusively in a marine or estuarine (brackish water) habitat; facultative marine are fungi from freshwater or terrestrial areas able to grow also in the natural marine environment..." (Kohlmeyer, 1974). In mangrove forests, estuaries and salt marshes, fungi are considered to be extremely important in nutrient cycling (Kohlmeyer et al., 1995; Hyde and Lee, 1995). Numerous studies have examined the manglicolous fungal taxonomical composition, diversity and biogeography (Johnson and Sparrow, 1961; Kohlmeyer and Kohlmeyer, 1979; Kohlmeyer and Volkmann-Kohlmeyer, 1991, 1998; Jones and Alias, 1997; Hyde and Pointing, 2000; Schmit and Shearer, 2003), succession (Newell, 1976; Tan et al., 1989), vertical distribution (Hyde, 1988, 1989a, b; Hyde et al., 1993), abundance or biomass (Newell, 1992; Newell and Fell, 1992), and a summary to manglicolous fungi ecology in general was given by Hyde and Lee (1995). Furthermore, many studies have examined the amount of litter production in mangrove forests (Saenger and Snedaker, 1993; Bunt, 1995), the role of microorganisms in decomposition of leaf litter (Fell and Master, 1973, 1980; Cundell et al., 1979; Robertson et al., 1992) and their role in the mangrove trophic web (Heald, 1971; Odum and Heald, 1972, 1975; Fell and Master, 1980; Robertson et al., 1992). The involvement of fungi in the breakdown of mangrove leaves and wood has also been documented (Hyde, 1990).

Recent attention has been directed towards mangrove tree mortalities, which are caused by anthropogenic misuse and unfavorable environmental conditions (Lugo and Snedaker, 1974; Saenger et al., 1983; Jiménez and Lugo, 1985; Anderson and Lee, 1995) as well as by fungal diseases (Fomba and Singh, 1991; Tattar and Wier, 2002; Schmit and Shearer, 2003), among other biotic (e.g., bacterial and viral diseases, etc.) and abiotic factors (e.g., adverse climatic conditions, edaphic drastic changes, pollution, etc.). Although marine, estuarine, and terrestrial manglicolous fungi have been extensively studied in various parts of the world (Johnson and Sparrow, 1961; Kohlmeyer and Kohlmeyer, 1979; Rollet, 1981; Hyde and Lee, 1995; Schmit and Shearer, 2003), in many Caribbean Islands these fungi are poorly known.

PREVIOUS WORK

Our knowledge of marine fungi in the Caribbean in general and Puerto Rico in particular is fragmentary. The fungi studied include marine fungi (Meyers, 1957; Kohlmeyer, 1968, 1980; Kohlmeyer and Volkmann-Kohlmeyer, 1987; Acevedo, 1987, 1997, 2001; Calzada, 1988, 1991; Tattar et al., 1994; Wier et al., 1996, 2000; Minter et al., 2001; Tattar and Wier, 2002; Schmit and Shearer, 2003; Nieves-Rivera and Santos-Flores, 2004), terrestrial fungi in aquatic and coastal environments (Carvajal-Zamora, 1971a, b; Hernández-Vera, 1972, 1975, 1982; Stevenson, 1975; Hernández-Vera and Almodóvar, 1983, 1984; Bunkley-Williams and Williams, 1994; Williams and Bunkley-Williams, 1996; Nagelkerken et al., 1997a, b; Nieves-Rivera et al., 1998; Calzada, 1999; Nieves-Rivera, 1999, 2000a, 2002, 2003; Minter et al., 2001; Nieves-Rivera et al., 2002; Schmit and Shearer, 2003; Nieves-Rivera and Stephenson, 2004; Ruiz-Suárez, 2004; Maldonado-Ramírez and Torres-Pratts, in press), yeasts (Valdéz-Collazo et al., 1987; Ricaurte, 1998; Ricaurte and Govind, 1999), and fungal-like organisms such as oomycetes (Rossy-Valderrama, 1955, 1956; Galler-Rimm, 1982).

During the Spanish governance of Puerto Rico no effort was made to study the marine mycobiota. During the period from 1900 to mid-1950's, some genera of halotolerant fungi (e.g., *Asteridiella* spp., *Cercospora* spp., *Gibberella* spp.) having some parasitic species and others that are commensals were reported by Heller (1900) throughout Weiss (1950) (Figure 12). The first published records of species of true marine fungi from Puerto

Rico were those of Meyers (1957), Kohlmeyer (1968, 1980), Kohlmeyer and Volkmann-Kohlmeyer (1987), and Acevedo (1987) (Figure 12). The largest number of new records was 62 taxa reported by Hernández-Vera (1982, discussed below) (Figure 12). Other important reports containing new records of marine fungi are quite recent (Nieves-Rivera 2004a; Ortiz et al., 2004; Silva et al., 2004), adding 50 taxa to the 41 taxa reported by Hernández-Vera (1972), the 32 taxa by Carvajal-Zamora (1971a, b), 30 taxa by Kohlmeyer and Volkmann-Kohlmeyer (1987) and Acevedo (1987), and 20 taxa by Minter et al. (2001) (Figure 12) (Table III).

Stevenson (1975) reported 11 species of fungi from mangrove forests, mostly as foliar diseases. He recorded *Anthostomella rhizomorphae* and *Polyporus fulvocinereus* (= *Datronia caperata*) on *R. mangle*; *Asteridiella sepulta* on *Avicennia nitida* Jacq. (= *A. germinans*); *Asteridiella laguncularia*, *Meliola nigra*, *Physalospora laguncularia*, *Schizothyrium laguncularia*, *Spiropes capensis* on *L. racemosa*; *A. laguncularia*, *Cercospora conocarpi*, *S. capensis* on *C. erectus* (Stevenson, 1975). He reported 6 new taxa of halotolerant fungi (Figure 12) (Table III).

During 1979 to 1981, Hernández-Vera (1972, 1982) conducted a mycological survey (mostly for Mitosporic fungi) covering the supralitoral, intertidal, and sublitoral zones in the north and south coasts of Puerto Rico. He studied four beaches in the north (Guajataca, Sardinera, Arecibo River, and Poza del Obispo) and two at the south (Caña Gorda Beach and Enrique Reef at La Parguera). During the first year of study (1979-1980), a total of 1657 fungi were isolated and 1405 fungal isolated on the second year (1980-1981). The most common taxon isolated at the three zones was *Aspergillus* spp. Of the 2974 fungal isolates of both years, Hernández-Vera found 28 genera and 71 species, mostly mitosporic fungi, zygomycetes, oomycetes (Stramenopilus fungi), a few yeasts (e.g., *Saccharomyces* and *Cryptococcus* spp.), and an ascomycete (*Neurospora crassa*). Hernández-Vera (1982) also developed a new culture medium (known as “Almodóvar Agar”) made of marine algae (*Acanthophora spicifera*, *Dictyota divaricata*, *Laurencia obtusa*, *Spyridia filamentosa*, and *Ulva lactuca*), agar, and sea water (35 g/L). He tested this seawater medium and the fungal tolerance to salinity with the species he previously reported. Ninety-six percent (96%) of the species tolerated salinities up to 45 g/L. It was found that the dinoflagellate *Gonyaulax tamarensis* and the red alga *Falkenbergia hillebrandii* were found to be fungistatic to the majority of the species previously reported (Hernández-Vera, 1972, 1982; Hernández-Vera and Almodóvar, 1983, 1984).

Acevedo (1987) added a total of 30 genera and 41 species of obligate and facultative marine fungi collected from driftwood, red mangrove and sandy beaches. She collected driftwood from three reefs (Cayos Enrique, Laurel, and Turrumote), and sampled *R. mangle* wood and beach sand of an offshore island (Isla Cueva), off the coast of La Parguera, southwestern Puerto Rico. She also reported 18 species of manglicolous fungi (ascomycetes and mitosporic fungi) from *R. mangle* (Table III).

In 1992, the USDA Forest Service, the Center for Forest Mycology Research, Forest Products Laboratory in Madison Wisconsin, through a series of grants from the National Science Foundation, began a fungal survey in the tropics and subtropics. The coordinator of this project for Puerto Rico, the Forest Service botanist D. Jean Lodge, along with mycologist Timothy J. Baroni of the University of New York at Cortland, and other renowned mycologists, were surveying the fungi in the forests of Puerto Rico, especially basidiomycetes. The project title was the "Basidiomycetes of the Greater Antilles" (Lodge et al., 1998), and although it originally only considered the Caribbean National Forest El Yunque, it later also included some coastal forests, mangroves, and beaches (e.g., Piñones Commonwealth Forest). Some interesting new records and new basidiomycetous species have been collected in beaches and sand dunes (Table III) (Lodge, 1996a; Lodge et al., 1998, Cantrell and Lodge, 2000; Miller et al., 2000).

Nieves-Rivera et al. (1998) reported *Schizophyllum commune* and *Hypoxylon* Sect. *Hypoxylon* in *Avicennia nitida* (*A. germinans*) and *R. mangle*, respectively, from the Boquerón Wildlife Refuge, southwestern Puerto Rico. Other fungal checklists for coastal environments of Puerto Rico and offshore islands have been documented in the coastal plains

(Nieves-Rivera et al., 1999), mangrove forests, and saltpeter bed margins (Stevenson, 1975; Nieves-Rivera et al., 1998).

Calzada (1999) studied three phytopathogenic fungi, *Pestalotiopsis disseminata*, *Phoma eupyrena*, and *Pterosporidium rhizophorae*, caused foliar signs ("signs" as defined by Williams et al., 1993), such as spots and deterioration to the leaves in *R. mangle* of La Parguera (Phosphorescent Bay and La Parguera channels). However, *Aspergillus* sp. and *Cladosporium* sp. were found to be saprophytes (Calzada, 1999). Recently, Tattar et al. (1994), Wier et al. (1996, 2000), and Tattar and Wier (2002) documented *Cytospora rhizophorae* as a plant pathogen in *R. mangle* in the southwestern coast of Puerto Rico (Table III).

Acevedo (2001) assayed marine endophytic, manglicolous, and lignicolous fungi (e.g., *Didymosphaeria rhizophorae* (= *Lineolata rhizophorae*), *Hydronectria tethys*, *Hypoxylon oceanicum* (= *Halorosellinia oceanica*), *Lulworthia grandispora*, *Pestalotia* sp., *Xylaria* spp., as well as other undetermined species of ascomycetes and mitosporic fungi) by High Pressure Liquid Chromatograph (HPLC) for biotransformation of polycyclic aromatic hydrocarbon (PAH) such as phenanthrene in algal and mangrove (*R. mangle*) substrata. Phenanthrene is toxic and found in marine biota and petroleum. She found that 12 marine fungi of the 30 assayed by HPLC to be able to biotransform phenanthrene (Table 4, page 49 of Acevedo, 2001); although she reported that those tests were inconclusive. Of particular interest for microbiology are marine fungi and notably algal endophytes (e.g., *Xylaria* spp.) which are potentially useful organisms for bioremediation in marine environments.

Tattar et al. (1994), Wier et al. (1996, 2000), and Tattar and Wier (2002) documented the incidence of *Cytospora rhizophorae* as a plant pathogen in *R. mangle* in the southwestern coast of Puerto Rico. The occurrence of *C. rhizophorae* cirri on *Rhizophora* spp. have been reported in the Caribbean, including Puerto Rico (e.g., Magueyes Island, Los Morrillos, La Parguera, and Boquerón Commonwealth Forest, southwestern Puerto Rico), Bahamas, Florida, Guatemala, and Mexico (Kohlmeyer and Kohlmeyer, 1979; Shaw, 1989). Dieback of seedlings and young plants of *R. mangle* caused by *C. rhizophorae* has been widely studied in Puerto Rico (Tattar and Wier, 2002). The cirri of *C. rhizophorae* are at first yellow, the orange, and those kept in herbaria dark red to almost black (Shaw, 1989) (Figures 5A–F). This species is halotolerant and considered an obligate and facultative marine fungus on submerged and emerged host (Kohlmeyer and Kohlmeyer, 1979; Shaw, 1989).

Minter et al. (2001) gave a summary of manglicolous fungi of the Caribbean, including Puerto Rico, updating the records of Stevenson (1975). More recently, the work of Schmit and Shearer (2003) summarized worldwide manglicolous fungi, including early collections in Puerto Rico and the Caribbean. Schmit and Shearer (op. cit.) reported 30 species of manglicolous fungi for Puerto Rico alone, showing the need for updated surveys.

FINAL COMMENTS

The checklist of coastal and mangrove-associated fungi is presented in Table III. This checklist considers some works that were not reviewed by Minter et al. (2001) because of they were not readily available. For example, some of these unpublished works (theses, reports, and abstracts) are not available on the internet. However, many of the species on this checklist have been reported since these earlier works were published. It seems likely that many new coastal and mangrove-associated fungi remain to be found.

Ascomycetes found in the intertidal and submerged parts of mangroves are undoubtedly the best known marine fungi because of their wide geographic distribution (Hyde and Lee, 1995; Schmit and Shearer, 2003). It was also found that mitosporic fungi dominates in the sediments, and apparently this is not due to sampling error (Schmit and Shearer, op. cit.). Terrestrial fungi (mostly mitosporic fungi) are in general not the subjects of most surveys according to Schmit and Shearer (2003). In Table III, most of the coastal and mangrove associated fungi in Puerto Rico are mitosporic fungi. This might be caused by sampling bias. This bias may due that throughout the years, most of the Puerto Rican mycologists are better trained in mitosporic fungi taxonomy than in any other fungal or fungal-like organism taxa.

The differences in substrate affinities among fungal and fungal-like organisms (e.g., oomycetes) are well documented. The ascomycetes, for instance, often possess appendages and gelatinous sheaths which aid in their attachment to wood in the intertidal zone (Rees and Jones, 1984; Kohlmeyer and Volkmann-Kohlmeyer, 1991). Mitosporic fungi are largely lacking these appendages. This may explain why they are uncommon in the intertidal zone and most common in sediments, where such appendages would not be needed for spores for attachment (Schmit and Shearer, 2003). In general, basidiomycetes are rare in aquatic and marine environments, which explain their restriction to wood above high tide. In the terrestrial environment, basidiomycetes play an important role in the decay of plant material. In coastal environments, however, almost all dead leaves and wood fall to the forest floor and come into contact with seawater, which hampers the growth of most basidiomycetes. Marine oomycetes, on the other hand, seem to be present on almost all dead intertidal mangrove leaves, at least in the early stages of decay (Newell and Fell, 1995, 1997).

In this survey, we have found that several species potentially pathogenic to man (e.g., *Aspergillus* spp., *Candida* spp., *Cryptococcus* spp., *Epidermophyton floccosum*, *Nectria hematoccoca*, *Galactomyces geotrichum*, *Rhodotorula glutinis*, *Scopulariopsis brevicaulis*, *Candida glabrata*, and *Trichosporon* spp., Table III) that were reported in the literature, similar to the study of González et al. (2000). However, species composition reported by González et al. (2000) differs greatly due to the methodology and types of bait used. González et al. (2000) isolated a total of 17 keratinophilic fungi, of which 13 were hyphomycetes and 4 ascomycetes. González et al. (2001) found a larger variety of species in Mexico; therefore, their checklist contains 47 ascomycetes, 14 mitosporic fungi, and 1 basidiomycete. In a Cuban survey, González et al. (2003) reported 29 marine fungi (25 ascomycetes and 4 mitosporic fungi), of which 19 were new records. In contrast, the present checklist (Table III) contains 604 taxa of fungi, including 65 fungal-like organisms (oomycetes and myxomycetes). These are divided among the principal divisions of fungi as follows: 23.7 % Ascomycota, 40.7 % Mitosporic fungi, 21.7 % Basidiomycota, 2.5 % Zygomycota, 5.1 % Oomycota, 0.5 % Chytridiomycota, 0.2 % Plasmodiophoromycota, and

5.6 % Myxomycota (Table III). The present study found some potentially new species. Some of these fungi have not yet been identified to species, thus there is a possibility that they might or not represent new species. There were 13 new records for Puerto Rico generated as a result of the studies described herein (*Aigialus* cf. *grandis*, *Asteromassaria* sp., *Calonectria morganii*, *Cochliobolus pallescens*, *Hysterium* sp., *Leptosphaeria australiensis*, *Strigula* sp. (Ascomycota), *Curvularia robusta*, *Exserohilum* sp., *Koorchaloma* sp., *Stemphylium* cf. *gracilariae*, *Trimmatostroma* sp. (Mitosporic fungi), and *Halophytophthora* sp. (Oomycota)). The marine basidiomycetes *Halocyphina villosa* and *Nia vibrissa* were expected to be found but were never encountered. This may be because both marine basidiomycetes apparently require colder temperatures for growth than those found in the waters of Puerto Rico.

Several phytopathogenic species have been commonly found in many of the publications reviewed during the course of this survey (e.g., *Cytospora* spp., *Helminthosporium* spp., *Pestaloriopsis disseminata*, *Phoma* spp., *Phytophthora palmivora*, *Pythium* sp., *Uredo* spp., *Stemphylium* spp., Table III). Also, 34 plasmodial slime molds (myxomycetes) have been isolated from or collected in coastal plants, including mangroves. This group, along with the cellular slime molds (Dictyosteliomycota and Protosteliomycota) is the least studied group in coastal ecosystems, especially in mangrove forests. Although freshwater myxomycetes have been reported (Shearer and Crane, 1986), there are as yet no reports on this group from the marine environment.

Most of the marine fungal species collected are arenicolous (*Arenariomyce*s cf. *majusculus*, *A. triseptatus*, *Corollosopora* cf. *colossa*, *C. filiformis*, *C.* cf. *pseudopulchella*). *Arenariomyces triseptatus* has been previously recorded from Cuba (González et al., 2003), Mexico (Kohlmeyer, 1983), and Puerto Rico (Kohlmeyer and Volkmann-Kohlmeyer, 1987). *Halorosellinia oceanica*, *Lulworthia* sp., and *Torpedospora radiata* are lignicolous species (Kohlmeyer and Kohlmeyer, 1979). Other fungal species isolated in this survey are saprobes living in parts of angiosperms, algae, drifting wood and other plant debris, including blades of seagrasses.

Some fungal parasites have been found living on fishes (e.g., *Paecilomyces* spp., *Saprolegnia* spp.; Bunkley-Williams and Williams, 1994, 1995, 2004a-c; Williams and Bunkley-Williams, 1996; Bunkley-Williams et al., 1998; Rand et al., 2000) or commensalistic in the gut of living crustaceans (e.g., *Asellaria ligiae* and *Enterobryus* spp.; Cafaro, 1999; White et al., 1999, 2000). Bunkley-Williams and Williams (1994, 1995) reported saprolegniasis affecting sport fishes in artificial lakes (freshwater) and natural lagoons (freshwater and brackish waters) of Puerto Rico. Examples of the latter are: San José, Torrecillas, Piñones, Tortuguero, Mandri, Santa Teresa, Joyuda, and Rincón lagoons (Bunkley-Williams and Williams (1994). Nieves-Rivera (2000a) isolated *Aspergillus fumigatus* (= *Fennellia flavipes*), *A. flavus*, and *Helminthosporium* sp. (= *Bipolaris* sp.) from the skin of a *Caiman crocodilus* (Crocodylia: Alligatoridae) from the Tortuguero Lagoon, a freshwater and brackish natural lagoon located in Vega Baja, northern Puerto Rico. Cantrell and Betancourt (1992, 1995) and Bunkley-Williams and Williams (pers. comm., 2004) isolated *Fusarium* spp. from the freshwater prawn *Macrobrachium rosenbergii*, and Bunkley-Williams and Williams (op. cit.) isolated *Fusarium* sp. rarely from freshwater fishes in Puerto Rico.

The aquatic hyphomycete *Tetraploa aristata* is common in estuary Rincón Lagoon of the Boquerón Wildlife Refuge, as reported by Kirk (1969) for Chesapeake Bay. This microfungus is commonly found in river foam, sugarcane, and soil. Other geophilic (soil-loving) mitosporic and chytrid fungi could be transported by Sahara dust and might contribute to amphibian decline in Puerto Rico (Stallard, 2001; Burrowes et al., 2004). Burrowes et al. (op. cit.) monitored the populations of *Eleutherodactylus* in Puerto Rico from 1989 through 2001; they found chytrid fungi in two species collected as early as 1976, being the first report of chytrid fungus in the Caribbean. Analysis of weather data indicates significant periods of drought and the decline of amphibians in Puerto Rico. There is a possibility of a synergistic interaction between drought and the pathological effect of the chytrid fungus on amphibian populations (Burrowes et al., 2004).

According to Dring (1980), the basidiomycete *Clathrus crispus* is the familiar West Indian species, one of the longest known but strangely lacking an adequate description before that by Wright (1949). Unfortunately, certain doubts arose whether *Clathrus cancellatus* (= *Clathrus ruber*) collections were the same as *C. crispus*. However, we agree with Dennis (1953), who considered that *C. crispus* is a tropical species with corrugated rims, different from *C. cancellatus* which does not have corrugated rims, and according to Burk (1979), *C. cancellatus* is not tropical (Nieves-Rivera et al., 1999). The polypore *Datronia caperata* was originally described as *Coriolopsis fulvocinera* (and not *Polyporus*) from Cuba and the type is a specimen of the common *D. caperata*, probably one of the most common species of polypores in the tropical zone and rather variable as to pileus color and cover (pubescent zones are changing with black glabrous ones according to growth conditions) (Leif Ryvarden, personal communication, 2004).

In conclusion, the data on coastal and mangrove-associated fungi are too poor to speculate on such subjects as dispersal and island biogeography, especially in Puerto Rico and in the Caribbean. Most of the taxonomic information presented herein was collected from fragmentary surveys in published and unpublished reports (e.g., technical reports, theses, abstracts) from Puerto Rico. However, these data suggest that the taxonomic composition of coastal and mangrove-associated fungi is more complex than previously suspected. In other words, beaches, estuaries, sand dunes, and mangrove forests may support a larger assemblage of fungal species than indicated by the previous published records. Therefore, it would seem important to continue studying such habitats, in order to contribute to the conservation and knowledge of the biodiversity of coastal and mangrove-associated fungi of Puerto Rico.

Table III. Checklist of previous and recent mycological collections (including marine— obligate and facultative— and terrestrial fungi) in mangroves and mangrove-associated plants, coastal forests, estuaries, beaches, sand dunes, and marine habitats in Puerto Rico.[1]

Fungus	Substrata or Host[2]	References
ASCOMYCOTA		
Acanthostigma lantanae Theiss.	Lc	Stevens (1917); Wellman (1961); Stevenson (1975); Minter et al. (2001)
**Aigialus* cf. *grandis* Kohlm. & S. Schatz	Bs, Ll, Sf	Nieves-Rivera (unpubl. data, Rincón Lagoon, Boquerón Wildlife Refuge, southwestern Puerto Rico)
Antennospora caribbea Meyer	Df	Meyer (1957); Stevenson (1975); Minter et al. (2001)
A. quadricornuta (Cribb & J.W. Cribb) T.W. Johnson	Rh	Kohlmeyer (1969); Stevenson (1975); Schmit and Shearer (2003)
Anthostosmella rhizomorphorae (Kunze) Berl. & Voglino, in Sacc.	Rh	Stevens (1920); Seaver and Chardón (1926); Kohlmeyer (1969); Stevenson (1975); Minter et al. (2001); Schmit and Shearer (2003); Schmit (2004)
Anthostosmella sp.	Pa, Un	Lodge (1996a)
Aphosphaeria sp. (*s. str.* Pérez Samot, 1986) = *Apiosphaeria* sp.		
Apiosphaeria sp.	Am	Pérez Samot (1986)
Arenariomyces cf. *majusculus* Kohlm. & Volkm.-Kohlm.	Bs, Sf	Nieves-Rivera and Santos-Flores (2004b)
A. trifurcatus (Höhn.) Kohlm.	Bs, Ll, Sf	Acevedo (1987)
A. triseptatus Kohlm.	Bs, Sf	Nieves-Rivera and Santos-Flores (2004a, b)

Asteridiella lagunculariae (Earle) Hansf.	Co, La	Heller (1900); Earle (1901); Stevens (1916); Toro (1925); Seaver and Chardón (1926); Ryan (1926); Stevens (1927, 1928); Seaver et al. (1932; Hansford (1961, 1963); Kohlmeyer (1969); Stevenson (1975); Minter et al. (2001); Schmit and Shearer (2003); Schmit (2004)
A. manca (Ellis & G. Martin) Hansf.	Mc	Hansford (1961); Minter et al. (2001)
A. sepulta (Pat.) Hansf.	Av	Stevens (1917); Chardón (1920); Toro (1925); Seaver and Chardón (1926); Stevens (1927, 1928); Hansford (1961, 1963); Kohlmeyer (1969); Stevenson (1975); Minter et al. (2001); Nieves-Rivera et al. (2002); Schmit and Shearer (2003)
Asterina coccolobae Ferd. & Winge	Cu	Seaver and Chardón (1926); Stevenson (1975); Francis and Lowe (2000); Minter et al. (2001)
Asterolibertia schroeteri (Rehm) Arx, in E. Müll. & Arx	Ch	Ryan (1924); Stevenson (1975); Minter et al. (2001)
**Asteromassaria* sp.	Rh	Nieves-Rivera (unpubl. data, on bark of living aerial *Rhizophora mangle* L. roots and trunk, south of Magueyes Island, La Parguera, Lajas, southwestern Puerto Rico; Figure 13). Remarks.–Thallus deposited with the U.S. National Fungus Collection (BPI) by ÁMNR, 29 November 2001, BPI 843791.
Astrosphaeriella aff. *mangrovei* (Kohlm. & Vittal) Aptroot & K.D. Hyde	Df, La, Ll, Sf	Acevedo (1987); Nieves-Rivera and Santos-Flores (2004a, b)
Botryosphaeria quercuum (Schwein.) Sacc.	Ca, Cn, Ll	Phelps and Landgraf (1972); Stevenson (1975); Minter et al. (2001)
Botryotinia allii (Sawada) W. Yamam., in Yamam., Oyasu & H. Iwasaki		

	Bs, Rh, Ss	Minter et al. (2001); Nydia J. Rodríguez (unpubl. data, from seawater in *R. mangle* roots, María Langa Cay, Guayanilla Bay, Guayanilla, southwestern Puerto Rico) Remarks.–Strain deposited with the American Type Culture Collection (ATCC) as *Cladosporium sphaerospermum* Penzig. MYA-3069 (NJRR-1).
Byssosphaeria schiedermayeriana (Fuckel) M.E. Barr	Cn, Un	Stevenson (1975); Lodge (1996a); Minter et al. (2001)
**Calonectria morganii* Crous, Alfenas & M.J. Wingf.	Ce	Nieves-Rivera (unpubl. data, Boquerón Beach and Magueyes Island) Remarks.– The anamorph of this species is *Cylindrocladium scoparium* Morgan (*s. str.* Miller and McRitchie (1973)).
Capnodium sp.	Av, La, Tc	Minter et al. (2001); Nieves-Rivera et al. (2002)
Ceratocystis paradoxa (Dade) C. Moreau = *Endoconidiophora paradoxa*		
Chaetomastia cf. *typhicola* (P. Karst.) M.E. Barr	Bs, Sf	Stevens (1917); Chardón (1920); Seaver (1922); Lodge (1996a); Nieves-Rivera and Santos-Flores (2004b) Remarks.–Minter et al. (2001) reported *Chaetomastia* sp. in Puerto Rico (Río Grande) on the branches of an undetermined plant.
Chaetomium globosum Kunze	Hp, Ss	Stevenson (1975); Minter et al. (2001); Silva et al. (2004); Ortiz et al. (2004)
Chaetophoma sp.	Dv, Ll	Lodge (1996a); Acevedo (2001); Minter et al. (2001) Remarks.–Minter et al. (2001) reported *Chaetophoma* sp. on *Syngonium auritum* (L.) Schott

		(= *Xanthosoma undipes* (C. Koch) C. Koch (Araceae).
**Cochliobolus pallescens* (Tsuda & Ueyama) Sivan.	Ba, Bs, Ll, Sf, Ss	Nieves-Rivera (unpubl. data, Rincón Lagoon, Boquerón Wildlife Refuge)
Corollospora cinnamomea Koch	Ss	Schmit (2004)
C. cf. *colossa* Nakagiri & Toruka	Bs, Sf	Nieves-Rivera and Santos-Flores (2004a, b)
C. filiformis Nakagiri, in Nakagiri & Toruka	Bs, Sf	Nieves-Rivera and Santos-Flores (2004a, b)
C. maritima Werderm.	Bs, Sa, Sf	Acevedo (1987)
C. cf. *pseudopulchella* Nakagiri & Toruka	Bs, Sf	Nieves-Rivera and Santos-Flores (2004b)
Coronopapilla aff. *mangrovei* (K.D. Hyde) Kohlm. & Volkm.-Kohlm.	Df, Sf	Nieves-Rivera and Santos-Flores (2004b)
C. cf. *mangrovei* (K.D. Hyde) Kohlm. & Volkm.-Kohlm. = *Coronopapilla* aff. *mangrovei*		
Dactylospora haliotrepha (Kohlm. & E. Kohlm.) Hafellner	La	Acevedo (1987); Minter et al. (2001)
Dictyonella erysiphoides (Rehm) Höhn.	Cu	Stevenson (1975); Minter et al. (2001)
Didymosphaeria enalia Kohlm. = *Verruculina enalia*		
D. rhizophorae Kohlm. & E. Kohlm. = *Lineolata rhizophorae*		
Didymosphaeria sp.	Rh, Un	Lodge (1996a); Minter et al. (2001); Nieves-Rivera (unpubl. data, Boquerón Wildlife Refuge and Mona Island)
Diplotheca tunae (Spreng.) Starbäck	Od	Stevens (1917); Fitzpatrick (1927); Stevenson (1975); Minter et al. (2001)
Dyrithium lividum (Fr.) M.E. Barr	Co	Barr (1994); Minter et al. (2001)
Emericella nidulans (Eidam) Vuill.	Bs	Hernández-Vera (1972, 1975); Minter et al. (2001)
E. unguis Malloch & Cain	Hp	Silva et al. (2004); Ortiz et al. (2004)
Endoconidiophora paradoxa (De Seynes) R.W. Davidson	Cn	Stevenson (1975); Francis and Lowe (2000); Minter et al. (2001)
Endoxyla sp.	Un	Minter et al. (2001); Nieves-Rivera (unpubl. data, Mona Island)

Eutypella stellulata (Fr.) Sacc.	Ca, Un	Stevenson (1975); Minter et al. (2001)
Fennellia flavipes B.J. Wiley & E.G. Simmons	Bs, Hr, Ll, Rp, Ss	Carvajal-Zamora (1971a, b); Hernández-Vera (1972, 1975); Nieves-Rivera (2000a, b); Minter et al. (2001)
Galactomyces geotrichum (E.E. Butler & L.J. Petersen) Readhead & Malloch	Bs, Ss	Carvajal-Zamora (1971a, b); Hernández-Vera (1972, 1975, 1982); Hernández-Vera and Almodóvar (1983, 1984); Minter et al. (2001)
Genicularia cytosporia (Dudd.) Rifai & R. C. Cooke	Bs	Hernández-Vera (1982); Hernández-Vera and Almodóvar (1983, 1984)
Gibberella baccata (Wallr.) Sacc.	Bs, Ss	Hernández-Vera (1982); Hernández-Vera and Almodóvar (1983, 1984); Lodge (1996a)
G. fujikuroi (Sawada) S. Ito	Ma, Un	Weiss (1950); Stevenson (1975); Cantrell and Betancourt (1995); Minter et al. (2001)
G. intricans Wollenw.	Ma, Ss, Un	Stevenson (1975); Cantrell and Betancourt (1995); Minter et al. (2001)
G. subglutinans (E.T. Edwards) P.E. Nelson, Toussoun & Marasas	Bs, Ma, Ss	Hernández-Vera (1982); Hernández-Vera and Almodóvar (1983, 1984); Cantrell and Betancourt (1995)
Halorosellinia oceanica (S. Schatz) Whalley, E.B.G. Jones, K.D. Hyde & T. Laessøe	Rh, Sf	Acevedo (2001); Nieves-Rivera and Santos-Flores (2004b)

Halosphaeria cucullata (Kohlm.) Kohlm.	Bs, Rh, Sf	Nieves-Rivera and Santos-Flores (2004b)
H. quadricornuta Cribbs & J.W. Cribbs	Co, Rh, Un, Wd	Kohlmeyer (1968, 1980); Stevenson (1975); Kohlmeyer and Volkmann-Kohlmeyer (1987); Acevedo (1987); Minter et al. (2001); Schmit (2004)
H. salina (Meyers) Kohlm.	Ba	Acevedo (1987)
Halosphaeria sp.	Bs, Sf	Nieves-Rivera and Santos-Flores (2004a, b)
Hydronectria tethys Kohlm. & E. Kohlm.	Df, Rh	Acevedo (1987, 2001)
Hypocrea rufa (Pers.: Fr.) Fr.	Cn, Un	Stevenson (1975); Minter et al. (2001)
Hypoxylum culmorum Cooke = *Kretzschmariella culmorum*		
H. quisquiliarum Mont.	Cn, Un	Miller (1961); Stevenson (1975); Minter et al. (2001)
H. oceanicum S. Schatz = *Halorosellinia oceanica*		

H. rubiginosum (Pers.: Fr.) Fr.	Ba	Stevenson (1975); Minter et al. (2001)
Hypoxylon section *Hypoxylon*	Av, Rh	Nieves-Rivera et al. (1998)
Hypoxylum sp.	La, Ll, Un	Stevenson (1975); Minter et al. (2001)
**Hysterium* sp.	Un	Nieves-Rivera (unpubl. data, Magueyes Island)
Hysterographium sp.	Un	Lodge (1996a); Minter et al. (2001); Nieves-Rivera (unpubl. data, Magueyes Island)
Irene laguncularíae (Earle) Toro = *Asteridiella laguncularíae*		
Irenina laguncularíae (Earle) F. Stevens = *Asteridiella laguncularíae*		
Irenopsis molleriana (G. Winter) F. Stevens	Hi, Tr	Seaver et al. (1932); Poonyth et al. (2000); Minter et al. (2001); Schmit and Shearer (2003); Schmit (2004)
I. molleriana var. *major* Hansf.	Hi	Minter et al. (2001)
I. triumfettae (F. Stevens) Hansf. & Deighton	Hi	Stevens (1916); Seaver and Chardón (1926); Kohlmeyer (1969); Stevenson (1975); Poonyth et al. (2000); Minter et al. (2001); Schmit and Shearer (2003); Schmit (2004)
Kirschsteiniothelia aff. *maritima* (Linder) D. Hawksw.	Sf, Un	Minter et al. (2001); Nieves-Rivera and Santos-Flores (2004a, b)

Krestzchmaria rugosa Earle = *Penzigia cantareirensis*		
K. zonatum (Lév.) P.M.D. Martin	Cn, Un	Minter et al. (2001)
Kretzschmariella culmorum (Cooke) Y.M. Ju & J.D. Rogers	Ba	Stevenson (1975); Lodge (1996a); Minter et al. (2001)
Kymadiscus haliotrephus (Kohlm. & E. Kohlm.) Kohlm. & E. Kohlm. = *Dactylospora haliotrepha*		
Lecanidion atratum (Hedw.) Rabeh.	Cn, Un	Stevenson (1975); Minter et al. (2001)
Lecidea gymnocarpa Fink, in J. Hedrick	Cn	Hedrick (1930); Imshaug (1957); Minter et al. (2001)
Lembosia coccolobae Earle	Cu	Chardón (1920); Seaver and Chardón (1926); Stevenson (1975); Meurer-Grimes et al. (1992); Minter et al. (2001)
L. tenella Lév.	Cu, Un	Earle (1904); Chardón (1921); Spegazzini (1923); Ryan (1924); Stevenson (1975); Francis and Lowe (2000); Minter et al. (2001)
Leptogium azureum (Sw.) Mont., in P.B. Webb & S. Berthelot	Cn, Un	Müller (1888); Imshaug (1957); Minter et al. (2001)
**Leptosphaeria australiensis* (Cribb & J.W. Cribb) G.C. Hughes	Av, Rh	Nieves-Rivera (unpubl. data, on intertidal wood of *A. germinans* and *R. mangle* roots, La Parguera Channels and Magueyes Island)
Leptosphaeria sp.	Df, La, Rh	Acevedo (1987)
Lindra marinera Meyers	Bs	Acevedo (1987)
L. thalassiae Orpurt, Meyer, Boral & Simms	Th	Calzada (1988, 1991); Acevedo (1997)
Lindra sp.	Bs, Sf	Acevedo (1987); Nieves-Rivera and Santos-Flores (2004b)
Lineolata rhizophorae (Kohlm. & E. Kohlm.) Kohlm. & Volkm-Kohlm.	Df, Rh	Acevedo (1987, 2001)
Lophionema bambusae Höhn.	Ba	Stevenson (1975); Minter et al. (2001)

Lophiostoma mangrovei Kohlm. & Vittal = *Astrosphaeriella mangrovei*		
Lulworthia grandispora Meyers	Av, Rh, Th	Meyers (1957); Acevedo (1987, 2001); Minter et al. (2001); Schmit and Shearer (2003)
L. medusa (Ellis & Everh.) Cribb & J.W. Cribb	Wd	Meyers (1957); Minter et al. (2001); Schmit and Shearer (2003); Schmit (2004)
L. medusa var. *biscaynia* Meyers	Wd	Meyers (1957); Minter et al. (2001)
Lulworthia sp.	Av, Bs, Co, Cy, Hi, Rh, Sf, Th, Wd	Kohlmeyer (1980); Kohlmeyer and Volkmann-Kohlmeyer (1987); Minter et al. (2001); Nieves-Rivera and Santos-Flores (2004b)
Maublancia uleana (Pazschke) Arx, in E. Müll. & Arx	Ch	Stevenson (1975); Minter et al. (2001)
Meliola ambigua Pat. & Gaillard	Lc, Le, Ls, Lv	Hansford (1961); Stevenson (1975); Minter et al. (2001)
M. nigra F. Stevens	La	Stevens (1916, 1920); Chardón (1920); Seaver and Chardón (1926); Hansford (1961, 1963); Kohlmeyer (1969); Stevenson (1975); Poonyth et al. (2000); Minter et al. (2001); Schmit and Shearer (2003); Schmit (2004)
M. panici Earle	Se	Chardón (1920); Hansford (1961); Meurer-Grimes et al. (1992); Stevenson (1975); Poonyth et al. (2000); Minter et al. (2001); Schmit and Shearer (2003)
M. triumfettae F. Stevens = *Irenopsis triumfettae*		
Micropeltis ingae Bat. & Peres	Tc	Gómez-Acosta (1995); Minter et al. (2001)
Microsphaera sp.	Ad	Roure and Ramírez (1970); Betancourt et al. (1980)
Microthyrium laguncularіae G. Winter = *Schizothyrium laguncularіae*		
Microthyrium sp.	Ch	Ryan (1924); Minter et al. (2001)
Moellerodiscus lentus (Berk. & Broome) Dumont	Cn, Ll, Un	Minter et al. (2001)

Monographella nivalis (Schaffnit) E. Müll.	Bs	Hernández-Vera (1982); Hernández-Vera and Almodóvar (1983, 1984); Minter et al. (2001)
Mycosphaerella chrysobalani Miles	Ch	Miles (1917); Stevenson (1975); Minter et al. (2001)
Nectria calami (Henn. & E. Nyman) Rossman	Cn, Un	Rossman (1983); Minter et al. (2001)
N. episphaeria (Tode) Fr.	Ss, Un	Carvajal-Zamora (1971a, b); Stevenson (1975); Minter et al. (2001) Remarks.–This species was also known as *Fusarium aquaeductuum* Lagerh. var. *medium* Wallenw. (*s. str.* Booth (1971) and Minter et al. (2001)).
N. haematococca Berk. & Broome	Bs, Ma, Ss	Carvajal-Zamora (1971a, b); Hernández-Vera (1972, 1975, 1982; Hernández-Vera and Almodóvar (1983, 1984); Cantrell and Betancourt (1995); Lodge (1996a); Minter et al. (2001)
N. inventa Pethybr.	Ss	Carvajal-Zamora (1971a, b)
N. suffula Berk & M.A. Curtis, in Berk.	Cn, Ll, Un	Stevenson (1975); Minter et al. (2001)
Neurospora crassa Shear & B.O. Dodge	Bs, Ss, Un	Hernández-Vera (1972, 1975, 1982); Hernández-Vera and Almodóvar (1983, 1984); Minter et al. (2001)
Neurospora sp.	Ad, Ma	Roure and Ramírez (1970); Betancourt et al. (1980); Cantrell (1991); Cantrell and Betancourt (1992)
Penzigia cantareirensis (Henn.) J.H. Mill.	Ba	Stevenson (1975); Lodge (1996a); Minter et al. (2001)
Perisporina lantanae F. Stevens	Ls	Hansford (1946); Minter et al. (2001)
Phylacia bomba (Mont.) Pat.	Ca, Un	Minter et al. (2001); Nieves-Rivera (unpubl. data, Mona Island)
Phyllacora graminis (Pers.) Nitschke	Se	Garman (1915); Chardón (1920); Minter et al. (2001)

P. minuta Henn.	Hi	Chardón (1920); Seaver and Chardón (1926); Stevenson (1975); Minter et al. (2001)
P. paspalicola Henn.	Pv	Stevens (1917); Chardón (1920); Fitzpatrick (1927); Orton (1944); Stevenson (1975); Minter et al. (2001)
P. sphaerosperma G. Winter	Cc, Cs	Chardón (1920); Orton (1944); Stevenson (1975); Minter et al. (2001)
Physalospora laguncularíae Rehm	La	Stevens (1917); Seaver and Chardón (1926); Stevenson (1975); Minter et al. (2001)
Pleospora sp.	Co, Rh	Acevedo (1987); Lodge (1996a); Minter et al. (2001); Nieves-Rivera (unpubl. data, on *R. mangle* submerged wood and mangrove mud, Magueyes Island)
Poronia oedipus (Mont.) Mont.	Un	Toro (1924); Stevenson (1975); Guzmán (1986); Nieves-Rivera et al. (1998); Minter et al. (2001)
Pterosporidium rhizomorphae (Kunze: Curr.) W.H. Ho & K.D. Hyde	Rh	Ho and Hyde (1996); Poonyth et al. (2000); Schmit and Shearer (2003); Schmit (2004)
P. rhizophorae (Vizioli) W.H. Ho & K.D. Hyde	Rh	Kohlmeyer (1969); Fell and Master (1973); Ho and Hyde (1996); Calzada (1999); Poonyth et al. (2000); Schmit and Shearer (2003); Schmit (2004)
Puiggarina laguncularíae (Rehm) Speg. = *Physalospora laguncularíae*		
Pyrenographa sp.	Un	Minter et al. (2001); Nieves-Rivera (unpubl. data, Mona Island)
Pyrenula sp.	Un	Minter et al. (2001); Nieves-Rivera (unpubl. data, Mona Island)
Rhytidhysterium rufulum (Spreng.: Fr.) Speg.	Ca, Tc, Un	Stevenson (1975); Minter et al. (2001)
Rosellinia corticium (Schwein.) Sacc.	Ca	Stevenson (1975); Minter et al. (2001)

Saccardoella rhizophorae K.D. Hyde	Rh, Un	Minter et al. (2001); Nieves-Rivera (unpubl. data, Mona Island)
Saccardoella sp.	Co, Df, Un	Lodge (1996a); Minter et al. (2001); Nieves-Rivera (unpubl. data, Mona Island)
Saccharomyces cerevisiae Meyen: E. C. Hansen	Bs	Hernández-Vera (1982); Hernández-Vera and Almodóvar (1983, 1984); Minter et al. (2001)
Schizothyrium lagunculariae (G. Winter) Arx, in E. Müll. & Arx	La	Earle (1901); Stevens (1917); Seaver and Chardón (1926); Stevenson (1975); Minter et al. (2001)
Scutellinia sp.	Cn, Ll, Ss, Un	Pfister (1979); Minter et al. (2001)
Sphaeria zonata Lév. = *Kretzschmaria zonatum*		
Spiropes capensis (Thüm.) M.B. Ellis	Co, La, Me	Stevens (1917, 1919); Spegazzini (1923); Stevenson (1975); Minter et al. (2001)
**Strigula* sp.	Un	Nieves-Rivera (unpubl. data, Mona Island)
Telimena ecastophylli (Lév.) Cif.	De	Stevenson (1975); Minter et al. (2001)
Thyridaria sp.	Un	Minter et al. (2001); Nieves-Rivera (unpubl. data, Mona Island)
Thyronectria pseudotrichia (Schwein.) Seeler	Cn, Un	Chardón (1920); Stevenson (1975); Minter et al. (2001)
Torpedospora radiata Meyers	Co, Df, Hi, Sf, Th	Acevedo (1987); Nieves-Rivera and Santos-Flores (2004a, b); Nieves-Rivera (unpubl. data, Rincón Lagoon, Boquerón Wildlife Refuge)
Trichocladium sp. = *Microsphaera* sp.		
Trichomerium coccolobae Bat. & Cif.	Cu	Stevenson (1975); Minter et al. (2001)
T. ornatum Bat. & Cif.	Mc	Stevenson (1975); Minter et al. (2001)
Varicosporina ramulosa Meyers & Kohlm.	Bs, Sp	Acevedo (1987, 2001)
Verruculina enalia Kohlm. & Volkm.-Kohlm.	Df, Rh	Acevedo (1987); J. Kohlmeyer (pers. comm., 2004)
Xylaria adscendens Fr.	Lp, Un	Lodge (1996a); Acevedo (2001); Minter et al. (2001)

X. arbuscula Sacc.	Ba	Stevenson (1975); Lodge (1996a); Minter et al. (2001)
X. feejeensis (Berk.) Fr.	Un	Lodge (1996a); Nieves-Rivera et al. (1999) Remarks.–Britton (1915) reported as *Xylaria* sp. Misidentified as *Pterula capilaris* (Lév.) Sacc. (*sensu* Saccardo (1888)) by Nieves-Rivera (1996)
X. multiplex (Kunze) Fr.	Lp, Ss	Lodge (1996a); Acevedo (2001); Minter et al. (2001)
X. scruposa (Fr) Fr.	Cn, Un	Stevenson (1975); Minter et al. (2001)
Xylaria sp.	Af, As, Ch, Cu, Db, Dd, Go, Gs, Ip, Lp, Pg, Rh, Sp	Acevedo (2001); Minter et al. (2001); Rodríguez et al. (2004); Nieves-Rivera (unpubl. data, on intertidal *R. mangle* wood, Magueyes Island)
Unknown sp. 1	Bs, Sf	Nieves-Rivera and Santos-Flores (2004b)
Unknown sp. 2	Sf	Nieves-Rivera and Santos-Flores (2004b)
Unknown sp. 3	Rh	Nieves-Rivera (unpubl. data, on *R. mangle* dead wood, Magueyes Island)
Unknown sp. 4	Rh	Nieves-Rivera (unpubl. data, on *R. mangle* dead wood, Magueyes Island)

MITOSPORIC FUNGI (ANAMORPHIC FUNGI)

Acremonium murorum (Corda) W. Gams	Bs	Hernández-Vera (1982); Hernández-Vera and Almodóvar (1983, 1984)
Acremonium sp.	Ad, Am, Tm	Roure and Ramírez (1970); Betancourt et al. (1980); Pérez Samot (1986); Bunkley-Williams and Williams (per. comm., 2004)
Alternaria humicola Oudem. = *Alternaria tenuissima*		
A. tenuissima (Kunze) Wiltshire	Bs, Ss	Hernández-Vera (1972, 1975); Minter et al. (2001)
Alternaria sp.	Ad, Bs, Ec, Ll, Rh, Sf, Ss	Roure and Ramírez (1970); Betancourt et al. (1980); Acevedo (1987); Lodge (1996a); Minter et al. (2001); Ortiz Rivera and Semidey Laracuente (2004); Nieves-Rivera (unpubl. data, on intertidal *R. mangle* wood, Magueyes Island)
Anguillospora cf. *longissima* (Sacc. & P. Syd.) Ingold	Bs, Ll, Rf, Sf, Un	Lodge (1996a); Santos-Flores and Betancourt-López (1997); Minter et al. (2001); Nieves-Rivera and Santos-Flores (2004b)
Antennariella persea Bat., Nascim. & Cif.	Cn	Stevenson (1975); Minter et al. (2001)
Apiocarpella sp.	Am	Pérez Samot (1986)
Arthrinium sp.	Un	Acevedo (2001)
Articulospora tetracladia Ingold	Rf, Sf	Santos-Flores and Betancourt-López (1997); Minter et al. (2001); Nieves-Rivera and Santos-Flores (2004b)
Aschersonia cubensis Berk. & M.A. Curtis	Cn	Stevenson (1975); Minter et al. (2001)
A. turbinata Berk.	Cn	Stevenson (1975); Minter et al. (2001)
Aschersonia sp.	Am	Pérez Samot (1986)
Aspergillus caespitosus Raper & Thom	Hp	Silva et al. (2004); Ortiz et al. (2004)
A. candidus Link	Bs, Hp, Ss	Hernández-Vera (1972, 1975, 1982); Hernández-Vera and Almodóvar (1983, 1984); Minter et al. (2001); Silva et al. (2004); Ortiz et al. (2004)

A. clavatus Desm.	Bs, Ss	Hernández-Vera (1982); Hernández-Vera and Almodóvar (1983, 1984); Minter et al. (2001)
A. flavipes (Bainier & R. Sartory) Thom & Church	Hp, Ss	Minter et al. (2001); Silva et al. (2004); Ortiz et al. (2004)
A. flavus Link	Bs, Hp, Rp, Ss	Hernández-Vera (1982); Hernández-Vera and Almodóvar (1983, 1984); Lodge (1996a); Nieves-Rivera (2000a); Minter et al. (2001); Silva et al. (2004); Ortiz et al. (2004); Ruiz-Suárez, (2004)
A. fumigatus Fresen. = *Fennellia flavipes*		
A. funiculosus G. Sm.	Bs, Ss	Hernández-Vera (1972, 1975, 1982); Hernández-Vera and Almodóvar (1983, 1984); Minter et al. (2001)
A. humicola Chaudhuri & Sachar	Bs, Ss	Hernández-Vera (1982); Hernández-Vera and Almodóvar (1983, 1984)
A. luchuensis Inui = *Aspergillus niger* var. *awamori*		
A. nidulans (Eidam) Winter = *Emericella nidulans*		
A. niger Tiegh.	Bs, Rh, Ll, Ss, Tm	Hernández-Vera (1972, 1975, 1982); Hernández-Vera and Almodóvar (1983, 1984); Lodge (1996a); Minter et al. (2001); Ruiz-Suárez, (2004); Bunkley-Williams and Williams (pers. comm., 2004); Nieves-Rivera (unpubl. data, on intertidal *R. mangle* wood and leaves, Magueyes Island and mouth of the Manatí River; Figures 14A–B)
A. niger Tiegh. var. *awamori* (Nakaz.) Al-Musallam	Bs, Ss	Carvajal-Zamora (1971a, b); Hernández-Vera (1972, 1975, 1982); Hernández-Vera and Almodóvar (1983, 1984); Minter et al. (2001)
A. oryzae (Ahlb.) Cohn	Bs	Hernández-Vera (1972, 1975); Minter et al. (2001)
A. okazakii Okazaki	Bs	Hernández-Vera (1982) ; Hernández-Vera and Almodóvar (1983, 1984)

A. ostianus Wehmer	Hp	Silva et al. (2004); Ortiz et al. (2004)
A. *ruber* (J. König, Spieck. & Bremer) Thom & Church	Bs	Hernández-Vera (1982) ; Hernández-Vera and Almodóvar (1983, 1984)
A. sydowii (Bainier & R. Sartory) Thom & Church	Bs, Gf, Gv, Ss	Hernández-Vera (1982; Hernández-Vera and Almodóvar (1983, 1984); Ernesto Weil (pers. obs., 2000, Enrique Cay, La Parguera); Minter et al. (2001); Nieves-Rivera (2002); Greetchen Díaz and Rafael Montalvo-Rodríguez (pers. comm., 2004, hypersaline lagoons of Salinas Bay, refer to "Fig. 1" of Montalvo-Rodríguez et al., 1997: pp. 99)
A. terreus Thom, in Thom and Church	Bs, Ll, Rh, Ss	Hernández-Vera (1972, 1975, 1982) ; Hernández-Vera and Almodóvar (1983, 1984); Minter et al. (2001); Ruiz-Suárez, (2004); Nieves-Rivera (unpubl. data, on submerged *R. mangle* wood and leaves, Magueyes Island)
A. unguis (Émile-Weil & L. Gaudin) Thom & Raper = *Emericella unguis*		
A. ustus (Bainier) Thom & Church	Rh, Ll	Minter et al. (2001); Nieves-Rivera (unpubl. data, on submerged *R. mangle* wood and leaves, Magueyes Island)
A. versicolor (Vuill.) Tirab.	Bs, Ss	Hernández-Vera (1972, 1975, 1982); Hernández-Vera and Almodóvar (1983, 1984); Lodge (1996a); Minter et al. (2001)
A. violaceus-fuscus Gasperini	Bs, Ss	Hernández-Vera (1972, 1975, 1982); Hernández-Vera and Almodóvar (1983, 1984); Minter et al. (2001)
Aspergillus sp.	Ad, Am, Bs, Ch, Cn, Cu, Ga, Hp, Ip, Lh, Ll, Ma, Ms, Rh, Ss, Te, Th, Tm, Tu	Roure and Ramírez (1970); Betancourt et al. (1980); Pérez Samot (1986); Acevedo (1987, 2001); Cantrell (1991); Cantrell and Betancourt (1992);

		Vargas et al. (1998); Calzada (1999); Minter et al. (2001); Silva et al. (2004); Ortiz et al. (2004); Rodríguez et al. (2004); Ruiz-Suárez, (2004)
Atractilina parasitica (G. Winter) Deighton & Piroz.	Ls	Stevens (1917); Stevenson (1975); Minter et al. (2001)
Aureobasidium sp.	Ad, Go, Gx, Ss, Th	Betancourt et al. (1980); Lodge (1996a); Acevedo (2001); Minter et al. (2001)
Beauveria bassiana (Bals.-Criv.) Vuill.	Cu	Wolcott (1948, 1955a, b); Stevenson (1975); Minter et al. (2001)
B. brogniartii (Sacc.) Petch	Ss	Carvajal-Zamora (1971a, b)
Beltrania rhombica Penz.	Bs, Cu, Ll, Sf	Lodge (1996a); Santos-Flores & Betancourt-López (1997); Minter et al. (2001); Nieves-Rivera (unpubl. data, Rincón Lagoon, Boquerón Wildlife Refuge)
Bipolaris cynodontis (Marignoni) Shoemaker	Cd	Theis (1953); Stevenson (1975); Minter et al. (2001)
Bipolaris sp.	Rp, Un	Nieves-Rivera (2000a); Acevedo (2001)
Blodgettia bornetii E.P. Wright	Wd	Kohlmeyer (1980); Minter et al. (2001); Schmit (2004, isolated from algae?)
Botryoderma lateritium Papendorf & H.P. Upadhyay	Bs	Hernández-Vera (1982); Hernández-Vera and Almodóvar (1983, 1984)
Brachiosphaera tropicalis Nawawi, in Descals	Rf, Sf	Santos-Flores & Betancourt-López (1997); Minter et al. (2001); Nieves-Rivera and Santos-Flores (2004a, b); Nieves-Rivera (unpubl. data, Rincón Lagoon, Boquerón Wildlife Refuge)
Camarosporium roumeguerii Sacc.	Df	Acevedo (1987)
Camposporidium sp.	Sf	Lodge (1996a); Santos-Flores & Betancourt-López (1997); Minter et al. (2001); Nieves-Rivera and Santos-Flores (2004b)
Campylospora sp. (*s. str.* Santos-Flores & Betancourt-López, 1997)		

	Df, Hi, Ll, Rf, Sf	Santos-Flores & Betancourt-López (1997); Minter et al. (2001); Nieves-Rivera and Santos-Flores (2004a, b)
Candida glabrata (H.W. Anderson) S.A. Mey. & Yarrow, in Yarrow & S.A. Mey.		
	Bs	Hernández-Vera (1982); Hernández-Vera and Almodóvar (1983, 1984); Minter et al. (2001)
C. guillermondi (Castell.) Langeron & Guerra	Bs, Ss	Carvajal-Zamora (1971a, b); Hernández-Vera (1982); Hernández-Vera and Almodóvar (1983, 1984); Minter et al. (2001)
C. krusei (Castell.) Berkhout	Bs, Ss	Carvajal-Zamora (1971a, b); Hernández-Vera (1982); Hernández-Vera and Almodóvar (1983, 1984); Stevenson (1975); Minter et al. (2001)
C. parapsilosis (Ashford) Langeron & Talice	Bs, Ss	Carvajal-Zamora (1971a, b); Hernández-Vera (1972, 1975, 1982); Hernández-Vera and Almodóvar (1983, 1984); Minter et al. (2001)
C. pseudotropicalis (Castell.) Basgal	Bs, Ss	Hernández-Vera (1972, 1975, 1982); Hernández-Vera and Almodóvar (1983, 1984); Minter et al. (2001)
C. tropicalis (Castell.) Berkhout	Bs, Ss	Carvajal-Zamora (1971a, b); Hernández-Vera (1972, 1975, 1982); Hernández-Vera and Almodóvar (1983, 1984); Minter et al. (2001)
Candida sp.	Ad	Roure and Ramírez (1970)
Catenophora sp.	Bs, Ss	Hernández-Vera (1972, 1975); Minter et al. (2001)
Cephalosporium acremonium Corda	Bs, Ss	Hernández-Vera (1982); Hernández-Vera and Almodóvar (1983, 1984); Lodge (1996a); Minter et al. (2001)
C. asperum Harz	Bs	Hernández-Vera (1982); Hernández-Vera and Almodóvar (1983, 1984)
C. coremioides Raillo = *Verticillium lecanii*		

C. curtipes Sacc.	Bs, Ss	Hernández-Vera (1982); Hernández-Vera and Almodóvar (1983, 1984); Minter et al. (2001)
C. lecanii Zimm. = *Verticillium lecanii*		
Cephalosporium sp.	Bs	Acevedo (1987)
Cercospora chrysobalani Ellis & Everh.	Ch	Weiss (1950); Chupp (1953); Stevenson (1975); Minter et al. (2001)
C. conocarpi Chupp & A.S. Mull.	Co	Chupp (1953); Stevenson (1975); Minter et al. (2001)
C. hibisci Tracy & Earle = *Pseudocercospora abelmoschi*		
C. hibiscina Ellis & Everh.	Hi	Stevenson (1975); Minter et al. (2001)
C. ipomoeae G. Winter	Ip	Toro (1931); Chupp (1953); Stevenson (1975); Minter et al. (2001)
Cercospora sp.	Av, Rh, Se, Tc, Tp	Hansford (1946); Minter et al. (2001); Nieves-Rivera (unpubl. data, Mona Island; Figures 15A–B)
Chaetomella sp.	Bs, Ss	Hernández-Vera (1972, 1975); Minter et al. (2001)
Cladosporium cladosporoides (Fresen.) G.A. de Vries	Bs, Hr, Ss, Un	Hernández-Vera (1972, 1975, 1982); Hernández-Vera and Almodóvar (1983, 1984); Lodge (1996a); Nieves-Rivera (2000b); Minter et al. (2001); Ruiz-Suárez, (2004)
C. herbarum (Pers.) Link	Bs, Ss, Un	Stevens (1917); Weiss (1950); Wellman (1961); Stevenson (1975); Minter et al. (2001); Ruiz-Suárez, (2004)
C. oxysporum Berk. & M.A. Curtis, in Berk.	Ba, Bs, Cn, Rh, Ss	Minter et al. (2001); Nieves-Rivera (unpubl. data, from seawater in *R. mangle* roots, Los Morrillos and Bahía Sucia, Cabo Rojo, southwestern Puerto Rico) Remarks.–Strain deposited with the ATCC as *Cladosporium oxysporum* Berk. & M.A. Curtis MYA-3068 (ÁMNR-7).

C. sphaerospermum Penz. = *Botryotinia allii*		
C. werneckii Horta = *Phaeoannellomyces werneckii*		
Cladosporium sp.	Ad, Am, Av, Bs, Hp, Lh, Ma, Ms, Rh, Sp, Ss, Td, Te, Tm, Tu	Roure and Ramírez (1970); Carvajal-Zamora (1971a, b); Betancourt et al. (1980); Pérez Samot (1986); Acevedo (1987, 2001); Cantrell (1991); Cantrell and Betancourt (1992); Vargas et al. (1998); Calzada (1999); Minter et al. (2001); Sánchez and Santos (2004); Silva et al. (2004); Ortiz et al. (2004); Ruiz-Suárez, (2004)
Clavatospora bulbosa (Anastasiou) Nakagiri & Tubaki	Bs, Rf, Sf	Nieves-Rivera and Santos-Flores (2004a, b)
Coniosporium shiraianum (Syd.) Bub.	Ba	Stevenson (1975); Minter et al. (2001)
Coniothyrium sp.	Am	Pérez Samot (1986)
Cryptococcus laurentii (Kuff.) Skinner	Bs, Ss	Hernández-Vera (1982); Hernández-Vera and Almodóvar (1983, 1984)
C. neoformans (San Felice) Vuill.	Bs, Ss	Hernández-Vera (1972, 1975); Minter et al. (2001)
Curvularia pallescens Boedijn = *Cochliobolus pallescens*		
**C. robusta* Kilp. & Luttr.	Bs, Ll, Sf	Nieves-Rivera (unpubl. data, Rincón Lagoon, Boquerón Wildlife Refuge)
C. subulata (Nees) Boedijn	Ss	Carvajal-Zamora (1971a, b)
Curvularia sp.	Ad, Bs, Df, Ec, Lh, Ll, Ms, Sf, Ss, Td, Te, Tm, Tu	Roure and Ramírez (1970); Betancourt et al. (1980); Acevedo (1987); Vargas et al. (1998); Minter et al. (2001); Ortiz Rivera and Semidey Laracuente (2004); Nieves-Rivera and Santos-Flores (2004b); Sánchez and Santos (2004); Ruiz-Suárez, (2004); Nieves-Rivera (unpubl. data, La Parguera Channels and Phosphorescent Bay in Lajas, southwestern Puerto Rico)

Cylindrocarpon sp.	Bs, Cu, Ll, Ss	Carvajal-Zamora (1971a, b); Hernández-Vera (1972, 1975); Minter et al. (2001)
Cylindrocladium scoparium Morgan (*s. str.* Miller and McRitchie, 1973) = *Calonectria morganii*		
Cytospora palmicola Berk. & M.A. Curtis	Cn	Stevenson (1975); Minter et al. (2001)
C. rhizophorae Kohlm. & E. Kohlm.	Ba, Rh	Acevedo (1987); Tattar et al. (1994); Wier et al. (1996, 2000); Tattar and Wier (2002); J. Kohlmeyer (pers. comm., 2004); Nieves-Rivera (unpubl. data, on *R. mangle* prop roots, Magueyes Island, Los Morrillos, and Boquerón Commonwealth Forest, southwestern Puerto Rico; Figures 16A–F). Remarks.–The orange to deep orange cirri of *Cytospora* sp. (= *Cytospora rhizophorae* Kohlm. & E. Kohlm.) on *R. mangle* prop roots (south of Magueyes Island, La Parguera, Lajas, southwestern Puerto Rico) was deposited with BPI by ÁMNR, 15 March 2001, BPI 843790.
Cytospora sp.	Ll	Lodge (1996a)
Dactylaria sp.	Bs, Cu, Ll, Un	Hernández-Vera (1982); Hernández-Vera and Almodóvar (1983, 1984)
Dendryphiella arenaria Nicot	Bs, Dd, Sa, Sp, Th	Hernández-Vera (1982); Acevedo (1987, 2001); Hernández-Vera and Almodóvar (1983, 1984)
Dictyochaeta sp.	Cn, Cu, Ll, Un	Minter et al. (2001)
Dictyonella erysiphoides (Rehm) Höhn.	Cu	Stevenson (1975); Minter et al. (2001)
Dictyosporium sp.	Cu, Ll, Un	Minter et al. (2001)
Diheterospora sp.	Am	Pérez Samot (1986)
Diplocladiella scalaroides G. Arnaud	Cu, Ll, Rf, Sf, Un	Santos-Flores & Betancourt-López (1997); Minter et al. (2001); Nieves-Rivera and Santos-Flores (2004b); Nieves-Rivera (unpubl. data, Rincón Lagoon, Boquerón Wildlife Refuge)

Diplocladiella sp.	Cu, Sf	Lodge (1996a); Santos-Flores & Betancourt-López (1997); Minter et al. (2001)
Diplococcium spicatum Grove	Bs, Ss	Hernández-Vera (1972, 1975); Minter et al. (2001)
Diplodia epicocos Cooke	Cn	Francis and Lowe (2000)
D. natalensis Pole-Evans = *Lasiodiplodia theobromae*		
D. oraemaris Linder	Df	Acevedo (1987)
Diplodia sp.	Bs	Acevedo (1987)
Diploidia sp. = *Septoidium* sp.		
Dreschlera gigantea (Heald & F.A. Wolf) S. Ito	Cd	Stevenson (1975); Minter et al. (2001)
Dreschlera sp.	Bs, Ch, Cu, Ip, Ss	Rodríguez et al. (2004); Ruiz-Suárez, (2004)
Endocalyx melanoxanthus (Berk. & Broome) Petch	Cn, Ll, Un	Stevenson (1975); Minter et al. (2001)
Epidermophyton floccosum (Harz) Langeron & Miloch.	Bs	Hernández-Vera (1972, 1975); Minter et al. (2001)
Exophiala werneckii (Horta) Arx = *Phaeoannellomyces werneckii*		
**Exserohilum* sp.	Bs, Ll, Rh, Sf	Nieves-Rivera (unpubl. data, Rincón Lagoon, Boquerón Wildlife Refuge)
Fusarium aquaeductum (Radl. & Raben.) Sacc. = *Nectria episphaeria*		
F. aquaeductuum Lagerh. var. *medium* Wallenw. = *Nectria episphaeria*		
F. chlamydosporium Wollenw. & Reinking	Ma	Cantrell and Betancourt (1995)
F. episphaerica (Tode) W.C. Snyder & H.N. Hansen = *Gibberella baccata*		
F. epishaericum (Cooke & Ellis) Sacc. = *Gibberella baccata*		
F. equiseti (Corda) Sacc. = *Gibberella intricans*		
F. lateritium Nees = *Gibberella baccata*		
F. moniliforme J. Sheld. = *Gibberella fujikuroi*		
F. moniliforme J. Sheld. var. *subglutinans* Wollenw. & Reinking = *Gibberella subglutinans*		
F. neoceras Wollenw. & Reinking = *Gibberella subglutinans*		
F. nivale (Fr.) Sorauer = *Monographella nivalis*		
F. oxysporum Schltdl.	Bs, Hr, Un	Hernández-Vera (1982); Hernández-Vera and Almodóvar (1983, 1984); Nieves-Rivera (2000b); Minter et al. (2001)

F. roseum Link.: Fr.	Bs, Ss	Hernández-Vera (1982); Hernández-Vera and Almodóvar (1983, 1984)
F. semitectum Berk. & Ravenel, in Berk.	Hp, Ma	Cantrell and Betancourt (1995); Silva et al. (2004); Ortiz et al. (2004)
F. solani (Mart.) Sacc. = *Nectria haematococca*		
Fusarium sp.	Ac, Ad, Am, Bs, Df, Ec, Go, Hi, Lh, Ll, Hp, Ma, Ms, Sf, Ss, Td, Te, Tm, Tu, Un	Roure and Ramírez (1970); Betancourt et al. (1980); Pérez Samot (1986); Acevedo (1987, 2001); Cantrell (1991); Cantrell and Betancourt (1992); Lodge (1996a); Vargas et al. (1998); Minter et al. (2001); Ortiz Rivera and Semidey Laracuente (2004); Sánchez and Santos (2004); Silva et al. (2004); Ortiz et al. (2004); Nieves-Rivera and Santos-Flores (2004b); Ruiz-Suárez, (2004); Bunkley-Williams and Williams (pers. comm., 2004)
Fusicoccum microspermum Har. & P. Karst.	Tc	Stevenson (1975); Minter et al. (2001)
Fusoma sp. (nom. dub.)	Ma	Cantrell (1991); Cantrell and Betancourt (1992)
Gelatinosporium sp.	Bs, Ss	Hernández-Vera (1972, 1975); Minter et al. (2001)
Geotrichum candidum Link = *Galactomyces geotrichum*		
Geotrichum sp.	Bs, Ch, Cu, Ip, Ss, Tm	Rodríguez et al. (2004); Ruiz-Suárez, (2004); Bunkley-Williams and Williams (per. comm., 2004)
Gilmaniella sp.	Ad	Betancourt et al. (1980)
Gliocladium roseum Bainier	Bs, Ss	Hernández-Vera (1972, 1975, 1982); Hernández-Vera and Almodóvar (1983, 1984); Lodge (1996a); Minter et al. (2001)
G. virens J.H. Mill., Giddens & A.A. Foster	Ss	Carvajal-Zamora (1971a, b); Hernández-Vera (1972, 1975, 1982); Hernández-Vera and

		Almodóvar (1983, 1984); Lodge (1996a); Minter et al. (2001)
Gliomastix murorum (Corda) S. Hughes = *Acremonium murorum*		
Graphium squarrosum Ellis & Langl.	Ba	Stevenson (1975); Minter et al. (2001)
Harposporidium sp. = *Harposporium* sp.		
Harposporium sp.	Bs	Hernández-Vera (1972, 1975); Minter et al. (2001)
Helicomyces roseus Link = *Tubeufia cylindrothecia*		
H. torquatus L.C. Lane & Shearer	Bs, Ll, Sf	Santos-Flores & Betancourt-López (1997); Minter et al. (2001); Nieves-Rivera (unpubl. data, Rincón Lagoon, Boquerón Wildlife Refuge)
Helicorhoida sp. = *Helicorhoidion* sp.		
Helicorhoidion sp.	Ad	Betancourt et al. (1980)
Helicosporium griseum Berk. & M.A. Curtis, in Sacc.	Ba, Bs, Cn, Hi, Ll, Un	Minter et al. (2001)
Helicosporium sp.	Ba, Cn, Hi, Ll, Un	Minter et al. (2001)
Helminthosporium anomalum J.C. Gilman & E.V. Abbott	Bs, Ss	Hernández-Vera (1972, 1975, 1982); Hernández-Vera and Almodóvar (1983, 1984); Minter et al. (2001)
H. velutinum Link	Bs	Hernández-Vera (1982); Hernández-Vera and Almodóvar (1983, 1984); Minter et al. (2001)
Helminthosporium sp.	Ad, Bs, Cd, Cn, Ss, Un	Theis (1953); Roure and Ramírez (1970); Betancourt et al. (1980); Acevedo (1987); Minter et al. (2001)

Heterosporium sp. = *Cladosporium* sp.		
Hirsutella saussurei (Cooke) Speare	Cn, Un	Wolcott (1948); Stevenson (1975); Minter et al. (2001)
Histoplasma sp.	Ad	Roure and Ramírez (1970)
Hormodendron sp. = *Hormodendrum* sp.		
Hormodendrum sp. = *Cladosporium* sp.		
Hortaea werneckii (Horta) Nishim. & Miyaji. = *Phaeoannellomyces werneckii*		
Humicola brevis (J.C. Gilman & E.V. Abbott) J.C. Gilman	Ss	Carvajal-Zamora (1971a, b)
Hyaloflorea sp. = *Cylindrocarpon* sp.		
Hyalopicnic sp. = *Hyalopycnis* sp.		
Hyalopycnis sp.	Bs	Hernández-Vera (1982); Hernández-Vera and Almodóvar (1983, 1984)
Khuskia oryzae H.J. Huds.	Bs, Cu, Hr, Ip, Sf, Un	Stevenson (1975); Lodge (1996a); Nieves-Rivera (2000b); Minter et al. (2001); Rodríguez et al. (2004); Nieves-Rivera (unpubl. data, Rincón Lagoon, Boquerón Wildlife Refuge)
Koorchaloma sp.	Sr	Nieves-Rivera (unpubl. data, Magueyes Island)
Lasiodiplodia theobromae (Pat.) Griffon & Maubl.	Ba, Ca, Cn, Hi, Tc	Francis and Lowe (2000); Minter et al. (2001)
Lemonniera pseudofloscula Dyko, in Descals, J. Webster & Dyko	Ll, Rf, Sf	Santos-Flores and Betancourt-López (1997); Minter et al. (2001); Nieves-Rivera and Santos-Flores (2004b)
Leprieurina radiata Toro	Ch	Stevenson (1975); Minter et al. (2001)
Macrophoma sp.	Av, Df, Rh	Acevedo (1987) Ortiz Rivera and Semidey Laracuente (2004);
Macrophomina sp.	Ec	Ortiz Rivera and Semidey Laracuente (2004);
Melanconium saccharinum Penz. & Sacc. = *Papularia vinosa*		
Microdochium nivale (Fr.) Samuels & I.C. Hallett = *Monographella nivalis*		

Microxyphium aciculiforme Cif., Bat. & Nascim.	Cn, Ll	Stevenson (1975); Minter et al. (2001)
M. atrocarpi Bat., Nascim. & Cif., in Bat. & Cif.	Cn, Ll	Stevenson (1975); Minter et al. (2001)
Monodyctis sp.	Ba, Cn, Cu, Ll, Un	Minter et al. (2001)
Mycovellosiella lantanae (Chupp) Deighton	Lc	Toro (1931); Chupp (1953); Wellman (1961); Stevenson (1975); Minter et al. (2001)
Myrothecium sp.	Ec	Ortiz Rivera and Semidey Laracuente (2004);
Nigrospora sphaerica (Sacc.) E.W. Mason	Cc, Ch, Cu, Ip, Un	Stevenson (1975); Minter et al. (2001); Rodríguez et al. (2004)
N. oryzae (Berk. & Broome) Petch = *Khuskia oryzae*		
Nigrospora sp.	Ad, Am, Ss	Roure and Ramírez (1970); Betancourt et al. (1980); Pérez Samot (1986); Minter et al et al. (2001)
Nodulisporium sp.	Ad, Lp, Ss	Betancourt et al. (1980); Lodge (1996a); Acevedo (2001); Minter et al et al. (2001)
Ochroconis humicola (G.L. Barron & L.V. Busch) de Hoog & Arx	Tm	Bunkley-Williams and Williams (per. comm., 2004)
Odiodendrum griseum Robak = *Oidiodendron griseum*		
Oidiodendron griseum Robak	Bs	Hernández-Vera (1982); Hernández-Vera and Almodóvar (1983, 1984)
Paecilomyces javanicus (K. Friedericks & Bally) A.H.S. Br. & G. Sm.	Ca	Stevenson (1975); Minter et al. (2001)
P. lilacinus (Thom) Samson	Ss, Tm	Bunkley-Williams et al. (1998); Rand et al. (2000); Minter et al. (2001); Bunkley-Williams and Williams (per. comm., 2004) Remarks.–Rand et al. (2000) reported it as the causative agent of tilapia-wasting disease in brackish and freshwater environments.
Paecilomyces sp.	Ss	Carvajal-Zamora (1971a, b); Williams and Bunkley-Williams (1996)

Papularia vinosa (Berk. & M.A. Curtis) E.W. Mason	Ba	Seaver and Chardón (1926); Stevenson (1975); Minter et al. (2001)
Papularia sp.	Am	Pérez Samot (1986)
Penicillium aculeatum Raper & Fennell	Ss	Carvajal-Zamora (1971a, b)
P. albicans Bainier	Bs	Hernández-Vera (1982); Hernández-Vera and Almodóvar (1983, 1984)
P. brevicompactum Dierckx	Bs, Ss	Hernández-Vera (1972, 1975); Minter et al. (2001)
P. canadense G. Sm.	Bs	Hernández-Vera (1982); Hernández-Vera and Almodóvar (1983, 1984)
P. canescens Sopp	Bs	Hernández-Vera (1982); Hernández-Vera and Almodóvar (1983, 1984)
P. chermesium Biourge	Bs	Hernández-Vera (1982); Hernández-Vera and Almodóvar (1983, 1984)
P. citrinum Thom	Bs, Ss	Carvajal-Zamora (1971a, b); Hernández-Vera (1972, 1975, 1982); Hernández-Vera and Almodóvar (1983, 1984); Lodge (1996a); Minter et al. (2001)
P. coeruleoviridae Biourge	Ss	Carvajal-Zamora (1971a, b)
P. corylophilum Dierckx	Bs, Ss	Hernández-Vera (1972, 1975, 1982); Hernández-Vera and Almodóvar (1983, 1984); Lodge (1996a); Minter et al. (2001)
P. digitatum (Pers.) Sacc.	Bs, Ss	Hernández-Vera (1972, 1975, 1982); Hernández-Vera and Almodóvar (1983, 1984); Minter et al. (2001)
P. duclauxii Delacr.	Bs	Hernández-Vera (1982); Hernández-Vera and Almodóvar (1983, 1984)
P. fellutanum Biourge	Bs, Ss	Hernández-Vera (1972, 1975, 1982); Hernández-Vera and Almodóvar (1983, 1984); Lodge (1996a); Minter et al. (2001)

P. frequentans Westling	Bs, Ss	Carvajal-Zamora (1971a, b); Hernández-Vera (1982); Hernández-Vera and Almodóvar (1983, 1984)
P. funiculosum Thom	Bs, Ss	Hernández-Vera (1972, 1975); Lodge (1996a); Minter et al. (2001)
P. godlewiskii K.M. Zalessky = *Penicillium jensenii*		
P. janczewskii K.M. Zalessky	Ss	Carvajal-Zamora (1971a, b); Stevenson (1975); Minter et al. (2001)
P. jensenii K.M. Zalessky	Ss	Carvajal-Zamora (1971a, b)
P. nigricans Bainier: Thom = *Penicillium janczewskii*		
P. ochro-chloron Biourge	Bs, Ss	Carvajal-Zamora (1971a, b); Hernández-Vera (1972, 1975); Minter et al. (2001)
P. oxalicum Currie & Thom	Bs, Ss	Hernández-Vera (1972, 1975); Minter et al. (2001)
P. paxilli Bainier	Bs, Ss	Carvajal-Zamora (1971a, b); Hernández-Vera (1972, 1975); Minter et al. (2001)
P. pulvillorum Turfitt = *Penicillium simplicissimum*		
P. roqueforti Thom	Ll	Lodge (1996a)
P. roqueforti Thom var. *carneum* Frisvad	Av, Rh	Nieves-Rivera (unpubl. data, on intertidal *A. germinans* and *R. mangle* wood and leaves, Magueyes Island and Boquerón Wildlife Refuge)
P. sclerotiorum T.H. Beyma	Bs, Ss	Carvajal-Zamora (1971a, b); Hernández-Vera (1972, 1975); Lodge (1996a); Minter et al. (2001)
P. simplicissimum (Oudem.) Thom	Bs, Ss	Hernández-Vera (1972, 1975); Minter et al. (2001)
P. spinulosum Thom	Ll, Rh	Nieves-Rivera (unpubl. data, on intertidal *R. mangle* wood and leaves, Magueyes Island)
P. steckii K.M. Zalessky = *Penicillium citrinum*		
P. waksmani K.M. Zalessky	Bs	Hernández-Vera (1982); Hernández-Vera and Almodóvar (1983, 1984)
Penicillium sp.	Ad, Am, Bs, Ch, Cn, Cu, Ga, Hp, Hr, Ip, Lh, Ll, Ma, Ms, Ss, Td, Te, Tm, Tu, Un	

		Roure and Ramírez (1970); Betancourt et al. (1980); Pérez Samot (1986); Acevedo (1987, 2001); Cantrell (1991); Cantrell and Betancourt (1992); Vargas et al. (1998); Nieves-Rivera (2000b); Minter et al. (2001); Sánchez and Santos (2004); Silva et al. (2004); Ortiz et al. (2004); Rodríguez et al. (2004); Ruiz-Suárez, (2004)
Periconia byssoides Pers.	Cn, Hi, Ll, Un	Stevenson (1975); Minter et al. (2001)
Periconia prolifica Anastasiou = *Halosphaeria cucullata*		
Periconia sp.	Hi, Hp	Minter et al. (2001); Silva et al. (2004); Ortiz et al. (2004)
Pestalotia adusta Ellis & Everh.	Ch	Guba (1961); Stevenson (1975); Minter et al. (2001)
P. coccolobae Ellis & Everh. = *Pestalotiopsis versicolor*		
P. disseminata Thüm. = *Pestalotiopsis disseminata*		
P. gibberosa Sacc.	Cn	Guba (1961); Stevenson (1975); Minter et al. (2001)
P. palmarum Cooke = *Pestalotiopsis palmarum*		
P. pezizoides de Not.	Bs	Hernández-Vera (1982); Hernández-Vera and Almodóvar (1983, 1984)
Pestalotia sp.	Ad, Am, Bs, Bt, Cn, Cu, Ps, Rh, Ss, Td	Carvajal-Zamora (1971a, b); Hernández-Vera (1972, 1975); Betancourt et al. (1980); Pérez Samot (1986); Lodge (1996a); Acevedo (2001); Minter et al. (2001); Sánchez and Santos (2004); Nieves-Rivera (unpubl. data, on *Cocos nucifera* L., *Pseudophoenix sargentii* H. Wendland, and *Thrinax morrisii* H. Wendland, Mona Island)
Pestalotiopsis disseminata (Thüm.) Steyaert	Av, Bs, Ll, Rh, Sf, Tc	Stevenson (1975); Calzada (1999); Minter et al. (2001); Nieves-Rivera (unpubl. data, on *R. mangle*

		leaves, Magueyes Island, La Parguera Channels, Los Morrillos, and Boquerón Wildlife Refuge; Figures 17A-B) Remarks.–This species is common on *R. mangle* leaves after wet chamber.
P. palmarum (Cooke) Steyaert	Cn, Ps	Stevens (1917); Weiss (1950); Guba (1961); Stevenson (1975); Francis and Lowe (2000); Minter et al. (2001)
P. versicolor (Speg.) Steyaert	Cn, Cu	Stevens (1917); Guba (1961); Stevenson (1975); Lodge (1996a); Francis and Lowe (2000); Minter et al. (2001)
Pestalotiopsis sp.	Ch, Cu, Ip	Rodríguez et al. (2004)
Peyronellaea sp. = *Phoma* sp.		
Phaeoannellomyces werneckii (Horta) McGinnis & Schell	Bs, Hp, Ss, Tm	Hernández-Vera (1982); Hernández-Vera and Almodóvar (1983, 1984); Lodge (1996a); Silva et al. (2004); Ortiz et al. (2004); Bunkley-Williams and Williams (per. comm., 2004)
Phialophorophoma litoralis Linder	Df, La, Rh	Acevedo (1987)
Phoma eupyrena Sacc.	Rh	Calzada (1999)
P. humicola J.C. Gilman & E.V. Abbott	Bs	Hernández-Vera (1982); Hernández-Vera and Almodóvar (1983, 1984)
Phoma sp.	Ad, Am, Av, Df, Ll, Ls, Ma, Rh, Ss	Roure and Ramírez (1970); Kohlmeyer (1980); Betancourt et al. (1980); Pérez Samot (1986); Acevedo (1987); Cantrell (1991); Cantrell and Betancourt (1992); Lodge (1996a); Minter et al. (2001)
Phomopsis cocöes Petch	Cn	Stevenson (1975); Minter et al. (2001)

Phyllosticta bonduc F. Stevens	Cb	Stevens (1917); Seaver and Chardón (1926); Stevenson (1975); Poonyth et al. (2000); Minter et al. (2001); Schmit and Shearer (2003); Schmit (2004)
P. *coccolobae* Ellis & Everh., in A.S. Hitchcok	Cu	Young (1915); Seaver and Chardón (1926); Stevenson (1975); Francis and Lowe (2000); Minter et al. (2001)
P. *lantanicola* Sacc.	Lc, Lv	Stevens (1917); Wellman (1961); Stevenson (1975); Minter et al. (2001)
Pithomyces sp.	Ad	Betancourt et al. (1980)
Podoxyphium ampullaceum Bat. & H. Maia, in Bat. & Cif.	Cn, Hi, Ll	Stevenson (1975); Minter et al. (2001)
Pseudocercospora abelmoschi (Ellis & Everh.) Deighton	Hi	Young (1916); Seaver and Chardón (1926); Kohlmeyer (1969); Stevenson (1975); Minter et al. (2001)
Pyricularia grisea (Cooke) Sacc.	Se	Theis (1953); Stevenson (1975); Minter et al. (2001)
Rhodotorula glutinis (Fresen.) F.C. Harrison	Bs	Hernández-Vera (1982); Hernández-Vera and Almodóvar (1983, 1984); Minter et al. (2001)
Rhodotorula sp.	Bs, Ss	Hernández-Vera (1972, 1975); Lodge (1996a); Minter et al. (2001)
Rhynchosporium sp.	Ad	Betancourt et al. (1980)
Sclerotium portoricense F. Stevens	Cd	Stevens (1917); Stevenson (1975); Minter et al. (2001)
Scolecobasidium humicola G.L. Barron & L.V. Busch = *Ochroconis humicola*		
Scopulariopsis brevicaulis (Sacc.) Bainier	Bs	Hernández-Vera (1982); Hernández-Vera and Almodóvar (1983, 1984); Minter et al. (2001)
Scopulariopsis sp.	Bs, Ss	Carvajal-Zamora (1971a, b); Acevedo (1987)
Seimatosporium sp.	Ad	Betancourt et al. (1980)

Septoidium sp.	Ad	Roure and Ramírez (1970)
Septoria fici-indicae Voglino	Od	Stevens (1917); Stevenson (1975); Minter et al. (2001)
S. lantanae Garman	Lc	Garman (1915); Wellman (1961); Stevenson (1975); Minter et al. (2001)
Spegazzinia tessarthra (Berk. & M.A. Curtis) Sacc.	Ba, Bs, Ss	Hernández-Vera (1972, 1975); Stevenson (1975); Minter et al. (2001)
Sphaeropsis subglobosa Cooke, in Sacc.	Ba	Stevenson (1975); Minter et al. (2001)
Sphaeropsis sp.	Am, Ba, Bs, Ss	Hernández-Vera (1972, 1975); Stevenson (1975); Pérez Samot (1986); Minter et al. (2001)
Spicaria javanica K. Friedericks & Bally = *Paecilomyces javanicus*		
Sporotrichum schenckii Matr. = *Beauveria brogniartii*		
S. schenckii Matr. var. *fioccoi* C.W. Dodge = *Beauveria brogniartii*		
Sporotrichum sp.	Ad	Roure and Ramírez (1970)
Stachybotrys sp.	Ad	Roure and Ramírez (1970)
Stemphylium botryosum Wallr.	Bs, Rh, Sf, Ss	Hernández-Vera (1972, 1975); Minter et al. (2001)
**S.* cf. *gracilariae* E.G. Simmons	Rh, Sf	Nieves-Rivera (unpubl. data, Rincón Lagoon, Boquerón Wildlife Refuge)
Stemphylium sp.	Ad	Roure and Ramírez (1970)
Tetraploa aristata Berk. & Broome	Bs, Cn, Ll, Sf, Un	Stevenson (1975); Santos-Flores and Betancourt-López (1997); Minter et al. (2001); Nieves-Rivera (unpubl. data, Rincón Lagoon, Boquerón Wildlife Refuge)
Tetraploa sp.	Td	Sánchez and Santos (2004)
Thermomyces sp.	Bs, Ss	Hernández-Vera (1972, 1975); Minter et al. (2001)
Thielaviopsis paradoxa (De Seynes) Höhn. = *Ceratocystis paradoxa*		
Torula sp.	Ad, Cn, Un	Roure and Ramírez (1970); Betancourt et al. (1980); Minter et al. (2001)
Torulopsis glabrata (H.W. Anderson) Lodder & N.F. deVries = *Candida glabrata*		

Trichoderma album Preuss	Bs	Hernández-Vera (1982); Hernández-Vera and Almodóvar (1983, 1984)
T. glaucum E.V. Abbott	Bs	Hernández-Vera (1982); Hernández-Vera and Almodóvar (1983, 1984)
T. harzianum Rifai	Ss	Carvajal-Zamora (1971a, b)
T. koningii Oudem., in Oudem. & C.J. Koning	Bs, Ss	Carvajal-Zamora (1971a, b); Hernández-Vera (1982); Hernández-Vera and Almodóvar (1983, 1984); Lodge (1996a); Minter et al. (2001)
T. lignorum (Tode) Harz = *Trichoderma viride*		
T. longibranchiatum Rifai	Ss	Carvajal-Zamora (1971a, b)
T. viride Pers.	Bs, Ss	Hernández-Vera (1972, 1975, 1982); Hernández-Vera and Almodóvar (1983, 1984); Lodge (1996a); Minter et al. (2001)
Trichoderma sp.	Ad, Am, Bs, Hr, Ma, Ss, Un	Roure and Ramírez (1970); Betancourt et al. (1980); Pérez Samot (1986); Acevedo (1987); Cantrell (1991); Cantrell and Betancourt (1992); Nieves-Rivera (2000b); Minter et al. (2001)
Trichophyton rubrum (Castell.) Sabour.	Bs, Ss, Un	Hernández-Vera (1982); Hernández-Vera and Almodóvar (1983, 1984); Minter et al. (2001)
T. cf. *mentagrophytes* (C.P. Robin) Sabour. in Saccardo	Hr, Ss, Un	Carrión (1930, 1935); Kesten et al. (1932); Carrión and Silva (1944a, b); Stevenson (1975); Nieves-Rivera (2000b); Minter et al. (2001)
Trichosporium cutaneum (Küchenm. & Rabenh.) Vuill. = *Trichosporon cutaneum*		
T. pullulans (Lindner) Diddens & Lodder = *Trichosporon pullulans*		
Trichosporon cutaneum (Beurm., Gougerot & Vaucher) N. Ota	Bs, Ss	Hernández-Vera (1982); Hernández-Vera and Almodóvar (1983, 1984); Minter et al. (2001)

T. pullulans (Lindner) Diddens & Lodder	Bs	Hernández-Vera (1982); Hernández-Vera and Almodóvar (1983, 1984)
Trichosporon sp.	Ad	Roure and Ramírez (1970)
**Trimmatostroma* sp.	Av, Ba, La, Un	Nieves-Rivera (unpubl. data, on living leaves of *A. germinans* and *L. racemosa*, Piñones Commonwealth Forest at northern Puerto Rico, and from Boquerón Commonwealth Forest, Los Morrillos, Magueyes Island, and La Parguera Channels at southwestern Puerto Rico) Remarks.–Dematiaceous mycelium on living leaves of *A. germinans*, deposited with the U.S. National Fungus Collection by ÁMNR, 7 March 2002, BPI 863548.
Tripospermum roupalae (Syd.) S. Hughes	Cn, Un	Stevenson (1975); Minter et al. (2001)
Triscelophorus acuminatus Nawawi	Bs, Rf, Sf	Santos-Flores & Betancourt-López (1997); Minter et al. (2001); Nieves-Rivera and Santos-Flores (2004b)
Triscelophorus sp.	Sf	Nieves-Rivera and Santos-Flores (2004b)
Tubercularia pulvurulenta Speg.	Rh	Acevedo (1987)
Tubeufia cylindrothecia (Seaver) Höhn.	Bs, Rf, Sf	Toro (1924); Santos-Flores & Betancourt-López (1997, reported as *Helicomyces* cf. *roseus* Link); Minter et al. (2001); Nieves-Rivera and Santos-Flores (2004b)
Valsa chlorina Pat.	Cn	Stevenson (1975); Minter et al. (2001)
Vertcicladium effusum Earle	Cu	Francis and Lowe (2000)
Verticillium lateritium Berk. = *Nectria inventa*		
V. lateritium (Ehrenb.) Rabenh. = *Nectria inventa*		

V. lecanii (Zimm.) Viégas	Bs, Cn, Ss	Stevenson (1975); Hernández-Vera (1982); Hernández-Vera and Almodóvar (1983, 1984); Minter et al. (2001)
Verticillium sp.	Cu, Dd, Go, Ss, Th, Un	Acevedo (2001); Minter et al. (2001)
Zalerion maritimum (Linder) Anastasiou	Bs, Rh, Th, Wd	Schmit and Shearer (2003); Nieves-Rivera (unpubl. data, Rincón Lagoon, Boquerón Wildlife Refuge)
Mycelia Sterilia (Agonomycetales)	Ad, Bs, Ch, Cu, Hp, Ip, Lm, Ma, Ms, Te, Tm, Tu	Betancourt et al. (1980); Acevedo (1987); Cantrell (1991); Cantrell and Betancourt (1992); Vargas et al. (1998); Silva et al. (2004); Ortiz et al. (2004); Rodríguez et al. (2004); Nieves-Rivera (unpubl. data, Rincón Lagoon, Boquerón Wildlife Refuge, Boquerón Commonwealth Forest, Los Morrillos, Magueyes Island, and La Parguera Channels at southwestern Puerto Rico)
Unknown sp. 1	Df, Sf	Nieves-Rivera and Santos-Flores (2004b)
Unknown sp. 2	Ll, Sf	Nieves-Rivera and Santos-Flores (2004b)
Unknown sp. 3	Sf	Nieves-Rivera and Santos-Flores (2004b)
Unknown sp. 4	Df, Sf	Nieves-Rivera and Santos-Flores (2004b)
BASIDIOMYCOTA		
Acanthosphysium mirabile (Berk. & M.A. Curtis) Parmasto	Un	Lodge et al. (2000); Minter et al. (2001)
Agaricus johnstonii Murrill	Ba, Cn, Ll, Ss, Un	Stevenson (1975); Nieves-Rivera (1996); Nieves-Rivera et al. (1999); Minter et al. (2001)
Alboleptonia sp.	Ss, Un	Lodge et al. (2000); Minter et al. (2001)
Aleurodiscus mirabilis (Berk. & M.A. Curtis) Höhn. = *Acanthosphysium mirabile*		
Amanita cf./aff. *ingrata* Pegler	Ss	Guzmán (1986); Nieves-Rivera (unpubl. data, Mona Island)

		Remarks.–Misidentified as *Tricholomopsis* aff. *humboldtii* Singer, Ovrebo & Halling by Nieves-Rivera et al. (1999)
Amanita sp.	Bs, Cu, Ll, Ss	Nieves-Rivera et al. (1999); Minter et al. (2001)
Athelia rolfsii (Curzi) C.C. Tu & Kimbr.	Ba	Stevenson (1975); Minter et al. (2001)
Auricularia cornea Ehrenb., in Nees	Tp, Un	Lowy (1952, 1971); Lodge (1996a); Lodge et al. (2000); Minter et al. (2001); Nieves-Rivera (unpubl. data, Magueyes Island and La Parguera Channels)
A. delicata (Fr.) Henn.	Un	Lowy (1952, 1971); Nieves-Rivera et al. (1998); Minter et al. (2001)
A. polytricha (Mont.) Sacc. = *Auricularia cornea*		
Battarrea stevenii (Libosch.) Fr.	Ss	Nieves-Rivera et al. (1998); Minter et al. (2001)
B. phalloides (Dicks.) Pers. = *Battarrea stevenii*		
Boletus earlei (Murrill) Overh., in Seaver & Chardón	Bs, Ss	Murrill (1921); Seaver (1925); Seaver & Chardón (1926); Fitzpatrick (1927); Stevenson (1975); Minter et al. (2001)
Boletus section *Luridi*	Ss	Nieves-Rivera et al. (1999)
Boletus sp.	Bs, Cu, Ss	Minter et al. (2001)
Calvatia cyathiformis (Bosc.) Morgan	Ss	Nieves-Rivera et al. (1998); Minter et al. (2001)
Cantharellus cinnabarinus Schwein.	Cu, Ss	Murrill (1910); Pegler (1983); Minter et al. (2001)
Ceriporia xylostromatoides (Berk.) Ryvarden	Ca, Un	Lowe (1966); Stevenson (1975); Ryvarden (1985); Nieves-Rivera (1996); Nieves-Rivera et al. (1998, 1999); Minter et al. (2001)
Chlorophyllum molybdites (G. Mey.: Fr.) Massee	Bs, Ss	Guzmán (1986); Minter et al. (2001); Nieves-Rivera (unpubl. data, Caño Corazones, Mayagüez)
Clathrus baumii (Henn.) E. Fisch.	Ss, Un	Lodge (1996a); Minter et al. (2001) Remarks.–This species have a lilac volva (Lodge, 1996a).

C. crispus Turpin	Cn, Cu, Rh, Ss	Dennis (1953); Dring (1980); Nieves-Rivera et al. (1999); Minter et al. (2001) Lodge (1996a); Maldonado-Ramírez and Torres-Pratts (in press)
Coleosporium ipomoeae (Schwein.) Burrill	Is	Arthur (1915(b), 1917, 1924); Stevens (1917); Roure (1962, 1963); Stevenson (1975); Minter et al. (2001)
Collybia sp.	Cn, Ss, Tp	Nieves-Rivera et al. (1999); Minter et al. (2001); Nieves-Rivera (unpubl. data, Magueyes Island, southwestern Puerto Rico) Remarks.–White mycelium on decaying leaves of *Thespesia populnea*, deposited with the U.S. National Fungus Collection by ÁMNR, 17 March 2004, BPI 863547.
Copelandia cyanescens (Berk. & Broome) Singer	Dg, Ss, Un	Guzmán (1986); Navarro and Betancourt (1992)
Coprinus cf./aff. *ephemerus* (Bull.: Fr.) Fr.	Ca, Ss, Un	Nieves-Rivera (1996); Nieves-Rivera et al. (1999); Minter et al. (2001)
C. cf. *jamaicensis* Murrill (*s. str.* Dennis (1970))	Un	Nieves-Rivera et al. (1999); Minter et al. (2001)
C. cf. *plicatilis* (M.A. Curtis: Fr.) Fr.	Ss	Bor de Garrido (1969); Stevenson (1975); Nieves-Rivera (1996); Nieves-Rivera et al. (1998, 1999); Minter et al. (2001)

Coprinus sp.	Ba, Cn, Ll, Sb, Un	Pegler (1983); Dennis (1970); Minter et al. (2001)
Coriolopsis flocossa (Jungh.) Ryvarden	Ca, Hm, Rh	Ryvarden (1984); Minter et al. (2001); Nieves-Rivera et al. (2004)
C. fulvocinera Murrill = *Datronia caperata*		
Coriolopsis sp.	La	Minter et al. (2001)
Corticium debile Berk. & M.A. Curtis: Massee	Un	Burt (1925); Stevenson (1975); Nieves-Rivera (1996); Nieves-Rivera et al. (1999); Minter et al. (2001)
Crepidotus uber (Berk. & M.A. Curtis) Sacc.	Rh	Nieves-Rivera et al. (2004)
Crinipellis septotricha Singer	Ca, Cn, Cu, Un	Pegler (1983); Nieves-Rivera (1996); Nieves-Rivera et al. (1999); Minter et al. (2001)
Crinipellis sp.	Ca, Ll, Un	Lodge (1996a); Minter et al. (2001); Nieves-Rivera (unpubl. data, Magueyes Island)
Cyathus striatus (Huds.) Pers.	Cn, Ss, Un	Stevenson (1975); Nieves-Rivera et al. (1998); Minter et al. (2001)
Cyathus sp.	Tc, Un	Minter et al. (2001)
Dacryopinax spathularia (Schwein.) G.W. Martin	Ca, Cn, Rh, Un	Bresadola et al. (1893); Heller (1900); Britton (1915); Stevens (1917); Lowy (1971); Stevenson (1975); Nieves-Rivera (1996); Nieves-Rivera et al. (1998, 1999, 2004); Minter et al. (2001)
Datronia caperata (Berk.) Ryvarden	Ca, Rh, Un	Murrill (1915); Seaver (1925); Fitzpatrick (1927); Stevenson (1975); Minter et al. (2001)
Earliella scabrosa (Pers.) Gilb. & Ryvarden	Cn, Pt, Tc, Un	Ryvarden (1985); Stevenson (1975); Minter et al. (2001)
Flammula earlei Murrill	Cn	Stevenson (1975); Minter et al. (2001)
Fomes lividus (Kalchbr.) Sacc. = *Perenniporia tephroporia*		
Fomitopsis nivosa (Berk.) Gilb. & Ryvarden	Cn	Seaver & Chardón (1926); Lowe (1975); Stevenson (1975); Lodge (1996a); Minter et al. (2001)
Ganoderma australe (Fr.) Pat.	Ba, Cn, Un	Minter et al. (2001)

G. lucidum (Curtis) P. Karst.	Un	Stevenson (1975); Ryvarden (1985); Nieves-Rivera et al. (1998); Minter et al. (2001)
G. resinaceum Pat.	Cn, Hm, Un	Phelps and Landgraf (1972); Stevenson (1975); Ryvarden (1985); Minter et al. (2001)
G. zonatum Murrill	Ci	Stevenson (1975); Minter et al. (2001)
Gloeophyllum striatum (Sw.: Fr.) Murrill	Ca, Rh	Britton (1915); Murrill (1915); Stevenson (1975); Nieves-Rivera et al. (1998, 1999, 2004); Minter et al. (2001)
Gymnopilus sp.	Ba, Ca, Cn, Un	Lodge (1996a); Nieves-Rivera (1996); Nieves-Rivera et al. (1999); Minter et al. (2001)
Heterochaete sp.	Un	Minter et al. (2001); Nieves-Rivera et al. (1999)
Hexagonia hydnoides (Sw.: Fr.) M. Fidalgo	Ca, Cm, Cu, Hm, Rh, Un	Britton (1915); Stevenson (1975); Ryvarden (1984); Lodge (1996a); Nieves-Rivera (1996); Nieves-Rivera et al. (1998, 1999, 2004); Minter et al. (2001)
Hygrocybe acutoconica (Clem.) Singer = *Hygrocybe persistens*		
H. persistens (Britzelm.) Britzelm.	Bs, Cu, Ss	Cantrell and Lodge (2000); Minter et al. (2001)
Hymenochaete sp.	Cu	Minter et al. (2001)
Hymenogaster sp. (?)	Cn, Cu, Ss	Nieves-Rivera (1996); Nieves-Rivera et al. (1999)
Inonotus porrectus Murrill	La	Stevenson (1975); Minter et al. (2001)
Kuehneola malvicola Arthur	Pa	Seaver and Chardón (1926); Roure (1962, 1963); Minter et al. (2001)
Lachnella candida (Pers.) G. Cunn.	Ba	Stevenson (1975); Minter et al. (2001)
Lactarius coccolobea O.K. Miller & Lodge	Bs, Ss	Lodge et al. (2000); Miller et al. (2000)
Lactocollybia sp. (*L*. cf. *angiospermarum* Singer)	Cn, Ss, Tp, Un	Lodge et al. (2000); Minter et al. (2001); Nieves-Rivera et al. (1999); Nieves-Rivera (unpubl. data, Magueyes Island and La Parguera Channels)

Laetiporus persicinus (Berk & M.A. Curtis) Gilb.	Un	Lodge (1996a); Minter et al. (2001); Nieves-Rivera (unpubl. data, Magueyes Island)
Lentinus bertieri (Fr.) Fr.	Cn, Un	Pegler (1983); Minter et al. (2001)
Lentinus crinitus (L.: Fr.) Fr. = *Panus crinitus*		
Lenzites elegans (Spreng.: Fr.) Pat.	Ca, Cn, Rh, Un	Bresadola et al. (1893); Britton (1915); Stevenson (1975); Ryvarden (1984, 1985); Lodge (1996a); Nieves-Rivera (1996); Nieves-Rivera et al. (1998, 1999)
Lepiota sp.	Ba, Cu, Hi, Ll, Ss	Lodge (1996a); Nieves-Rivera et al. (1999); Minter et al. (2001)
Leucoagaricus hortensis (Murrill) Pegler	Ss, Un	Nieves-Rivera et al. (1998); Minter et al. (2001)
Leucocoprinus birnbaumii (Corda) Singer	Cn, Ll, Un	Bor de Garrido (1969); Stevenson (1975); Guzmán (1986); Lodge (1996a); Nieves-Rivera (1996); Nieves-Rivera et al. (1999); Minter et al. (2001)
Marasmiellus coilobasis (Berk.) Singer	Cn, Un	Pegler (1983); Minter et al. (2001)
M. semiustus Berk. & M.A. Curtis = *Marasmiellus semiustus*		
M. cf. *semiustus* (Berk. & M.A. Curtis) Singer	Ca, Cn, Un	Lodge (1996a); Nieves-Rivera et al. (1999); Minter et al. (2001) Remarks.—Lodge (1996a) reported *Marasmiellus semiustus* (Berk. & M.A. Curtis) Singer var. *sabali* Singer on palm.
Marasmiellus sp.	Ca, Cn, Ll, Pt, Ss	Minter et al. (2001)
Marasmius haematocephalus Mont.	Cn, Cu, Ll, Un	Dennis (1970); Pegler (1983); Minter et al. (2001)
M. pallescens Murrill	Cn, Un	Murrill (1915); Stevenson (1975); Nieves-Rivera et al. 1998; Minter et al. (2001)
M. sacchari Wakker	Cn, Un	Stevenson (1975); Minter et al. (2001)
Morganella fuliginea (Berk. & M.A. Curtis) Kriesel & Dring	Cn, Ll, Un	Guzmán (1986); Stevenson (1975); Minter et al. (2001)

Panaeolus antillarum (Fr.) Dennis	Dg, Ss, Un	Stevenson (1975); Guzmán (1986); Navarro and Betancourt (1992); Nieves-Rivera et al. (1998); Minter et al. (2001)
P. cyanescens Berk. & Broome = *Copelandia cyanescens*		
P. sphinctrinus (Fr.) Quél.	Dg, Ss, Un	Bor de Garrido (1969); Navarro and Betancourt (1992)
Panus crinitus (L.) Singer	Ca, Rh	Bresadola et al. (1893); Britton (1915); Bor de Garrido (1969); Stevenson (1975); Guzmán (1986); Lodge (1996a); Nieves-Rivera (1996); Nieves-Rivera et al. (1999, 2004); Minter et al. (2001) Remarks.—Lodge (1996a) reported this species as *Lentinus swartzii* Berk. (= *Lentinus crinitis* (L.: Fr.) Fr. sensu Berk.). Basidiocarps deposited with the U.S. National Fungus Collection by ÁMNR, 8 May 2002, BPI 863546.
Perenniporia tenuis var. *tenuis* (Schwein.) Ryvarden	Ca	Stevenson (1975); Minter et al. (2001) Remarks.– The name *Polyporus tenuis* Sacc. is *nomen illegitimum* and so *P. tenuis* Klotzsch. The taxonomic concept behind Saccardo's name is unclear (L. Ryvarden, pers. comm., 2004).
P. tephroporia (Mont.) Ryvarden	Ca, Cn	Stevenson (1975); Minter et al. (2001)
Phanaerochaete crassa (Lév.) Burdsall	Un	Burt (1920); Welden (1975); Stevenson (1975); Pegler (1983); Nieves-Rivera (1996); Nieves-Rivera et al. (1999)
Phellinus dependens (Murrill) Ryvarden	Ca, Un	Britton (1915); Lowe (1957); Stevenson (1975); Ryvarden (1985); Nieves-Rivera (1996); Nieves-Rivera et al. (1998, 1999); Minter et al. (2001)
P. gilvus (Schwein.) Pat.	Ba, Ca, Cn, Cu, Tc, Un	

		Stevenson (1975); Guzmán (1986); Ryvarden (1990); Minter et al. (2001)
P. merrillii (Murrill) Ryvarden	Rh	Nieves-Rivera et al. (2004)
P. rimosus (Berk.) Pilát	Hm	Ryvarden (1985); Minter et al. (2001)
Phellinus sp.	Ba, Co, Cu, La, Ll, Rh, Un	Minter et al. (2001)
Phlebia spp.	Rh, Ss	Minter et al. (2001); Nieves-Rivera et al. (2004; Figures 18A–B);
Phlebopus beniensis (Singer & Digilio) Heinem. & Rammeloo	Ss, Un	Lodge et al. (1998)
Phylloporia chrysites (Berk.) Ryvarden	Ca, Un	Britton (1915); Murrill (1915); Stevenson (1975); Ryvarden (1985); Lodge et al. (2000); Nieves-Rivera (1996); Nieves-Rivera et al. (1998, 1999); Minter et al. (2001)
P. frutica (Berk. & M.A. Curtis) Ryvarden	Ca, Un	Britton (1915); Murrill (1915); Stevenson (1975); Ryvarden (1984); Nieves-Rivera (1996); Nieves-Rivera et al. (1999); Minter et al. (2001)
Pleurotus djamor (Fr.) Boedijn	Ba, Ca, Cn, Cu, Rh, Sb	Guzmán et al. (1993); Lodge (1996a); Ortiz Santana (1997); Nieves-Rivera et al. (1998, 1999); Minter et al. (2001)
P. eugrammus (Mont.) Dennis	Cn, Un	Stevenson (1975); Pegler (1983); Guzmán (1986); Minter et al. (2001)
P. flabellatus Berk. & Broome	Cn, Un	Pegler (1983); Minter et al. (2001)
Pleurotus sp.	Rh	Minter et al. (2001)
Pluteus sp.	Cn, Hi, Ss	Nieves-Rivera et al. (1999); Minter et al. (2001)
Polyporus fulvocinereus (Murrill) Overh., in Seaver & Chardón = *Datronia caperata*		
Polyporus gilvus (Schwein.) Fr. = *Phellinus. gilvus*		
Polyporus lignosus Klotzsch in Fr. = *Rigidoporus microporus*		

P. nivosellus (Murrill) Sacc. & Trotter = *Fomitopsis nivosa*		
P. porrectus (Murrill) Sacc. & Trotter = *Inonotus porrectus*		
P. tricholoma Mont.	Un	Heller (1900); Stevenson (1975); Ryvarden (1984, 1985); Guzmán (1986); Lodge (1996a) ; Nieves-Rivera (1996); Nieves-Rivera et al. (1999); Minter et al. (2001)
P. zonalis Berk. = *Rigidoporus lineatus*		
Polyporus sp.	Cn, Ll, Ss, Un	Ryvarden (1984); Minter et al. (2001)
Prospodium tuberculatum (Speg.) Arthur	Lc, Lv	Arthur (1925); Kern and Whetzel (1926); Stevenson (1975); Minter et al. (2001)
Psathyrella spp.	Ss, Ll, Rh, Un	Lodge (1996a); Nieves-Rivera (1996); Nieves-Rivera et al. (1999, 2004); Minter et al. (2001)
Psilocybe cubensis (Earle) Singer	Dg, Ss, Un	Seaver and Chardón (1926); Stevenson (1975); Guzmán (1986); Navarro and Betancourt (1992); Minter et al. (2001); Guzmán et al. (2003)
P. subcubensis Guzmán	Dg, Ss, Un	Navarro and Betancourt (1992); Guzmán et al. (2003)
Puccinia cenchri Dietel & Holw., in Holw.	Cc, Ct	Arthur (1915b, 1916, 1917); Theis (1953); Roure (1962, 1963); Stevenson (1975); Minter et al. (2001)
P. cynodontis Lacroix, in Desm.	Cd	Arthur (1916, 1917); Theis (1953); Stevenson (1975); Minter et al. (2001)
P. heterospora Berk. & M.A. Curtis, in Berk.	Pa	Seaver and Chardón (1926); Roure (1962, 1963); Minter et al. (2001, reported on a leaf of the swamp mallow *Pavonia paludicola* D.H. Nicols.: Fryxell (= *Pavonia scabra* K. Presl. (Malvaceae)
P. lantanae Farl.	Lc, Le, Ls, Lv	Arthur (1915c, 1917); Kern (1932); Roure (1962, 1963); Stevenson (1975); Minter et al. (2001)
P. stenotaphricola J. Walker	Se	Stevenson (1975); Minter et al. (2001)

Pycnoporus sanguineus (L.: Fr.) Murrill	Ca, Cn, Rh, Un	Bresadola et al. (1893); Britton (1915); Dennis (1970); Stevenson (1975); Guzmán (1986); Lodge (1996a); Nieves-Rivera (1996); Nieves-Rivera et al. (1998, 1999, 2004); Minter et al. (2001)
Rigidoporus lineatus (Pers.) Ryvarden	Ba, Ca, Cn, Un	Stevenson (1975); Ryvarden (1984, 1988); Lodge (1996a); Minter et al. (2001)
R. microporus (Sw.) Overeem	Ca, Cn, Un	Stevenson (1975); Ryvarden (1984); Lodge (1996a); Minter et al. (2001)
Rigidoporus sp.	Cn, Ss, Un	Minter et al. (2001)
Russula cremeolilacina var. *coccolobicola* Pegler, in Pegler & Singer	Cu, Ss	Lodge et al. (2000, at Piñones Commonwealth Forest near Loíza); Minter et al. (2001)
R. littoralis Pegler = *Russula littoralis*		
R. littoralis Romagn., Chevassut & Privat, in Romagn.	Bs, Cu, Ss	Lodge (1996a); Nieves-Rivera (1996); Nieves-Rivera et al. (1999); Miller et al. (2000); Minter et al. (2001)
Russula sp.	Bs, Cu, Ss	Lodge (1996a); Minter et al. (2001)
Schizophyllum commune Fr.: Fr.	Ac, Av, Ba, Cn, La, Rh, Un	Bresadola et al. (1893); Britton (1915); Cooke (1961); Bor de Garrido (1969); Pegler (1983); Guzmán (1986); Dennis (1970); Stevenson (1975); Lodge (1996a); Nieves-Rivera (1996); Nieves-Rivera et al. (1998, 1999, 2004); Minter et al. (2001)
Sclerangium bermudense (Coker) D.A. Reid	Bs, Cu, Ss	Guzmán (1970, 1986); Reid (1977); Nieves-Rivera (1996); Nieves-Rivera et al. (1999); Minter et al. (2001)
S. bermudense (Coker) D.A. Reid var. *trinitense* Reid	Bs, Ss	Reid (1977)

Scleroderma stellatum Berk.	Bs, Cu, Ss	Guzmán (1970, 1986); Reid (1977); Nieves-Rivera (1996); Nieves-Rivera et al. (1999); Minter et al. (2001)
Sclerotium rolfsii Sacc. = *Athelia rolfsii*		
Solenia candida Pers.: Fr. = *Lachnella candida*		
Sphaerobolus stellatus Tode: Pers.	Ba, Un	Stevenson (1975); Minter et al. (2001)
Sporisorium cenchri (Lagerh.) Vánky	Cc	Stevenson (1975); Minter et al. (2001)
Thellephora sp.	Bs, Cu, Ll, Ss, Un	Minter et al. (2001)
Trametes corrugata (Pers.) Bres. = *Earliella scabrosa*		
T. cubensis (Mont.) Sacc.	Cn, Un	Stevenson (1975); Minter et al. (2001)
T. elegans (Spreng.: Fr.) Fr.). = *Lenzites elegans*		
T. maxima (Mont.) A. David & Racjchenb.	Ch	Fitzpatrick (1927); Stevenson (1975); Minter et al. (2001)
T. nivosella Murrill = *Fomitopsis nivosa*		
T. villosa (Fr.) Kriesel	Co	Stevenson (1975); Minter et al. (2001)
Tremellostereum dichroum (Lloyd) Ryvarden	Cu, Ss, Un	Minter et al. (2001)
Trogia cantarelloides (Mont.) Singer	Un	Pegler (1983); Nieves-Rivera (1996); Nieves-Rivera et al. (1999); Minter et al. (2001)
Tulostoma berkeleyi Lloyd	Ss	Stevenson (1975); Minter et al. (2001)
T. exasperatum Mont.	Ss	Stevenson (1975); Minter et al. (2001)
T. cf. *meridionale* J.E. Wright	Ss	Nieves-Rivera et al. (1998)
T. portorricense J.E. Wright	Bs	Wright (1987); Minter et al. (2001)
T. volvulatum I.G. Borshch., in Sorokĭn	Ss	Stevenson (1975); Minter et al. (2001)
Tyromyces cf. *chioneus* (Fr.) P. Karst.	Rh	Nieves-Rivera et al. (2004)
Tyromyces sp.	Rh	Ryvarden (1984); Minter et al. (2001)
Uredo coccolobae Henn.	Cu	Arthur (1917); Seaver and Chardón (1926); Thurston and Kern (1933); Roure (1962, 1963); Stevenson (1975); Francis and Lowe (2000); Minter et al. (2001)

U. ignava Arthur	Ba	Seaver and Chardón (1926); Stevenson (1975); Minter et al. (2001)
U. uvifera P. Syd. & Syd. = *Uredo coccolobae*		
Uromyces tenuicutis McAlpine	Sv	Arthur (1915a), 1916, 1917); Theis (1953); Stevenson (1975); Minter et al. (2001)
Ustilago affinis Ellis & Everh., in Cockerell	Se	Whetzel and Kern (1926); Theis (1953); Stevenson (1975); Minter et al. (2001)
Volvariella sp.	Ll, Ss, Un	Lodge et al. (2000); Minter et al. (2001)
Unknown sp. 1	Ll	Nieves-Rivera (unpubl. data, next to Cabo Rojo's lighthouse, Boquerón Commonwealth Forest, southwestern Puerto Rico) Remarks.–This unknown yellowish bolete (Basidiomycota: Boletaceae) was found under a grove of *Myrica* sp. (Myricaceae), Figures 19A–D.

ZYGOMYCOTA

Absidia sp.	Am	Pérez Samot (1986)
Asellaria ligiae Tuzet & Manier	Li	White et al. (2000)
Basidiobolus sp.	Am	Pérez Samot (1986)
Enterobryus spp.	Uc	White et al. (2000)
Gongronella sp.	Am	Pérez Samot (1986)
Haplosporangium sp. = *Mortierella* sp.		
Mortierella sp.	Am, Bs, Ss	Hernández-Vera (1972, 1975); Pérez Samot (1986); Minter et al. (2001)
Mucor bacilliformis Hasselt.	Ss	Carvajal-Zamora (1971a, b); Pérez Samot (1986)
M. christianiensis Hagem	Bs, Ss	Hernández-Vera (1972, 1975); Minter et al. (2001)
M. globosus A. Fisch.	Bs, Ss	Hernández-Vera (1972, 1975, 1982); Hernández-Vera and Almodóvar (1983, 1984); Minter et al. (2001)
M. jansseni Lendn.	Bs	Hernández-Vera (1982); Hernández-Vera and Almodóvar (1983, 1984)
Mucor sp.	Am, Bs, Ma, Ss	Pérez Samot (1986); Cantrell (1991); Cantrell and Betancourt (1992); Ruiz-Suárez, (2004)
Phycomyces sp.	Bs, Ss	Hernández-Vera (1972, 1975); Minter et al. (2001)
Rhizopus oryzae Went & Prins. Geerl.	Bs, Ss	Hernández-Vera (1972, 1975); Minter et al. (2001)
R. stolonifer Ehrenb. & Fr.	Ss	Carvajal-Zamora (1971a, b); Stevenson (1975); Minter et al. (2001)
Syncephalastrum racemosum Cohn: J. Schröt, in Cohn	Bs, Ss	Hernández-Vera (1972, 1975); Minter et al. (2001)
OOMYCOTA (CHROMISTA)		
Achlya americana Humprey	Bs, Ss	Rossy-Valderrama (1955, 1956); Johnson (1956); Stevenson (1975); Galler-Rimm (1982); Minter et al. (2001)
A. bisexualis Coker & Couch	Ss	De Santiago Serrano (1999)

A. cambrica (Trow) T.W. Johnson	Bs, Ss	Galler-Rimm (1982)
A. caroliniana Coker	Bs, Ss	Galler-Rimm (1982)
A. conspicua Coker	Bs, Ss	Rossy-Valderrama (1955, 1956); Johnson (1956); Stevenson (1975); Galler-Rimm (1982); Minter et al. (2001)
A. debaryana Humprey	Bs, Ss	Galler-Rimm (1982)
A. diffusa J.V. Harv.: T.W. Johnson, in T.W. Johnson	Bs, Ss	Rossy-Valderrama (1955, 1956); Johnson (1956); Stevenson (1975); Galler-Rimm (1982); Minter et al. (2001)
A. dubia Coker	Bs, Ss	Rossy-Valderrama (1955, 1956); Johnson (1956); Stevenson (1975); Galler-Rimm (1982); Minter et al. (2001)
A. flagellata Coker	Bs, Ss	Rossy-Valderrama (1955, 1956); Johnson (1956); Stevenson (1975); Galler-Rimm (1982); Longcore (1996); Minter et al. (2001)
A. klebsiana Pieters	Bs, Ss	Rossy-Valderrama (1955, 1956); Johnson (1956); Stevenson (1975); Galler-Rimm (1982); Minter et al. (2001)
A. orion Coker & Couch	Bs, Ss	Galler-Rimm (1982)
A. primoachlya Beneke	Bs, Ss	Galler-Rimm (1982)
A. prolifera Nees = *Achlya prolifera*		
A. prolifera Pringsh.	Bs, Ss	Rossy-Valderrama (1955, 1956); Johnson (1956); Stevenson (1975); Galler-Rimm (1982); De Santiago Serrano (1999); Minter et al. (2001)
A. rodrigueziana F.T. Wolf	Bs, Ss	Galler-Rimm (1982)
A. treleaseana (Humphrey) Kauffman	Ss	De Santiago Serrano (1999)
Achlya sp.	Tm	Bunkley-Williams and Williams (per. comm., 2004)
Albugo ipomoeae-panduratae (Schwein.) Swingle	Ip	Stevens (1917); Tucker (1927); Weiss (1950); Stevenson (1975); Minter et al. (2001)

A. ipomoeae-pes-caprae Cif.	Ip	Stevens (1917); Stevenson (1975); Minter et al. (2001)
Aphanomyces laevis de Bary	Ss	De Santiago Serrano (1999)
Brevilegnia crassa Rossy-Vald.	Bs, Ss	Rossy-Valderrama (1955, 1956); Johnson (1956); Stevenson (1975); Minter et al. (2001)
B. unisperma Coker & Braxton	Bs, Ss	Galler-Rimm (1982)
Dictyuchus monosporus Leitg.	Bs, Ss	Galler-Rimm (1982); De Santiago Serrano (1999)
D. pseudodictyon Pringsh.	Bs, Ss	Rossy-Valderrama (1955, 1956); Stevenson (1975); Galler-Rimm (1982); De Santiago Serrano (1999); Minter et al. (2001)
**Halophytophthora* sp.	Rh	Nieves-Rivera (unpubl. data, Magueyes Island)
Phytophthora palmivora (E.J. Butler) E.J. Butler	Cn, Un	Weiss (1950); Phelps and Landgraf (1972); Stevenson (1975); Francis and Lowe (2000); Minter et al. (2001)
P. nicotianae var. *parasitica* (Dastur) G.M. Waterh.	Cn, Hi, Op	Weiss (1950); Stevenson (1975); Minter et al. (2001)
Pythium spp.	Bs, Ss	Galler-Rimm (1982)
Saprolegnia ferax (Gruith.) Thuret	Ss	Nieves-Rivera and Betancourt-López (1994); De Santiago Serrano (1999)
S. parasitica Coker	Ms	Bunkley-Williams and Williams (1994)
S. torulosa de Bary	Bs, Ss	Rossy-Valderrama (1955, 1956); Stevenson (1975); Galler-Rimm (1982); Minter et al. (2001)
Saprolegnia spp.	Ao, Ht, Lh, Lm, Mf, Ms, Rm, Te, Tm, Tu	Bunkley-Williams and Williams (1994, 1995); Williams and Bunkley-Williams (1996); Minter et al. (2001); Nieves-Rivera (unpubl. data, Boquerón Wildlife Refuge)

CHYTRIDIOMYCOTA		
Allomyces spp.	Bs, Ss	Rossy-Valderrama (1955, 1956); Stevenson (1975); Galler-Rimm (1982); Minter et al. (2001)
Rhizophydium carpophilum Zopf	Bs, Ss	Galler-Rimm (1982)
Unknown sp. 1	Am	Burrowes et al. (2004)
PLASMODIOPHOROMYCOTA		
Woronina polycystis Cornu	Bs, Ss	Galler-Rimm (1982)
MYXOMYCOTA		
Arcyria cinerea (Bull.) Pers.	Av, Un	Seaver and Chardón (1926); Hagelstein (1932); Lodge (1996a); Minter et al. (2001); Novozhilov et al. (2001); Stephenson and Nieves-Rivera (unpubl. data, Magueyes Island)
A. incarnata (Pers.) Pers.	Un	Seaver and Chardón (1926); Hagelstein (1932); Minter et al. (2001); Novozhilov et al. (2001)
Badhamia gracilis (T. Macbr.) T. Macbr., in T. Macbr. & G.W. Martin	Mi, Pr	Lodge (1996a); Minter et al. (2001); Nieves-Rivera (unpubl. data, Magueyes Island)
Ceratiomyxa fruticulosa (O.F. Müll.) T. Macbr.	Ca, Cn, Ll, Un	Seaver and Chardón (1926); Hagelstein (1932); Farr (1976); Nieves-Rivera and Santos-Flores (1998); Minter et al. (2001)
Comatricha irregularis Rex	Cn	Hagelstein (1927, 1932); Stevenson (1975); Farr (1976); Minter et al. (2001)
C. longa Peck	Pt, Un	Seaver and Chardón (1926); Hagelstein (1927, 1932); Stevenson (1975); Minter et al. (2001)
C. typhoides (Bull.) Rostaf. = *Stemonitopsis typhoides*		

Craterium leucocephalum (Pers.) Ditmar	Cn, Ll, Un	Seaver and Chardón (1926); Hagelstein (1932); Stevenson (1975); Farr (1976); Minter et al. (2001)
Cribaria intricata Schrad.	Ca, Un	Hagelstein (1932); Nieves-Rivera and Santos-Flores (1998); Minter et al. (2001); Novozhilov et al. (2001)
C. violacea Rex	Tc, Un	Hagelstein (1927); Stevenson (1975); Farr (1976); Minter et al. (2001)
Cribaria sp.	Av	Stephenson and Nieves-Rivera (unpubl. data, Magueyes Island)
Dictydium cancellatum (Batsch) T. Macbr.	Ca, Un	Hagelstein (1932); Nieves-Rivera and Santos-Flores (1998); Minter et al. (2001)
Diderma effusum (Schwein.) Morgan	Av, Cn, Ll, Un	Stevenson (1975); Farr (1976); Minter et al. (2001); Stephenson and Nieves-Rivera (unpubl. data, Magueyes Island)
Didymium squamulosum (Alb. & Schwein.) Fr.	Cn, Ll, Un	Seaver and Chardón (1926); Hagelstein (1927, 1932); Stevenson (1975); Farr (1976); Minter et al. (2001)
Echinostelium minutum de Bary, in Rostaf.	Av	Stephenson and Nieves-Rivera (unpubl. data, Magueyes Island)
Fuligo septica (L.) F.H. Wigg.	Ba, Ca, Cn, Ss, Un	Seaver and Chardón (1926); Hagelstein (1927, 1932); Stevenson (1975); Farr (1976); Nieves-Rivera and Santos-Flores (1998); Minter et al. (2001)
Hemitrichia serpula (Scop.) Rostaf.: Lister	Cn, Ll, Un	Seaver and Chardón (1926); Hagelstein (1932); Stevenson (1975); Farr (1976); Minter et al. (2001)
H. stipitata (Massee) T. Macbr.	Cn, Un	Stevenson (1975); Minter et al. (2001)
Herpotrichia albidostoma (Peck) Sacc.	Cn, Un	Chardón (1921); Seaver (1922); Stevenson (1975); Farr (1976); Minter et al. (2001)
H. schiedermayeriana Fuckel = *Byssosphaeria schiedermayeriana* (Ascomycota)		

Licea operculata (Wingate) G.W. Martin	Pt, Un	Stevenson (1975); Farr (1976); Minter et al. (2001)
Lycogala sp.	Ca, Cn, Un	Nieves-Rivera and Santos-Flores (1998); Minter et al. (2001)
Metatrichia vesparium (Batsch) Nann.-Bremek.	Cn, Cu, Un	Stevenson (1975); Farr (1976); Minter et al. (2001)
Perichaena chrysosperma (Curr.) Lister	Av, Un	Lodge (1996a); Minter et al. (2001); Stephenson and Nieves-Rivera (unpubl. data, Magueyes Island)
P. depressa Lib.	Ac, Av, Cn, Un	Hagelstein (1932); Stevenson (1975); Farr (1976); Minter et al. (2001); Stephenson and Nieves-Rivera (unpubl. data, Magueyes Island)
Physarella oblonga (Berk. & M.A. Curtis) Morgan	Cn, Ss, Un	Hagelstein (1932); Stevenson (1975); Farr (1976); Minter et al. (2001)
Physarum gyrosum Rostaf.	Pr	Clark et al. (2004)
P. nutans Pers.	Un	Hagelstein (1932); Novozhilov et al. (2001)
P. polycephalum Schwein.	Un	Hagelstein (1932); Novozhilov et al. (2001); Minter et al. (2001)
P. pusillum (Berk. & M.A. Curtis) G. Lister	Mi, Pr, Un	Hagelstein (1932); Minter et al. (2001); Nieves-Rivera (unpubl. data, Magueyes Island)
Physarum sp.	Av, Un	Minter et al. (2001); Stephenson and Nieves-Rivera (unpubl. data, Magueyes Island)
Stemonitis axifera (Bull.) T. Macbr.	Ca, Un	Nieves-Rivera and Santos-Flores (1998); Minter et al. (2001)
S. splendens Rostaf.	Cn, Rh, Un	Seaver and Chardón (1926); Hagelstein (1932); Stevenson (1975); Farr (1976); Minter et al. (2001); Nieves-Rivera and Stephenson (2004); Nieves-Rivera (present work)
Stemonitis sp.	Tc	Minter et al. (2001)
Stemonitopsis typhoides (Bull.) T. N. Lakh. & Mukerji	Ag, Pt, Un	Seaver and Chardón (1926); Hagelstein (1932); Minter et al. (2001); Novozhilov et al. (2001)

Tubifera ferruginosa (Batsch) J.F. Gmel.	Cn, Tc, Un	Seaver and Chardón (1926); Hagelstein (1932); Stevenson (1975); Farr (1976); Nieves-Rivera and Santos-Flores (1998); Minter et al. (2001)

* New records for Puerto Rico.

[1]**Notes:** Some of the plants mentioned in this partial checklist, such as *Bambusa vulgaris*, *Casuarina equisetifolia*, *Coccoloba uvifera*, *Cocos nucifera* or cacti, are not considered as mangroves or plants associated with mangroves. However, much of their plant debris has been found as natural rafts (e.g., driftwood, floating leaves, propagules, etc.) in beaches, estuaries, and river mouths due to storms, aeolian and sea currents (Hedgpeth, 1994). It is possible that plant's mycobiota might be transported into littoral or pelagic environments, many of the fungi mentioned in this checklist are common on these and other substrata.

[2]**Substrata or hosts:** Plants found in mangroves (including mangrove-associated plants), sand dunes and coastal plains are named according to Martorell et al. (1981) and Craig (1991). Marine algal taxonomy was based on Ballantine and Aponte (1997). Abbreviations: Ac = *Acrostichum* spp. (Polypoidiacea); Ad = Air dust; Af = *Amphiroa fragilissima* (Rhodophyta); Ag = *Agave americana* L. (Agavaceae); Am = Amphibians (*Eleutherodactylus* spp.); Ao = *Astronotus ocellatus* (Pisces: Chiclidae); As = *Acanthophora spicifera* (Rhodophyta); Av = *Avicennia germinans* (Verbenaceae); Ba = *Bambusa vulgaris* (Gramineae); Bs = Beach sand; Bt = *Bryothamnion triquetrum* (Rhodophyta); Ca = *Casuarina equisetifolia* (Casuarinaceae); Cb = *Caesalpinia bonduc* (Caesalpiniaceae); Cc = *Cenchrus echinatus* (Gramineae); Cd = *Cynodon dactylon* (Gramineae); Ce = *Conocarpus erectus* var. *sericeus* (Combretaceae); Ch = *Chrysobalanus icaco* (Rosaceae); Ci = *Calophyllum inophyllum* (Guttiferae); Cm = *Coccoloba microstachya* (Polygonaceae); Cn = *Cocos nucifera* (Palmaceae); Co = *Conocarpus erectus* (Combretaceae); Cs = *Cenchrus myosuroides* (Gramineae); Ct = *Cenchrus tribuloides* (Gramineae); Cu = *Coccoloba uvifera* (Polygonaceae); Cy = *Cymodocea manatorum* (Potamogetonaceae); Db = *Dasya balillouviana* (Rhodophyta); Dd = *Dictyota dichotoma* (Phaeophyta); De = *Dalbergia ecastophyllum* (Fabaceae); Df = Driftwood; Dg = animal dung (mostly bovine or equine); Dv = *Dictyota divaricata* (Phaeophyta); Ec = *Eichhornia crassipes* (Pontederiaceae); Ga = *Gelidiella acerosa* (Rhodophyta); Gf = *Gorgonia flabellum* (Cnidaria: Gorgoniidae); Go = *Galaxaura oblongata* (Rhodophyta); Gr = *Gracilaria* sp. (Rhodophyta); Gs = *Galaxaura subverticillata* (Rhodophyta); Gv = *Gorgonia ventalina* (Cnidaria: Gorgoniidae); Gx = *Galaxaura* sp. (Rhodophyta); Ha = *Harrisia portoricensis* (Cactaceae); Hi = *Hibiscus tiliaceus* (Malvaceae); Hm = *Hippomane mancinella* (Euphorbiaceae); Hp = Hypersaline pool; Hr = hair (either animal and human); Ht = *Helostoma temmincki* (Pisces: Anabantidae); Ip = *Ipomoea pes-caprae* (Convolvulaceae); Is =

Ipomoea stolonifera (Convolvulaceae); La = *Laguncularia racemosa* (Combretaceae); Lc = *Lantana camara* (Verbenaceae); Le = *Lantana camara* var. *aculeata* (Verbenaceae); Lh = *Lepomis macrochirus* (Pisces: Centrarchidae); Li = *Ligia* sp. (Isopoda: Ligidae); Ll = Leaf litter; Lm = *Lepomis auritus* (Pisces: Centrarchidae); Lp = *Liagora pinnata* (Rhodophyta); Ls = *Lantana* sp. (Verbenaceae); Lv = *Lantana involucrata* (Verbenaceae); Ma = *Macrobrachium rosenbergii* (Decapoda: Palaemonidae); Mc = *Myrica cerifera* (Myricaceae); Me = *Meliola* spp. (Ascomycota: Meliolaceae); Mf = *Micropterus salmoides floridanus* (Pisces: Centrarchidae); Mi = *Melocactus intortus* (Cactaceae); Ms = *Micropterus salmoides salmoides* (Pisces: Centrarchidae); Od = *Opuntia dillenii* (Cactaceae); Op = *Opuntia* spp. (Cactaceae); Pa = *Pavonia spicata* (Malvaceae); Pg = *Pandina gymnospora* (Phaeophyta); Ps = *Pseudophoenix sargentii* (Palmaceae); Pt = *Pterocarpus officinalis* (Fabaceae); Pr = *Pilosocereus* cf. *royeni* (Cactaceae); Pv = *Paspalum vaginatum* (Gramineae); Rf = River foam; Rh = *Rhizophora mangle* (Rhizophoraceae); Rm = *Rivulus marmoratus* (Pisces: Aplocheilidae); Rp = Reptile (*Caiman crocodylus*); Sa = *Sargassum* sp. (Phaeophyta); Sb = *Sabal palmetto* (Palmae); Se = *Stenotaphrum secundatum* (Gramineae); Sf = Sea foam; Sp = *Sargassum polyceratium* (Phaeophyta); Sr = *Spartina* sp. (Gramineae); Ss = Sandy soil; Sv = *Sporobolus virginicus* (Gramineae); Tc = *Terminalia catappa* (Combretaceae); Td = *Typha domingensis* (Typhaceae); Te = *Tilapia rendalli* (Pisces: Chiclidae); Th = *Thalassia testudinum* (Hydrocharitaceae); Tm = *Tilapia mossambica* (Pisces: Chiclidae); Tp = *Thespesia populnea* (Malvaceae); Tr = *Triumfetta* spp. (Tiliaceae); Tu = *Tilapia urolepis hornorum* (Pisces: Chiclidae); Uc = *Uca* spp. (Decapoda: Ocypodidae); Un = Undetermined dead wood; Wd = Wood panel (*Pinus*) as bait.

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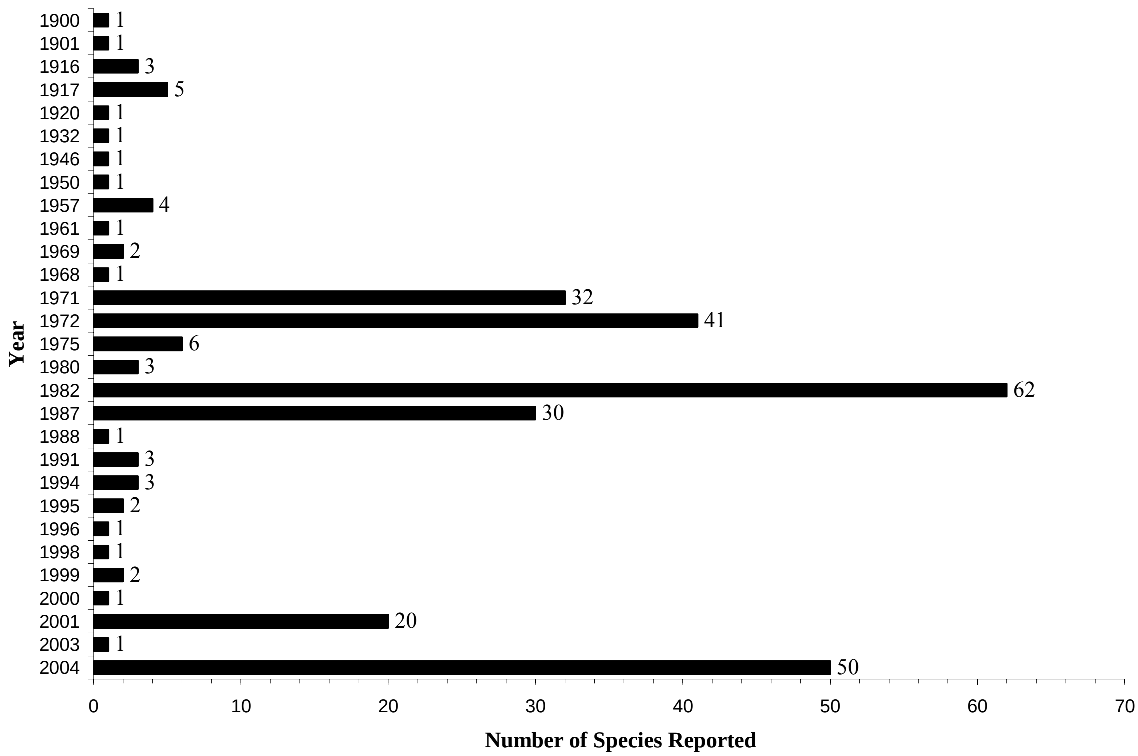
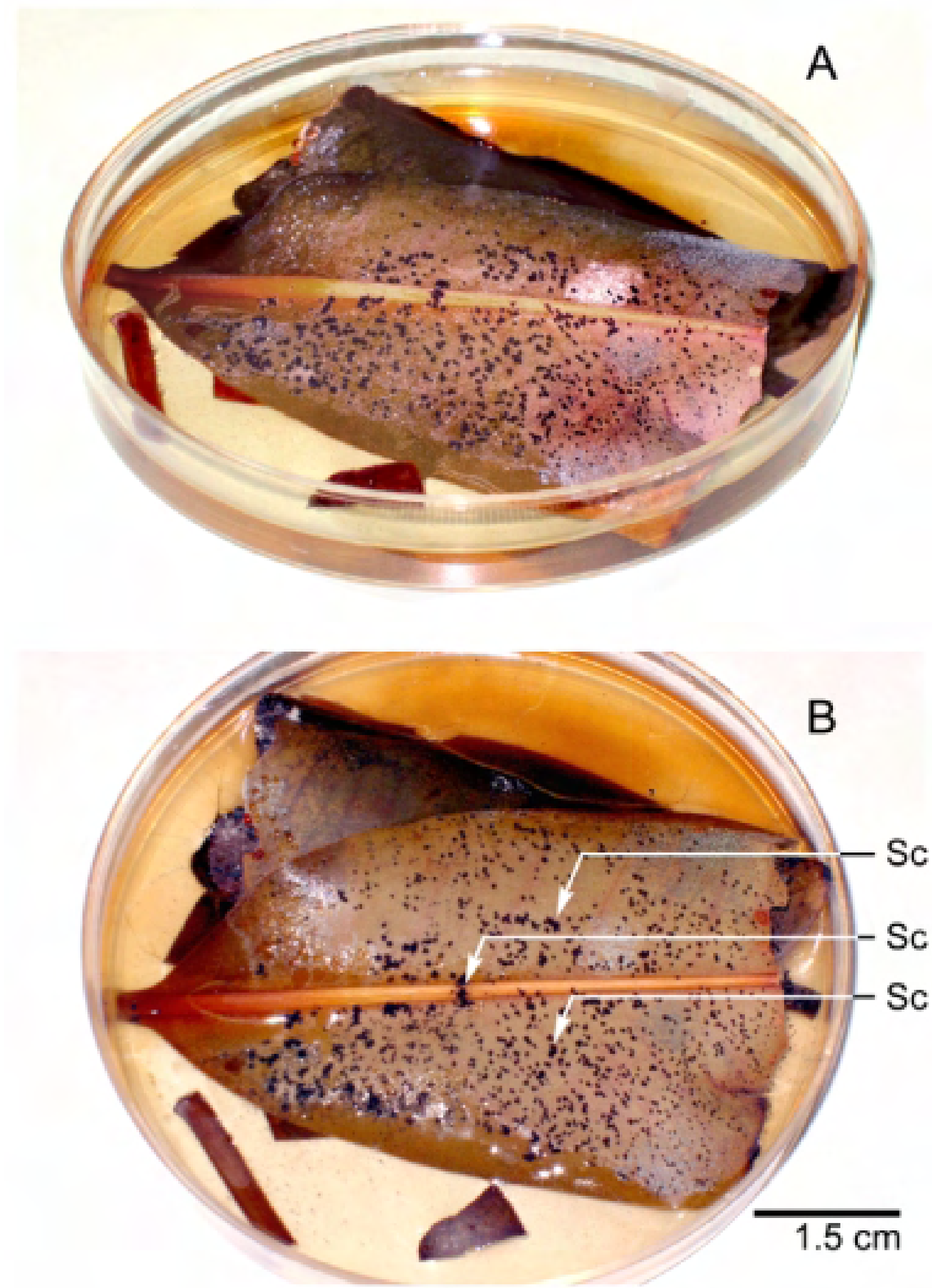
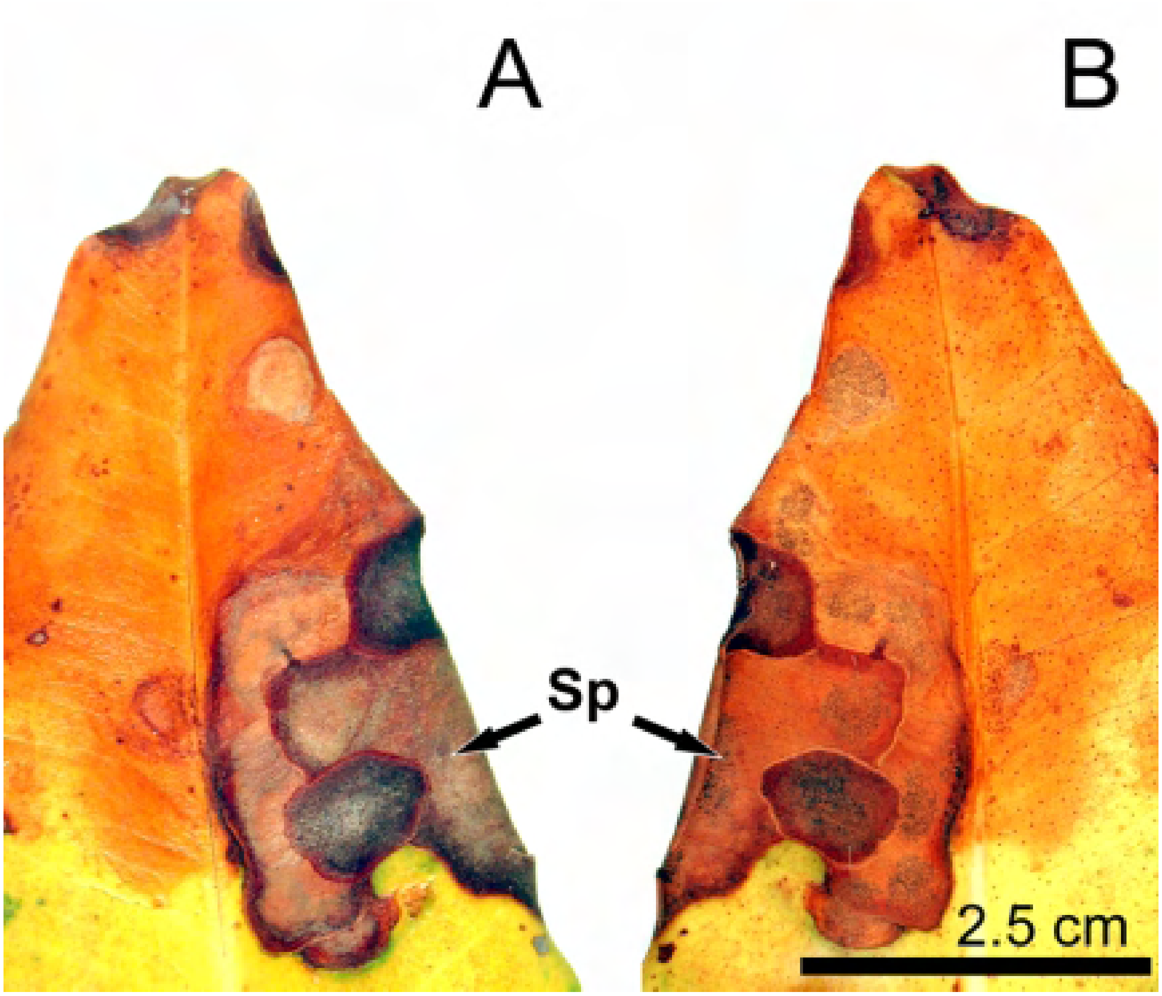


Figure 12. Taxa of marine fungi (including estuarine) reported for Puerto Rico in published and unpublished reports between 1900 and 2004. Years selected represent publication date of the records. Numbers given are not cumulative.

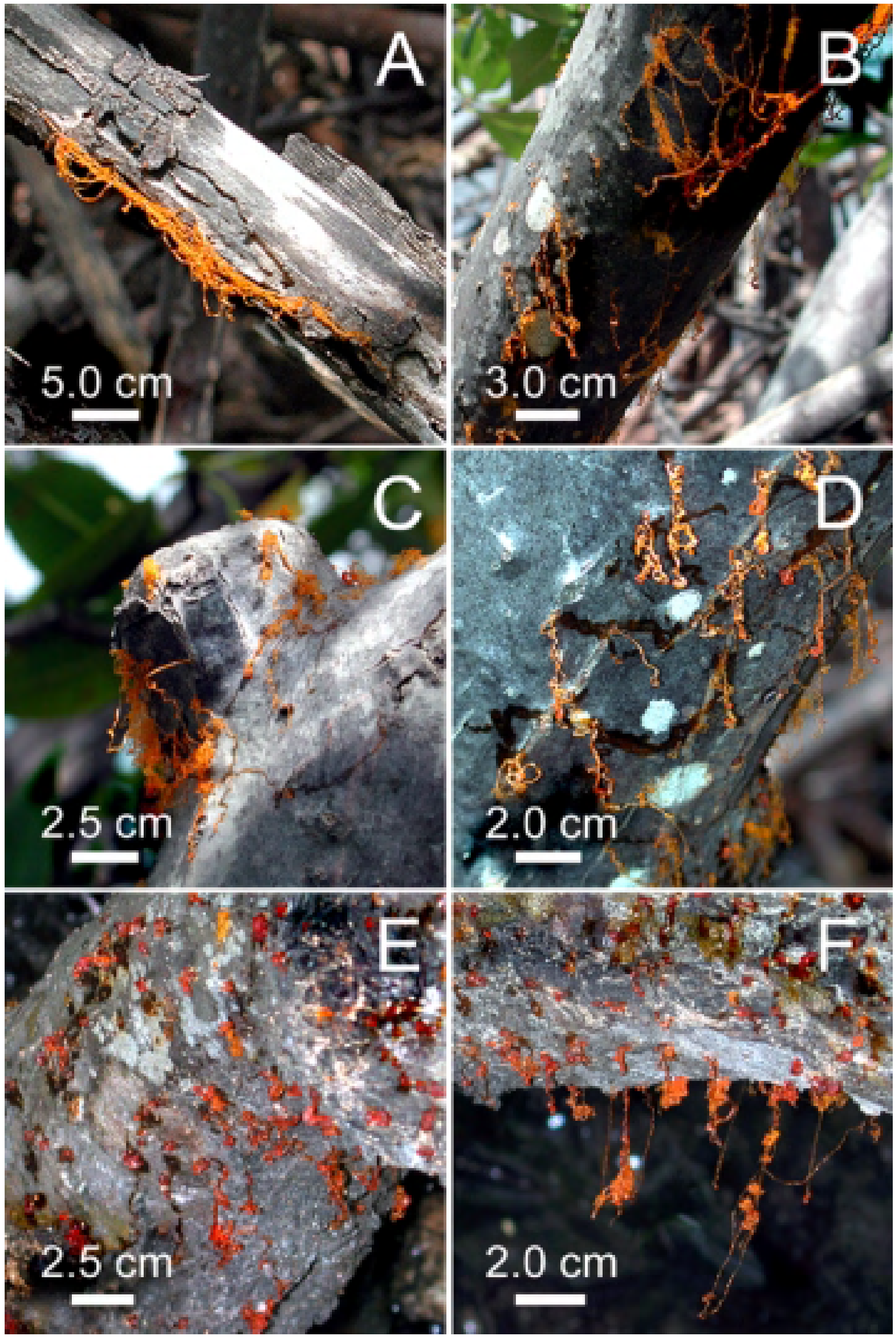
Figure 13. *Asteromassaria* sp. (Ascomycota) on aerial roots of *Rhizophora mangle* in Magueyes Island, southwestern Puerto Rico.



Figures 14A–B. *Aspergillus niger* (Mitosporic fungi) on *Rhizophora mangle* from La Parguera Channels, southwestern Puerto Rico (Sc = Sporocarps).



Figures 15A–B. Leaf spots and sporodochia (Sp) of *Cercospora* sp. (Mitosporic fungi) on a leaf of *Rhizophora mangle* from La Parguera Channels, southwestern Puerto Rico. A. Front. B. Back.



Figures 16A–F. *Cytospora rhizophorae* (Ascomycota) deep orange cirri on prop roots or trunks of *Rhizophora mangle* in southwestern Puerto Rico. A. Boquerón Wildlife Refuge. B-D. Magueyes Island. E-F. Los Morrillos.

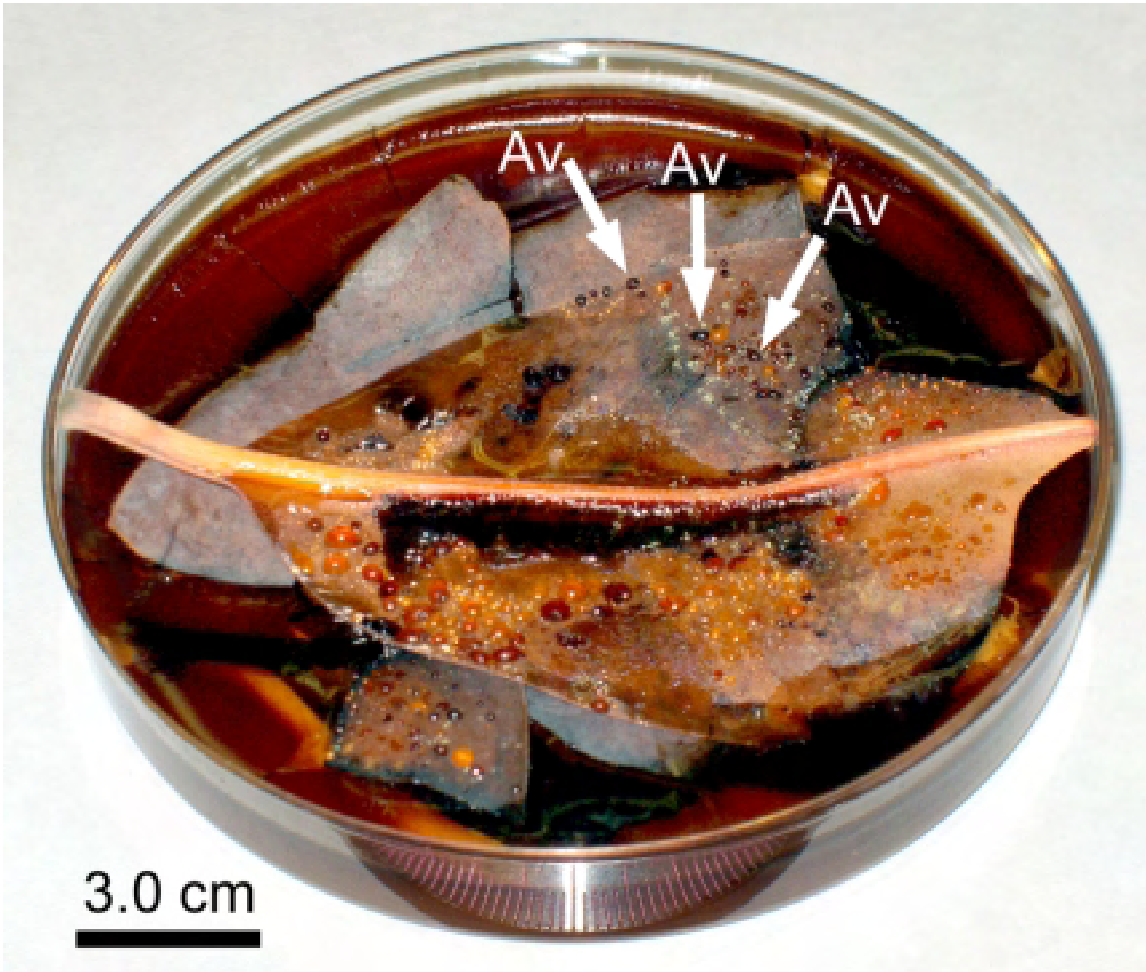
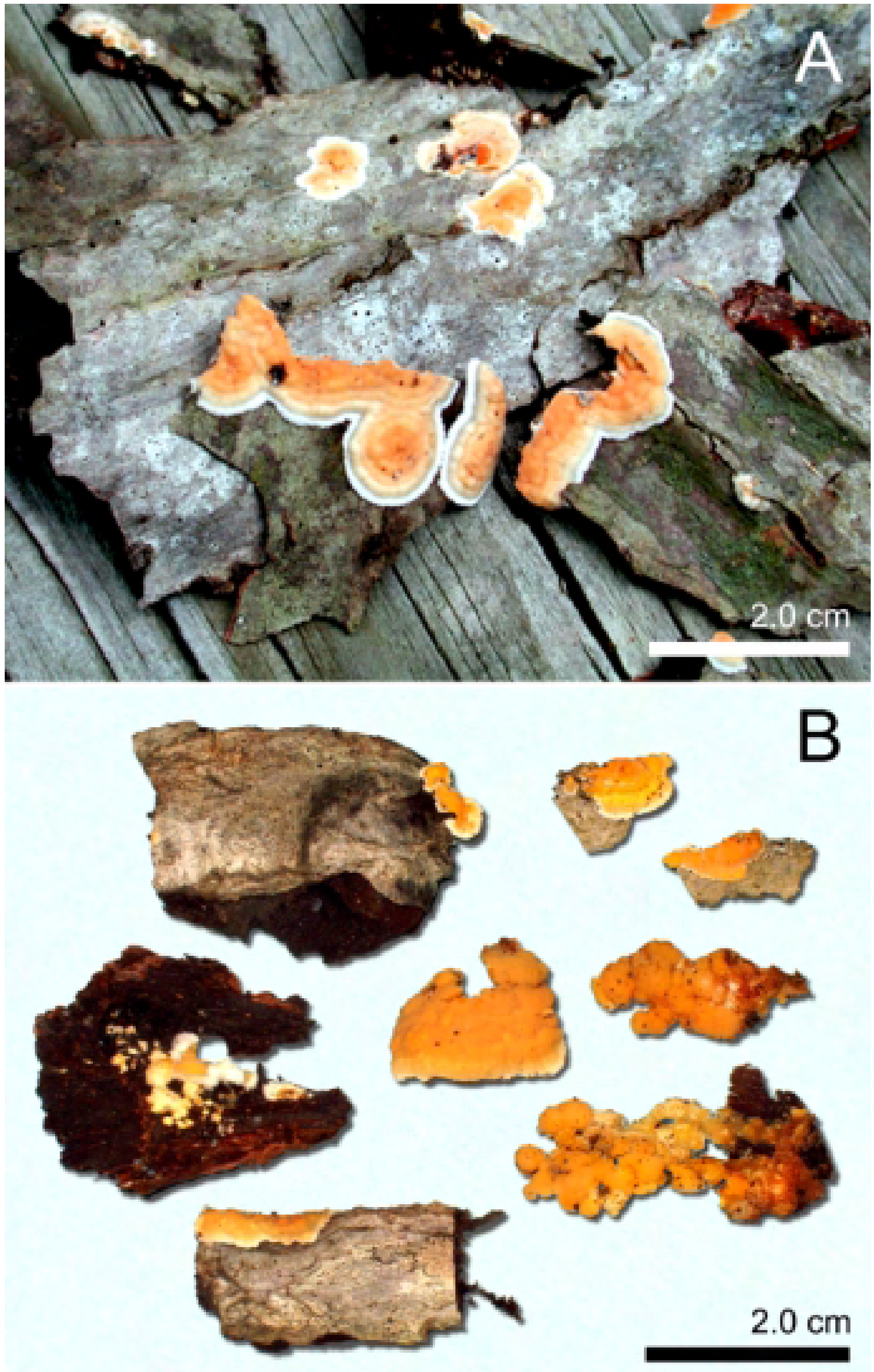
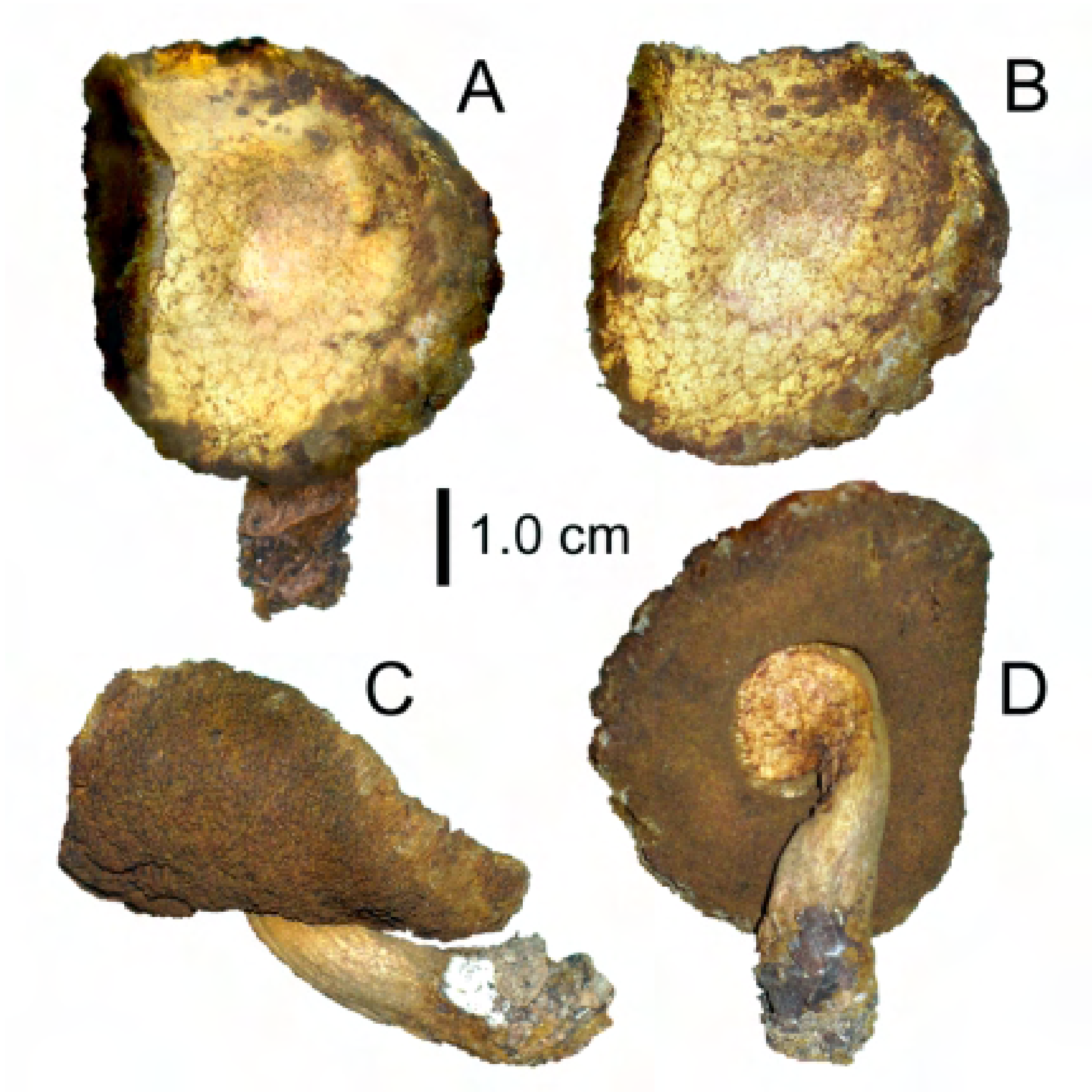


Figure 17. Acervuli (Av) of *Pestalotiopsis disseminata* (Mitosporic fungi) on leaves of *Rhizophora mangle* after growth in moist chambers from La Parguera Channels, southwestern Puerto Rico.



Figures 18A–B. *Phlebia* sp. (Basidiomycota) on *Rhizophora mangle* wood from Boquerón Wildlife Refuge, southwestern Puerto Rico.



Figures 19A–D. Bolete (*Fistulinella* cf.) basidiocarp (Basidiomycota) found under the grove of *Myrica* sp. (Myricaceae) next to Cabo Rojo's lighthouse, Boquerón Commonwealth Forest, southwestern Puerto Rico. A–B. Pileal view. C. Side view. D. Pore view.

CHAPTER 4

FILAMENTOUS FUNGI IN SEA FOAM AND MANGROVE SENESCENT LEAVES IN A TROPICAL ESTUARY

ABSTRACT

Samples of sea foam and senescent leaves of *Avicennia germinans* and *Rhizophora mangle* from an estuary known as Rincón Lagoon (Boquerón Beach Inlet = BBI; Boquerón Wildlife Refuge = BWR) in southwestern Puerto Rico were assessed for the frequency of occurrence of eight selected filamentous fungi. Among 12 bags of sea foam and 1296 leaves screened (108 leaves per month from February 2002 through January 2003), the samples consist of sporulating fungi and propagules, respectively. The species *Aigialus* sp. (*A*. cf. *grandis*) (Ascomycota) and *Penicillium roqueforti* var. *carneum* (Mitosporic fungi) are new records for Puerto Rico. *Cochliobolus pallescens* (Boquerón Beach Inlet [BBI] = 50.51%; Boquerón Wildlife Refuge [BWR] = 50.98%), *Exserohilum* sp. (BBI = 16.95%; BWR = 15.37%), *Tetraploa aristata* (BBI = 11.74%; BWR = 14.26%), and *Alternaria* sp. (BBI = 10.88%; BWR = 9.53%), were frequently found in sea foam, while *P. roqueforti* var. *carneum* and *Aspergillus niger* were frequently found in mangrove leaves (*A. germinans* and *R. mangle*) in both BBI and BWR, followed closely by *Pestalotiopsis disseminata*, and *Alternaria* sp. The two-way ANOVA performed to filamentous fungi (propagules and spore counts, N = 432) in sea foam and the ones isolated from mangrove leaves (colonies in *A. germinans*, N = 576; in *R. mangle*, N = 576) showed that variability was significant ($p > 0.05$) between the two communities studied (BBI and BWR). Statistical analysis suggested that date/site was significant ($p > 0.05$), although date was insignificant ($p < 0.05$) in regards to H_0. Thus, this analysis rejects H_0, in other words, it is unlikely that chance is operating to produce observed differences and the evidence is strong enough to support the significant effect, one that is probably not due to chance.

RESUMEN

Muestras de espuma marina y hojas seniles de *Avicennia germinans* y *Rhizophora mangle* de un estuario conocido como la Laguna Rincón (Isleta Playera de Boquerón = BBI; Refugio de Vida Silvestre de Boquerón = BWR) en el suroeste de Puerto Rico fueron evaluados en frecuencia de ocurrencia de ocho hongos filamentosos selectos. De entre las 12 bolsas de espuma marina y 1296 hojas muestreadas (108 hojas por mes desde febrero 2002 hasta enero 2003), las muestras consisten de hongos esporulantes y propágalos, respectivamente. Las observaciones de las carnadas (espuma marina y hojas de mangles y escombros incubado mostraron que estos ocho hongos filamentosos pertenecen a los ascomicetos (2 especies) y hongos mitospóricos (6 especies). Las especies *Aigialus* sp. (*A*. cf. *grandis*) (Ascomycota) y *Penicillium roqueforti* var. *carneum* (Hongos mitospóricos) son registros nuevos para Puerto Rico. *Cochliobolus pallescens* (Isleta de Playa de Boquerón [BBI] = 50.51%; Refugio de Vida Silvestre de Boquerón [BWR] = 50.98%), *Exserohilum* sp. (BBI = 16.95%; BWR = 15.37%), *Tetraploa aristata* (BBI = 11.74%; BWR = 14.26%) y *Alternaria* sp. (BBI = 10.88%; BWR = 9.53%), son encontrados frecuentemente en espuma marina, mientras que *P. roqueforti* var. *carneum* y *Aspergillus niger* han sido aislados frecuentemente en las hojas de mangle (*A. germinans* y *R. mangle*) en ambos BBI and BWR, seguidos de cerca por *Pestalotiopsis disseminata* y *Alternaria* sp. El ANOVA de dos vías que se hizo a los hongos filamentosos (conteo de propágulos y esporas, N = 432) en espuma marina y para los aislados de hojas de mangle (colonias en *A. germinans*, N = 576; en *R. mangle*, N = 576) mostró que la variabilidada fue significativa ($p > 0.05$) entre las dos comunidades estudiadas (BBI y BWR). El análisis estadístico sugirió que la fecha/lugar fue significativa ($p > 0.05$), aunque la fecha fue insignificante ($p < 0.05$) con respecto a H_0. Por lo tanto, este análisis rechaza la H_0, en otras palabras, es improbable que el azar esté operando para producer diferencias observadas y la evidencia es lo suficientemente fuerte para sostener el efecto es significativo, uno que es probablemente no debido al azar.

INTRODUCTION

Mangrove plants generate a large amount of litter in the form of branches, inflorescence, leaves, twigs, and other debris. In general, the estimated annual litter production in mangrove forests was slightly higher for Puerto Rico (9.45 $mg \cdot ha^{-1} \cdot yr^{-1}$) than Florida (8.10 $mg \cdot ha^{-1} yr^{-1}$) (Pool et al., 1975; Twilley et al., 1986). The contribution of mangroves debris is the input of organic matter that enriched the coastal ecosystem and in turn the fisheries (Cintrón and Schaeffer-Novelli, 1988).

Fungal distribution in marine and estuarine habitats are still poorly known, although a number of published reports and summaries of previous studies in the Caribbean were included in Stevenson (1975), Nishida (1989), Minter et al. (2001), and Schmit and Shearer (2003). Filamentous fungi (Carvajal-Zamora, 1971; Hernández-Vera, 1972, 1975, 1982; Stevenson, 1975; Hernández-Vera and Almodóvar, 1983, 1984; Minter et al., 2001; Nieves-Rivera and Santos-Flores, in press), yeasts (Valdéz-Collazo et al., 1987), and fungi-like organisms such as oomycetes (Rossy-Valderrama, 1956; Galler-Rimm, 1982) are known to occur in beaches close to river mouths and estuaries of Puerto Rico. Most estuarine and marine collections are in some cases sporadic. The purpose of this study is to understand the diversity and frequency of occurrence of eight selected filamentous fungi in marine foam and mangrove leaf litter from a river mouth of Puerto Rico, a subtropical island located between the coordinates 18°00'-18°30' N and 65°35'-67°15' W, in the northeastern Caribbean Sea.

MATERIALS AND METHOD

Study Sites

The Rincón Lagoon (RL) (also known as Boquerón Lagoon s. str. Anonymous, 1905) is located about 97 km southwestern of San Juan, Puerto Rico (Figure 20). This irregular brackish water lagoon (7.5 km^2 and 0.75 m of average depth) is open to the sea by a deep canal (0.2 km long by 0.1 km wide, being deeper at the mouth, where it reach 2.0 m deep) (Vázquez, 1983; Negrón-González, 1988; Aliaume et al., 1997). Candelas et al. (1973) and

Negrón-González (1988) surveyed RL and BWR, and found that RL has a depth of 1.3 to 2.0 m, a visibility obtained with the Secchi disk of 0.6 m and the coefficient of light extinction (QLE) of 2.51. RL has a shoreline development index of 2.10 (Negrón-González, 1988). It receives, through its drainage channel, a continuous freshwater input from two streams (Los Llanos and Boquerón Streams) and adjacent fields or, occasionally, from an impoundment when gates overflow. The impoundment area (17 km^2), nowadays known as the Boquerón Wildlife Refuge (BWR) is part of the Boquerón Commonwealth Forest (BCF) (Figures 21A-D), is filled with freshwater and was constructed in 1963-1964 (PRDNR, 1976). The BWR impoundment was constructed to replace the loss of wetland habitat caused by the eutrophication of Cartagena Lagoon and the loss of the natural lagoons, Guánica and Anegado which were being drained for agriculture purpose at the time. To control the flow of freshwater from the east, and seawater from the west, into and out of the impoundment a total of six floodgates were constructed along the dikes (PRDNR, 1976; Vázquez, 1983). Today the impoundment serves as both a waterfowl and hunting refuge. The geology of the region was treated by Volckmann (1984), USDA (1993), Torres-Figueroa (1993), and Barreto-Orta (1997).

The salinity of RL fluctuated between 30 to 39 g/L, especially at the bottom of the mouth of the lagoon; however, salinity changes had been as low as 8.0 g/L or as high as 40.2 g/L caused by terrestrial runoff or evaporation (Carvajal-Zamora, 1976; Negrón-González, 1988). The dissolved oxygen of RL was 3.7 to 58 mg/L and has a water temperature of 29.5 to 32.7°C (Candelas et al., 1973; Negrón-González, 1988). Nutrient concentrations at a depth of 0.5 to 1.0 m for RL was reported as total phosphorous (0.01 to 0.09 mg/L), phosphate (< 0.01 to 0.023 mg/L), total nitrogen (0.17 to 0.24 mg/L), nitrate (< 0.001 to 0.01 mg/L), nitrite (0.004 to 0.016 mg/L), and ammonium (< 0.05 mg/L) (Negrón-González, 1988). In general, the water column is considered to be mixed and the oxygen concentrations are low because of anthropogenic pollution (Negrón-González, 1988).

Mangroves are represented by *R. mangle*, *A. germinans*, *Laguncularia racemosa*, *Conocarpus erectus*, and *Thespesia populnea* which form thick coastal woodland surrounding the lagoon (Table IV) (Figures 21A-D). The terrestrial vegetation of BCF was treated by Toro and Colón (1986), Vázquez and Kolterman (1998), and Nieves-Rivera et al., (2002). Negrón González (1988) reported 35 genera of phytoplankton in RL, including *Clostrium*, *Synechococcus*, and *Phormidium*. The bioluminescent dinoflagellate *Pyrodinium bahamense* is also present in RL. Fish reported in RL included 15 species, from these, *Oreochromis mossambicus* was the most abundant species, followed by *Centropomus undecimalis*, *Mugil curema*, and *Caranx latus* (Negrón-González, 1988; Aliaume et al., 1997).

Field Studies

Six stations (subdivided in 3 replicates per station or two communities) were selected in the shores of RL and delimited by Global Position System (G.P.S.) (Table IV). Stations 1 to 3 are referred through the text as 'Boquerón Beach Inlet' (BBI) and the remaining stations (4 to 6) as 'Boquerón Wildlife Refuge' (BWR) (Figures 20 and 21A-D). During February 2002 through January 2003, intertidal sea foam and senescent leaves of *A. germinans* and *R. mangle* were collected from studied sites. Following each harvest, chemical parameters were taken from study sites. LaMotte® Saltwater Aquarium Kit (Model AG-104), Hach® Saltwater Aquaculture Test Kit (Model FF-3), and LaMotte® Limnology Kit (Model AM-02) were used to determined water chemical parameters.

Weather conditions at the time of sampling (February 2002 through January 2003) were obtained from the nearest weather station, which was located at Magueyes Island, PR (Station Identification Number 9759110, established on 1 December 1954), located at 17° 58.3'N, 67° 2.8'W, La Parguera, Lajas, southwestern Puerto Rico (NOAA, 2004) and a local weather station (WEATHER.CNN.COM, 2004). Further meteorological studies have been carried out in southwestern Puerto Rico which are pertinent to our study (Ewel and Whitmore, 1973; Glynn, 1973; Ravalo et al., 1986; Winter et al., 1998).

Sea Foam—Intertidal sea foam was collected with a sterile spoon and stored in sterile plastic bags (NASCO, Inc.) monthly (from February 2002 through January 2003). The foam was allowed to condense into liquid and a solution of 1.0% cotton-blue in lactophenol (1 ml of solution per 25 ml of foam) was added to stain and preserve the spores (Iqbal and Webster, 1973; Santos-Flores and Betancourt-López, 1997). Sea foam samples were stored in a refrigerator (4°C) to keep them fresh until examination. These fresh samples were baited in the laboratory with pieces of sterilized balsa wood.

Mangrove Leaves—A total of 1296 unspoiled, senescent leaves of *A. germinans* and *R. mangle* were collected from the lower part of the crown and used as bait. The leaves were dipped in 70% ethanol for 5 seconds, immersed in 10% hypochlorite for 90 seconds and finally rinsed in sterile water for 10 seconds. The leaves were dried in a NESCO food dehydrator (FD-1010 Gardenmaster®), and UV irradiated for 24 hrs. A set of three leaves of *A. germinans* and 3 leaves of *R. mangle* were separately enclosed in two 1.8 mm^2 mesh plastic-screen packet (as in Padgett, 1976) (Figure 22A-C). Preliminary experiments with various types of traps revealed that the flat design used here, where the leaves were tightly sandwiched between two layers of screening, allowed maximum exposure to the water and resulted in lesser build-up of sediment in the mesh. The packets were next arranged into groups, each of which contained enough packets of each species to serve as one of triplicates of each parameter to be measured when the group was harvested. All packets of a group were tied together with a nylon line and anchored to the underwater prop roots of *R. mangle*. Leaf baits and traps were prepared according to Padgett (1976).

Mangrove leaves were transported to the laboratory in sterile polythene bags, washed thoroughly in running water and processed within 24 hrs of collection. Leaf baits were placed in wet chambers at room temperature (25°C) following Agrios (1997: pp. 255-258) method to induce fungal sporulation. A sterilized square (~ 1 cm^3) of potato dextrose agar (PDA) was placed on each mangrove leaves while in wet chambers (wet chambers as described in Agrios, 1997). Leaves were incubated at room temperature (25±2°C) in sterile

Petri dishes with sterile freshwater. Each agar square was screened for the presence of fungal structures within a month of sampling. The Petri dishes were re-hydrated with sterile water once every two weeks.

Laboratory Studies

Media—According to Johnson and Sparrow (1961), filtered aged seawater is recommended for primary media preparation, although we used local filtered aged brackish water and on pure cultures filtered fresh water. The medium used in this study was potato dextrose agar (PDA) (Difco Laboratories, 1998), prepared with 39 g PDA in 1.0 L of water, 10% kasugamycin (hydrochloride), and 10% streptomycin, pH 5.6 ± 0.2 at 25°C.

Observations and Herbarium Collections —Microscopical observations were achieved by using semipermanent slides mounted in lactophenol with cotton blue. The illustrated keys are described elsewhere (Ellis, 1971, 1976; Ellis and Ellis, 1985; Barnett and Hunter, 1987; Kohlmeyer and Volkmann-Kohlmeyer, 1991; Santos-Flores and Betancourt-López, 1997; Hyde and Sarma, 2000). Permanent slides were prepared according to Volkmann-Kohlmeyer and Kohlmeyer (1996). Voucher specimens or slides of all species collected were deposited in the Center for Forest Mycology Research at Sabana Field Station (CFMR) and the National Fungus Herbarium (BPI).

Statistical and Ecological Analyses—A two-way analysis of variance (ANOVA) (Steel and Torrie, 1980; Sokal and Rohlf, 1995) was employed in a design completely randomized with 2 x 12 factorial treatments. The first factor to study was the two collection sites (BBI, BWR) and the second was sampling time (12 months). The two-way ANOVA test was used to determine any relationship between the chemo-physical parameters versus the occurrence of eight selected filamentous fungi in collection sites of the estuary. Computer statistical analysis was performed by using SPSS Graduate Pack 10.0 for Windows. The null hypothesis (H_0) proposed for this study is that sampling time (mm-yy), site or location, and the combination of both sources (intersect) will not affect significatively ($p < 0.05$) two filamentous fungal communities in a tropical estuary. I used a Type I error of 5% ($\alpha = 0.05$) for all hypotheses tested (Portney and Walkins, 1993).

RESULTS AND DISCUSSION

Environmental Features— Atmospheric and chemical environmental parameters were taken from study sites (Table V). Barometric pressure minimum (1009.4 mb) and maximum (1015.6 mb) values were obtained from BBI on July and May respectively (Table V). The air temperature minimum (24.8°C) and maximum (36.0°C) were recorded from BWR in October and January (Table V). The relative humidity obtained from BWR had a lower value (71.0%), while the highest (88.0%) on March was obtained from BBI on January (Table V). The annual rainfall in Magueyes Island Marine Laboratories (MIML) (La Parguera, southwestern Puerto Rico) showed a minimum (0 mm in July 2002) and a maximum (99.12 mm in April 2002) values, respectively (Figure 23). Therefore MIML was selected because it has the same xeric conditions as BWR and its proximity to the study site. MIML climatic data for February 2002 to January 2003 was summarized in Figures 23-27.

In general, seasonal variation in mean seawater temperature follows closely that of the atmosphere, ranging between 25 to 30°C, and reaching a maximum in August-October and a minimum in February (NOAA and PRDNR, 1984) (Figure 27). BWR showed a minimum and maximum values for surface water temperature (0 through 60 cm depth) of 24.0°C in May and 31.0°C in April (Table V; Figure 28). In general, annual variations in surface water temperature in southwestern Puerto Rico are generally less than 15.3°C (Coker and González, 1960; NOAA and PRDNR, 1984). Increased winds in the spring appear to be related to a slight decline in the surface thermal structure (Glynn, 1973) and for the sampling year of this study, the wind direction was mostly from the southwest (Figure 25).

Seawater salinity values normally vary less than 2.3 g/L in southwestern Puerto Rico (NOAA and PRDNR, 1984). The lesser value (12 g/L) for salinity was obtained from BWR on April and May, while the higher value was 38.0 g/L from BBI on February (Figure 29).

Salinity data obtained in BWR indicated a fluctuation of 12.0 g/L (minimum) through 34.0 g/L (maximum) between February and May respectively (Table V, Figure 29). These salinity values are similar to offshore values indicating that circulation of the inner shelf region is adequate to maintain open water salinity conditions (NOAA and PRDNR, 1984). Tropical storms in the region usually lower salinities considerably, thereby temporarily stressing marine communities (NOAA and PRDNR, 1984). Runoff from heavy rainfall, resuspension of bottom sediments by wave action and plankton blooms occasionally create turbid conditions. Water clarity within southwestern Puerto Rico varies only from about 1.0 m near the shore to about 30 m at the edge of the shelf (NOAA and PRDNR, 1984).

Minimum (6.2) and maximum (8.6) values of pH were obtained from BBI for October and December, respectively (Figure 30). Two secondary peaks (6.39 and 8.59) were obtained for BWR and BBI in October, respectively (Figure 30). In December, the minimum value of dissolved oxygen for BWR was 4.4 mg/L, while in October the maximum value was 8.5 mg/L for BBI (Figure 31). In December, the minimum value of alkalinity for BBI was 127.44 mg/L, while in February the maximum value was 575.81 mg/L for BWR (Figure 32).

Fungal Occurrence—According to the two-way ANOVA performed to the communities of filamentous fungi (propagules and spore counts, $N = 432$) in sea foam and the ones isolated from mangrove leaves (colonies in *A. germinans*, $N = 576$; in *R. mangle* $N = 576$), fungal variation was significant ($p > 0.05$) between the two communities studied (BBI and BWR) (Table VII). Statistical analysis suggested that intersept (date/site) was to be significant ($p > 0.05$), although date was insignificant ($p < 0.05$) in regards to H_0 (Table VII). Thus, this analysis reject H_0, in other words, it is unlikely that chance is operating to produce observed differences and the evidence is strong enough to support the significant effect, one that is probably not due to chance.

In sea foam samples from BBI and BWR, the microfungus *Cochliobolus pallescens* had the higher spore count (115.67 spores) in November, followed by *Exserohilum* sp. with 13.67 spores at the same month (Table VI, Figure 33). Similarly, at the same dates in BWR, *C. pallescens* had the higher spore count (144.00 spores), followed by *Exserohilum* sp. having 35.00 spores (Figure 34). Smaller peaks are noticeable in July (*C. pallescens* with 31.33 spores) and April (*C. pallescens* with 20.00 spores) (Figure 34).

In the *A. germinans* leaf baits from BBI, contained 72.33 colonies of *Penicillium roqueforti* var. *carneum* in May and a second peak (52.33 colonies) in November (Figure 35). The second most abundant fungus was *Aspergillus niger* with 54.67 colonies and a third smaller peak for *Pestalotiopsis disseminata* with 32.00 colonies, both in May (Figure 35). In BWR, 98.33 colonies of *P. roqueforti* var. *carneum* were isolated in November and 70.67 colonies in May (Figure 36). Both peaks were followed by *A. niger* with 65.33 colonies in May and 59.00 colonies in November (Figure 36).

From leaf baits of *Rhizophora mangle* in BBI 83.33 colonies were isolated of *P. roqueforti* var. *carneum* in May and 56.33 colonies in November (Figure 37). The second most abundant fungus was *A. niger* with 66.00 colonies in May and 38.67 colonies in November (Figure 37). Two more peaks are noticeable, one by *C. pallescens* (21.00 colonies) in November and the other by *P. disseminata* (20.67 colonies) in May (Figure 37). In BWR, *P. roqueforti* var. *carneum* had 100.00 colonies isolated in November and 78.67 colonies in May, and a third peak (47.33) appeared in February, and a fourth (25.33 colonies) in August (Figure 38). *Pestalotiopsis disseminata* also showed a small peak (15.67 colonies) in August (Figure 38). All these fungi were abundant in May and November (Figure 38) possibly because of the run-off input to RL by usually high rainfall (compare with Figure 23) in April to June and occurred again in August to October (Figure 38).

From the samples collected, I selected eight filamentous fungi, of which two belong to the ascomycetes and six to the mitosporic fungi (Table VI). The species *Aigialus* sp. (*A.* cf. *grandis*) (Ascomycota) and *Penicillium roqueforti* var. *carneum* (Mitosporic fungi) were new records for Puerto Rico. *Cochliobolus pallescens* (BBI = 50.51%; BWR = 50.98%), *Exserohilum* sp. (BBI = 16.95%; BWR = 15.37%), *Tetraploa aristata* (BBI = 11.74%; BWR = 14.26%), and *Alternaria* sp. (BBI = 10.88%; BWR = 9.53%), were frequently found in sea foam, while *P. roqueforti* var. *carneum* and *Aspergillus niger* were frequently found in mangrove leaves (*A. germinans* and *R. mangle*) in both BBI and BWR, followed closely by *Pestalotiopsis disseminata*, and *Alternaria* sp. in abundance (Figure 39, Table VII).

Other fungal species were also isolated from BBI and BWR sea foam and leaf litter: *Pleospora* sp., *Torpedorpora radiata* (Ascomycota), *Beltrania rhombica*, *Brachiosphaera tropicalis*, *Camposporidium* sp., *Curvularia robusta*, *Curvularia* sp., *Diplocladiella scalaroides*, *Helicomyces torquatus*, *Stemphylum* aff. *gracilariae*, and *Zalerion* cf. *maritimum* (Mitosporic fungi). *Camposporidium* sp. conidia resembled *Camposporidium* spp. reported from Río Sonadora and Quebrada Jiménez next to El Verde LTER Field Station, Puerto Rico (Hamilton, 1973: Figs. 36 and 39) and the one isolated from Río Manatí mouth by Nieves-Rivera and Santos-Flores (2004). Some specimens of *B. tropicalis* showed a halo around the central cell, while other *B. tropicalis* were typical, as reported by Nieves-Rivera and Santos-Flores (in press). Aquatic hyphomycetes are frequently found in estuarine habitats (Johnson and Sparrow, 1961; Kohlmeyer and Kohlmeyer, 1979). For example, Kirk (1969) reported two lignicolous aquatic hyphomycetes (*Clavatospora stellatacula* and *Tetraploa aristata*) adapted to seawater conditions on Chesapeake Bay. *Tetraploa aristata* have been previously isolated from dead stalks and leaves of sugar cane *Saccharum officinarum* in Puerto Rico (Minter et al., 2001). *Stemphylium botryotium* was isolated from Boquerón Public Beach by Hernández-Vera (1972, 1975). The BBI and BWR specimens are similar in spore shape to *Stemphylium gracilariae* although its size is somewhat smaller, thus I named it *Stemphylium* aff. *gracilariae*.

In conclusion, few marine ascomycetes were isolated probably due to the selectivity of the isolation method employed, substrates, environmental conditions, and geomorphology of the lagoon. Ascomycetes and mitosporic fungi (mostly aquatic hyphomycetes) are found mixed in foam, leaf litter, and beach sand of RL. Most of the species studied are terrestrial hyphomycetes that might have been introduced by the river flow or by land run-off into riverine or brackish stagnant waters. All species isolated in this study are saprobes living in parts of angiosperms, mangroves, debris, or in the blades of seagrasses.

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Table IV. Study sites in Boquerón Beach Inlet (BBI) and Boquerón Wildlife Refuge (BWR), both part of the Rincón Lagoon, Boquerón Commonwealth Forest, Cabo Rojo, southwestern Puerto Rico.

Locality	Collection Sites	Coordinates	Mangroves and Associates
BBI	Station 1	18°00’68.4” N, 67°10’32.2” W	*Avicennia germinans* *Laguncularia racemosa* *Rhizophora mangle*
BBI	Station 2	18°00’67.8” N, 67°10’31.4” W	*Avicennia germinans* *Laguncularia racemosa* *Rhizophora mangle* *Thespesia populnea*
BBI	Station 3	18°00’47.1” N, 67°10’65.2” W	*Avicennia germinans* *Laguncularia racemosa* *Rhizophora mangle*
BWR	Station 4	18°01’07.2” N, 67°09’94.6” W	*Acrostichum* spp. *Avicennia germinans* *Laguncularia racemosa* *Rhizophora mangle* *Thespesia populnea*
BWR	Station 5	18°00’95.4” N, 67°09’99.4” W	*Avicennia germinans* *Laguncularia racemosa* *Rhizophora mangle* *Thespesia populnea*
BWR	Station 6	18°00’65.3” N, 67°10’12.2” W	*Avicennia germinans* *Laguncularia racemosa* *Rhizophora mangle* *Thespesia populnea*

Table V. Monthly and annual environmental averages of study sites (Boquerón Beach Inlet: Stations 1-3; Boquerón Wildlife Refuge: Stations 4-6) from Rincón Lagoon, Cabo Rojo, southwestern Puerto Rico.

Boquerón Beach Inlet (BBI)

Date (mm-yy)	Barometric Pressure (mb)	Air Temperature (°C)	Relative Humidity (%)	Salinity (g/L)	Water Temperature (°C)	pH	Turbidity (JTU)	Dissolved Oxygen (mg/L)	Alkalinity (mg/L)	Ammonium (mg/L)	Nitrate (mg/L)	Nitrite (mg/L)
Feb-02	1012.33	25	76	37.78	26.22	7.79	37.22	6.92	161.63	0	0	0
Mar-02	1013	25.07	84.07	37.72	27.85	7.72	28.33	8.06	142.04	0	0	0
Apr-02	1014	25.56	78.33	38	24	8	10	7.13	146.93	0	0	0
May-02	1009.41	32	83.33	38	31.22	7.88	60	7.09	149.3	0	0	0
Jun-02	1015	32.83	80.22	37	30	8.23	31.11	7	143.96	0	0	0
Jul-02	1015.57	34.33	74.33	37	30.67	8.17	6.67	6.01	144.56	0.03	0	0
Aug-02	1010.89	32.78	78.22	35.11	29.89	7.92	43.33	5.54	131.96	0	0	0
Sep-02	1010.67	32.5	80.89	34.33	28.96	7.88	20	6.47	138.3	0	0	0
Oct-02	1013	33	73.33	34	29.89	8.59	26.67	5.27	140.22	0	0	0
Nov-02	1013	27.83	75.78	34	29.54	7.77	0	6.94	139.22	0	0	0
Dec-02	1014	27	83.33	33	27.66	6.2	53.33	8.37	127.44	0	0	0
Jan-03	1012	25.17	71.33	36.39	26.67	8.53	8.33	6.49	131	0	0	0
Annual Average	**1012.74**	**29.42**	**78.26**	**36.03**	**28.55**	**7.89**	**27.08**	**6.77**	**141.38**	**0.00**	**0.00**	**0.00**

Boquerón Wildlife Refuge (BWR)

Date (mm-yy)	Barometric Pressure (mb)	Air Temperature (°C)	Relative Humidity (%)	Salinity (g/L)	Water Temperature (°C)	pH	Turbidity (JTU)	Dissolved Oxygen (mg/L)	Alkalinity (mg/L)	Ammonium (mg/L)	Nitrate (mg/L)	Nitrite (mg/L)
Feb-02	1014	26	0	12	31.07	8.31	100	5.22	575.81	0	0	0
Mar-02	1014.33	30.83	87	22.67	30.33	7.94	100	6.56	167.22	0	0	0
Apr-02	1013	29	79.89	20.33	30	8.17	100	7.7	406.04	0	0	0
May-02	1009.89	29.56	80.78	17.63	28.94	7.54	100	6.51	223.96	0	1	0.02

Jun-02	1014.89	28.28	77.89	31.44	28.33	7.93	100	5.87	299.33	0	0.98	0.02
Jul-02	1013.33	34	75.67	27.99	30.89	8.17	100	5.35	274.44	0	1.1	0
Aug-02	1010.22	33	76.33	24.22	29.85	8.01	100	5.62	412.41	0	0	0
Sep-02	1010.67	32.56	77.11	22.33	29.78	8.08	95	5.86	141.56	0	0	0
Oct-02	1011	36.17	75.33	29.56	30.2	6.39	86.67	4.33	285.81	0	0	0
Nov-02	1012.33	27.24	78.76	30.28	30.11	7.86	77.78	6.86	300.96	0	0	0
Dec-02	1014	31.56	79	32.33	28.67	8.07	86.67	7.4	133	0	0	0
Jan-03	1012.67	24.5	77.93	33.67	27	7.48	100	7.28	133.89	0	0	0
Annual Average	**1012.53**	**30.23**	**72.14**	**25.37**	**29.60**	**7.83**	**95.51**	**6.21**	**279.54**	**0.00**	**0.26**	**0.00**

Table VI. Monthly and annual averages of selected filamentous fungi isolated from sea foam and mangrove leaves from collection sites in Rincón Lagoon, Boquerón Commonwealth Forest, southwestern Puerto Rico during February 2002 through January 2003.

Sea Foam/Boquerón Beach Inlet[1]

Date (mm-yy)	*Aigialus* sp.	*Alternaria* sp.	*Cochliobolus pallescens*	*Exserohilum* sp.	*Pestalotiopsis disseminata*	*Tetraploa aristata*
Feb-02	0.33	4.33	3.33	10.00	1.00	0.33
Mar-02	4.67	2.33	2.67	6.33	0.67	2.00
Apr-02	2.33	0.67	3.00	4.33	0.33	1.00
May-02	2.00	0.67	5.00	2.00	1.33	1.33
Jun-02	0.67	2.00	13.33	1.33	0.33	3.33
Jul-02	1.00	9.00	23.67	8.00	1.00	11.00
Aug-02	2.00	1.33	2.33	3.33	0.33	1.33
Sep-02	1.00	1.67	0.33	2.67	1.33	6.67
Oct-02	1.00	1.67	4.33	2.33	1.00	9.00
Nov-02	1.00	8.33	115.67	13.67	6.00	4.00
Dec-02	0.67	5.67	0.33	1.33	2.67	0.33
Jan-03	1.33	0.33	2.67	4.00	0.67	0.67
Total = 29.14	**1.50 = 5.15 %**	**3.17 = 10.88 %**	**14.72 = 50.51 %**	**4.94 = 16.95 %**	**1.39 = 4.77 %**	**3.42 = 11.74 %**

Sea Foam/Boquerón Wildlife Refuge[1]

Date (mm-yy)	*Aigialus* sp.	*Alternaria* sp.	*Cochliobolus pallescens*	*Exserohilum* sp.	*Pestalotiopsis disseminata*	*Tetraploa aristata*
Feb-02	1.00	3.00	8.33	4.00	0.67	5.00
Mar-02	12.67	6.33	11.67	6.00	3.67	17.33
Apr-02	2.67	8.00	20.00	12.67	0.67	3.33
May-02	0.00	3.00	8.67	3.33	0.67	3.33
Jun-02	1.67	1.33	11.67	2.67	3.00	4.67

Jul-02	5.67	13.00	31.33	7.67	0.33	10.00
Aug-02	0.00	1.00	1.67	0.33	0.00	0.00
Sep-02	0.00	0.00	0.33	0.33	0.00	6.67
Oct-02	0.67	2.33	5.33	0.00	1.00	13.33
Nov-02	1.33	9.00	144.00	35.00	9.00	7.00
Dec-02	3.00	1.00	13.33	6.00	2.33	1.67
Jan-03	0.00	0.33	2.33	0.00	0.00	0.00
Total = 42.29	**2.39 = 5.65 %**	**4.03 = 9.53 %**	**21.56 = 50.98 %**	**6.50 = 15.37 %**	**1.78 = 4.21 %**	**6.03 = 14.26 %**

Avicennia germinans Leaves/Boquerón Beach Inlet

Date (mm-yy)	*Aigialus* sp.	*Alternaria* sp.	*Aspergillus niger*	*Cochliobolus pallescens*	*Exserohilum* sp.	*Pestalotiopsis disseminata*	*Penicillium roqueforti*[2]	*Tetraploa aristata*
Feb-02	1.67	3.00	45.00	3.67	0.67	5.67	28.67	0.33
Mar-02	0.67	8.67	29.33	1.33	0.33	15.33	30.33	0.00
Apr-02	1.00	3.67	15.67	3.00	3.33	2.00	33.33	0.00
May-02	5.67	9.00	54.67	5.00	0.33	32.00	72.33	0.00
Jun-02	5.67	5.33	29.67	15.00	0.00	2.33	20.67	0.00
Jul-02	3.00	1.33	26.67	2.67	0.67	6.33	18.33	0.00
Aug-02	3.33	5.00	23.33	0.33	2.00	0.33	23.67	0.00
Sep-02	2.33	13.33	12.67	1.00	0.00	9.67	29.00	0.00
Oct-02	3.67	8.67	22.67	4.33	0.67	10.00	3.33	0.00
Nov-02	0.00	0.33	46.67	14.33	0.33	17.33	52.33	0.00
Dec-02	4.00	1.67	31.67	3.33	0.33	3.67	25.00	0.00
Jan-03	0.00	1.33	13.67	2.00	0.00	5.33	11.67	0.00
Total = 80.90	**2.58 = 3.19 %**	**5.11 = 6.32 %**	**29.31 = 36.23 %**	**4.67 = 5.77 %**	**0.72 = 0.89 %**	**9.17 = 11.33 %**	**29.06 = 35.92 %**	**0.28 = 0.35 %**

Avicennia germinans Leaves/Boquerón Wildlife Refuge

Date (mm-yy)	*Aigialus* sp.	*Alternaria* sp.	*Aspergillus niger*	*Cochliobolus pallescens*	*Exserohilum* sp.	*Pestalotiopsis disseminata*	*Penicillium roqueforti*[2]	*Tetraploa aristata*
Feb-02	1.33	3.00	45.00	0.67	0.00	2.33	51.67	0.00
Mar-02	0.00	1.67	18.67	0.33	0.00	1.00	41.33	0.00
Apr-02	0.67	1.00	18.67	4.67	3.00	0.33	48.00	0.00
May-02	3.00	1.67	65.33	1.00	1.67	4.67	70.67	0.33
Jun-02	0.33	0.67	33.33	0.33	1.00	1.67	14.67	0.33
Jul-02	0.00	4.33	24.00	2.33	1.00	2.33	12.00	0.00
Aug-02	0.33	0.67	23.33	0.33	2.00	3.00	14.00	0.00
Sep-02	0.00	2.33	7.67	0.67	1.33	1.33	4.33	0.00
Oct-02	0.00	2.33	24.67	0.33	0.00	1.67	4.00	0.33
Nov-02	0.00	0.00	59.00	2.67	3.67	0.33	98.33	0.00
Dec-02	0.00	0.00	47.67	2.33	4.00	1.33	19.33	1.00
Jan-03	0.00	1.00	13.33	0.33	0.00	0.00	29.67	0.00
Total = 73.87	**0.47 = 0.64 %**	**1.55 = 2.10 %**	**31.72 = 42.94 %**	**1.33 = 1.80 %**	**1.47 = 1.99 %**	**1.67 = 2.26 %**	**34.00 = 46.03 %**	**1.66 = 2.25 %**

Rhizophora mangle Leaves/Boquerón Beach Inlet

Date (mm-yy)	*Aigialus* sp.	*Alternaria* sp.	*Aspergillus niger*	*Cochliobolus pallescens*	*Exserohilum* sp.	*Pestalotiopsis disseminata*	*Penicillium roqueforti*[2]	*Tetraploa aristata*
Feb-02	3.67	6.67	33.67	4.33	0.33	6.67	29.33	0.33
Mar-02	0.67	9.00	37.67	1.33	1.00	13.00	23.00	0.00
Apr-02	8.00	6.00	14.33	2.33	4.33	2.00	25.00	0.67
May-02	8.00	9.67	66.00	3.67	2.33	20.67	83.33	0.33
Jun-02	5.00	8.33	25.33	11.00	0.00	5.67	23.67	0.33
Jul-02	3.00	0.33	27.33	6.33	2.00	7.00	24.33	0.00
Aug-02	4.33	3.33	22.67	0.33	4.00	2.00	25.33	0.00
Sep-02	3.33	9.67	7.67	3.33	0.33	8.67	26.33	0.00
Oct-02	7.00	13.67	29.00	2.67	1.67	8.33	6.00	0.00
Nov-02	0.00	2.00	38.67	21.00	0.67	10.67	56.33	0.00
Dec-02	3.33	4.67	24.67	4.00	1.00	11.67	12.00	0.00
Jan-03	0.33	0.33	17.67	6.33	0.00	4.67	12.33	0.00

Total = 83.25	**3.89 = 4.68 %**	**6.14 = 7.38 %**	**28.72 = 34.50 %**	**5.55 = 6.67 %**	**1.47 = 1.77 %**	**8.42 = 10.11 %**	**28.92 = 34.74 %**	**0.14 = 0.17 %**

Rhizophora mangle Leaves/Boquerón Wildlife Refuge

Date (mm-yy)	*Aigialus* sp.	*Alternaria* sp.	*Aspergillus niger*	*Cochliobolus pallescens*	*Exserohilum* sp.	*Pestalotiopsis disseminata*	*Penicillium roqueforti*[2]	*Tetraploa aristata*
Feb-02	2.33	6.67	33.67	1.67	0.00	4.00	47.33	0.00
Mar-02	0.00	2.67	39.33	1.00	0.00	1.67	31.67	0.00
Apr-02	2.33	5.67	32.33	6.00	7.67	1.00	46.67	1.00
May-02	8.00	3.00	48.33	1.33	4.00	9.00	78.67	0.67
Jun-02	0.00	1.00	22.00	0.67	1.00	5.67	15.33	0.67
Jul-02	0.67	3.00	25.33	2.00	1.67	2.33	12.00	0.00
Aug-02	1.67	3.67	22.67	0.33	4.00	15.67	25.33	0.00
Sep-02	1.67	3.33	5.33	1.67	5.67	1.67	18.33	0.00
Oct-02	3.00	6.33	30.33	2.33	0.00	3.67	6.67	2.00
Nov-02	0.00	0.00	76.67	7.33	1.67	2.33	100.00	0.67
Dec-02	1.00	0.00	30.33	5.33	4.67	6.00	16.00	0.00
Jan-03	0.00	1.67	18.67	1.00	0.00	0.00	8.67	0.00
Total = 80.70	**1.72 = 2.13 %**	**3.08 = 3.82 %**	**32.08 = 39.75 %**	**2.56 = 3.17 %**	**2.53 = 3.14 %**	**4.42 = 5.48 %**	**33.89 = 42.00 %**	**0.42 = 0.52 %**

[1] *Aspergillus niger* and *Penicillium roqueforti* var. *carneum* conidia were not counted from sea foam due to difficulties in isolation and identification of conidia by morphology alone.
[2] Although named *Penicillium roqueforti* in this table, it should be noticed that this species was identified as *Penicillium roqueforti* var. *carneum* (M. Klich, pers. comm., 2004).

Table VII. Univariate analysis of variance (Two-way ANOVA) of filamentous fungi collected from sea foam and mangrove leaves (*Avicennia germinans* and *Rhizophora mangle*) from Boquerón Beach Inlet (BBI) and Boquerón Wildlife Refuge (BWR) collection sites at Rincón Lagoon, Boquerón Commonwealth Forest, southwestern Puerto Rico during February 2002 through January 2003 ($\alpha = 0.05$).

Univariate Analysis of Variance (SEA FOAM)

Between-Subjects Factors

		Value Label	N
Date	FEB 02		36
	MAR 02		36
	APR 02		36
	MAY 02		36
	JUN 02		36
	JUL 02		36
	AUG 02		36
	SEP 02		36
	OCT 02		36
	NOV 02		36
	DEC 02		36
	JAN 03		36
Site	1	BWR	216
	2	BBI	216

Tests of Between-Subjects Effects

Dependent Variable: Seafoam spore count

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
Intercept	Hypothesis	15301.021	1	15301.021	29.545	.116
	Error	517.891	1	517.891[a]		
DATE	Hypothesis	24260.507	11	2205.501	9.108	.000
	Error	101463.581	419	242.157[b]		
SITE	Hypothesis	517.891	1	517.891	2.139	.144
	Error	101463.581	419	242.157[b]		

a. MS(SITE)

b. MS(Error)

Univariate Analysis of Variance (*Avicennia germinans*)

Between-Subjects Factors

		Value Label	N
Date	FEB 02		48
	MAR 02		48
	APR 02		48
	MAY 02		48
	JUN 02		48
	JUL 02		48
	AUG 02		48
	SEP 02		48
	OCT 02		48
	NOV 02		48
	DEC 02		48
	JAN 03		48
Site	1	BWR	288
	2	BBI	288

Tests of Between-Subjects Effects

Dependent Variable: Fungal spore count in *Avicennia*

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
Intercept	Hypothesis	52689.377	1	52689.377	344.059	.034
	Error	153.141	1	153.141[a]		
DATE	Hypothesis	13583.686	11	1234.881	4.490	.000
	Error	154856.797	563	275.056[b]		
SITE	Hypothesis	153.141	1	153.141	.557	.456
	Error	154856.797	563	275.056[b]		

a. MS(SITE)

b. MS(Error)

Univariate Analysis of Variance (*Rhizophora mangle*)

Between-Subjects Factors

		Value Label	N
Date	FEB 02		48
	MAR 02		48
	APR 02		48
	MAY 02		48
	JUN 02		48
	JUL 02		48
	AUG 02		48
	SEP 02		48
	OCT 02		48
	NOV 02		48
	DEC 02		48
	JAN 03		48
Site	1	BWR	288
	2	BBI	288

Tests of Between-Subjects Effects

Dependent Variable: Fungal spore count in *Rhizophora*

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
Intercept	Hypothesis	60475.007	1	60475.007	4115.501	.010
	Error	14.694	1	14.694[a]		
DATE	Hypothesis	14667.660	11	1333.424	5.126	.000
	Error	146448.639	563	260.122[b]		
SITE	Hypothesis	14.694	1	14.694	.056	.812
	Error	146448.639	563	260.122[b]		

a. MS(SITE)

b. MS(Error)

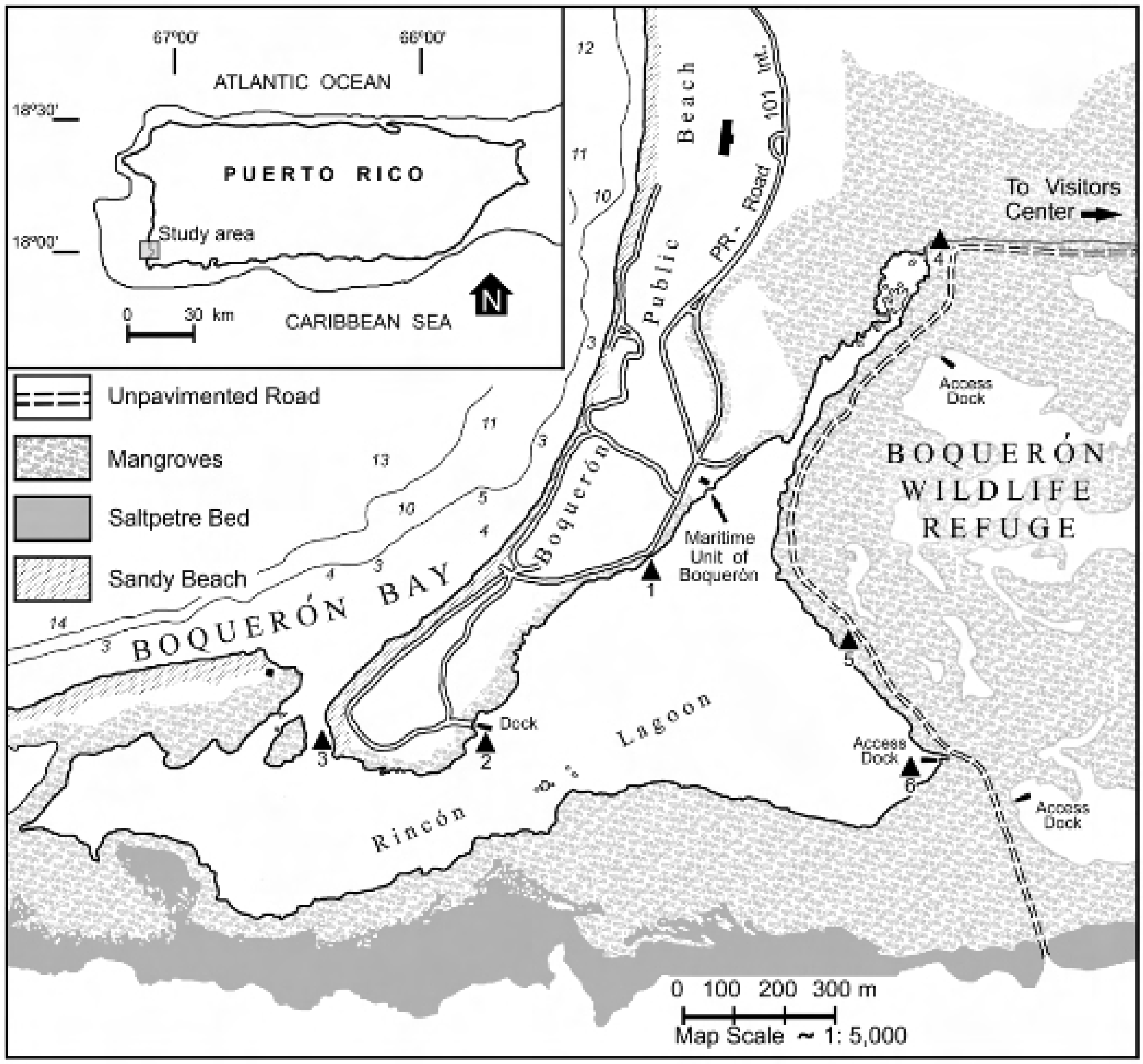

Figure 20. Location of sampling sites at Rincón Lagoon, Boquerón Commonwealth Forest, Cabo Rojo, southwestern Puerto Rico. Stations 1 to 3 are referred through the text as 'Boquerón Beach Inlet' (BBI) and the remaining stations (4 to 6) as 'Boquerón Wildlife Refuge' (BWR).

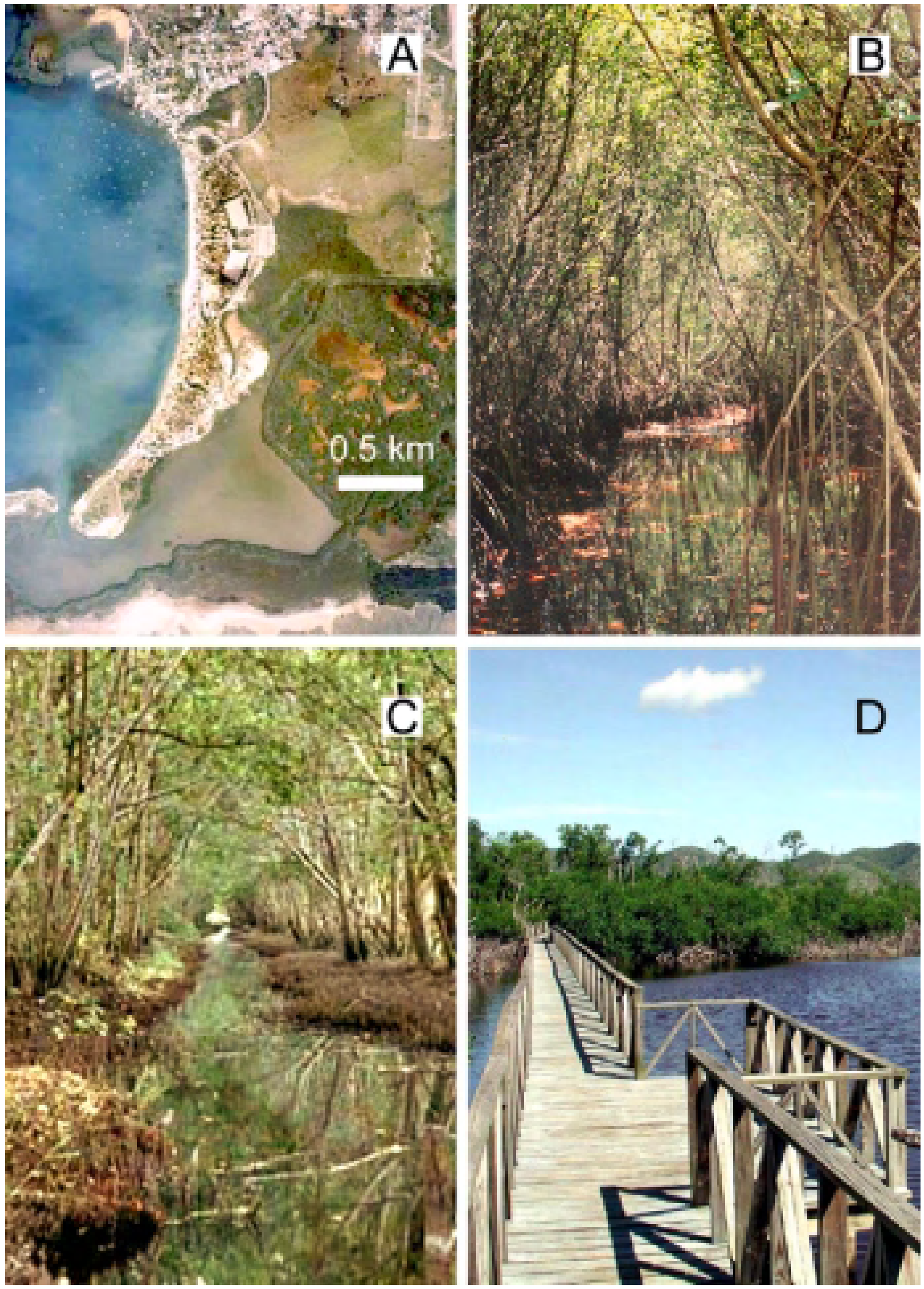

Figure 21A–D. Boquerón Commonwealth Forest, Cabo Rojo, southwestern Puerto Rico. A. Aerial photo of the Boquerón Bay, including view of the Rincón Lagoon, Boquerón Wildlife Refuge and Puerto Real. B–C. *Rhizophora mangle* (B) and *Avicennia germinans* (C) forming channels in the Boquerón Wildlife Refuge. D. Boardwalk prepared by the Puerto Rico Department of Natural Resources and brackish water lagoon.

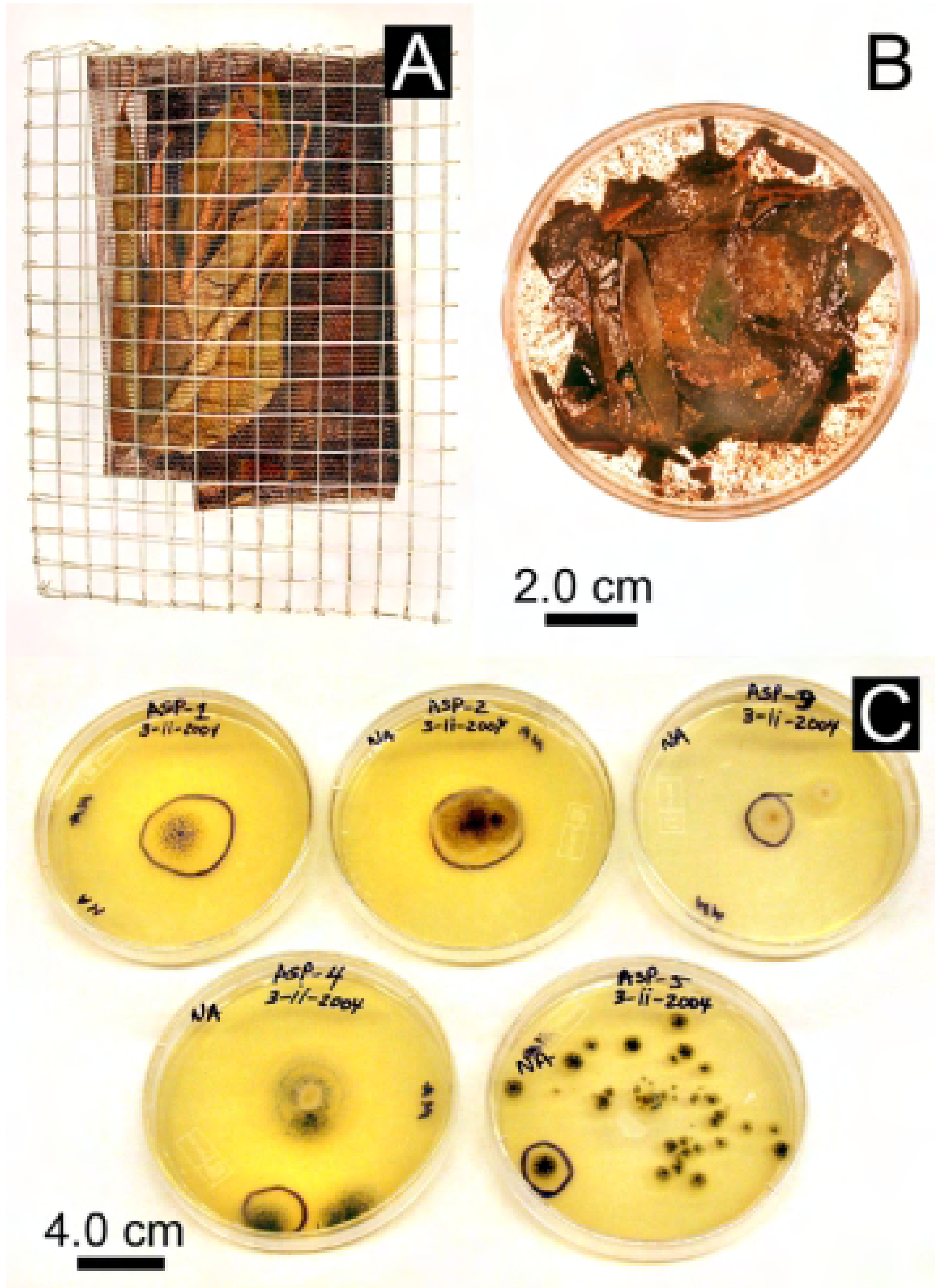

Figure 22A–C. Leaf baits and traps used for the isolation of estuarine fungi of Rincón Lagoon, Boquerón Commonwealth Forest, Cabo Rojo, southwestern Puerto Rico. A. Leaf baits (*Rhizophora mangle*) in 1.8 mm^2 mesh plastic-screen packet contained in a 1.0 cm^2 meshed aluminum envelope. B. Leaves of *R. mangle* culture in a Petri dish. C. Potato dextrose agar (PDA) with fungal isolates.

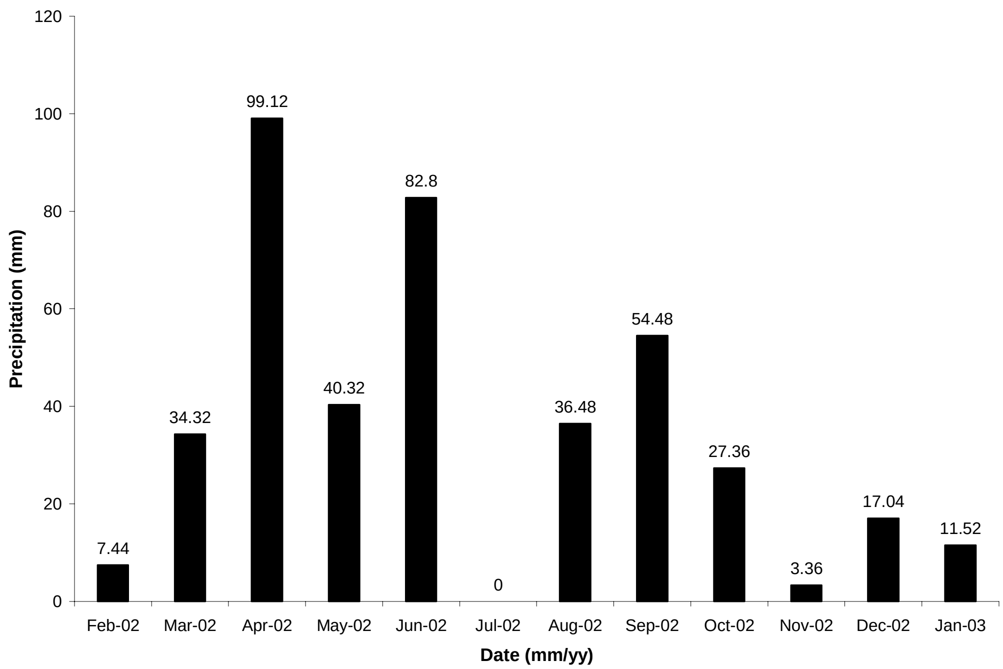

Figure 23. Annual rainfall (February 2002 to January 2003) in Magueyes Island Marine Laboratories, La Parguera, southwestern Puerto Rico.

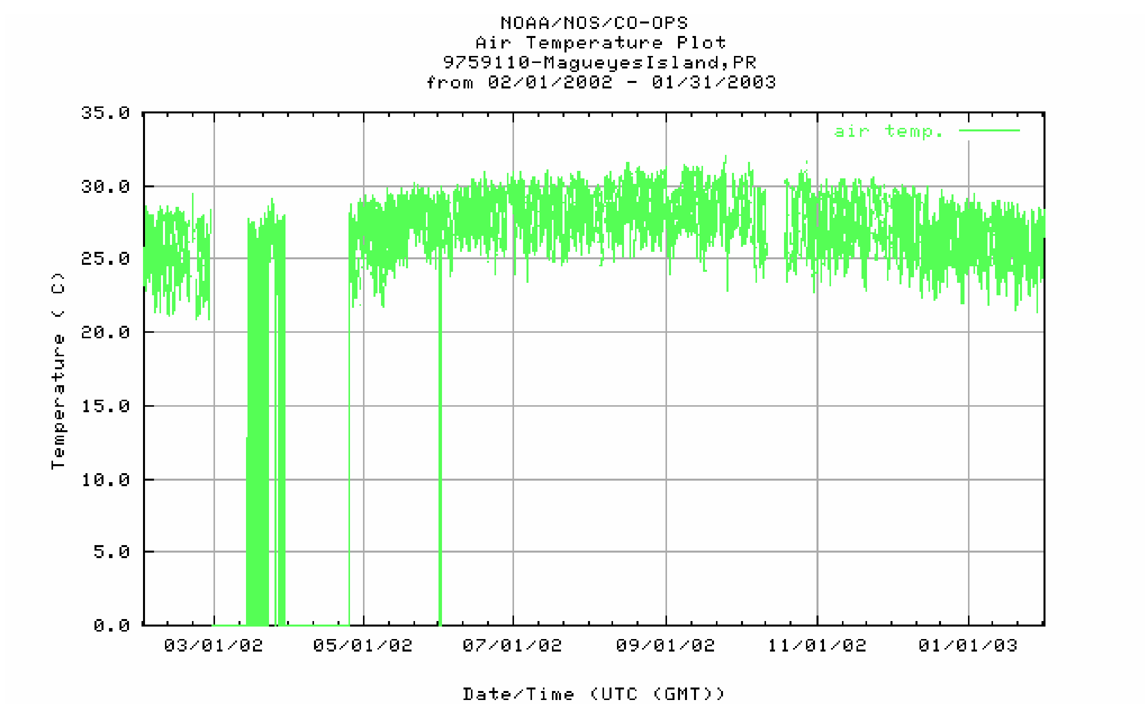

Figure 24. Average air temperature (°C) during February 2002 to January 2003 in Magueyes Island Marine Laboratories, La Parguera, southwestern Puerto Rico (graph courtesy of NOAA/NOS/CO-OPS).

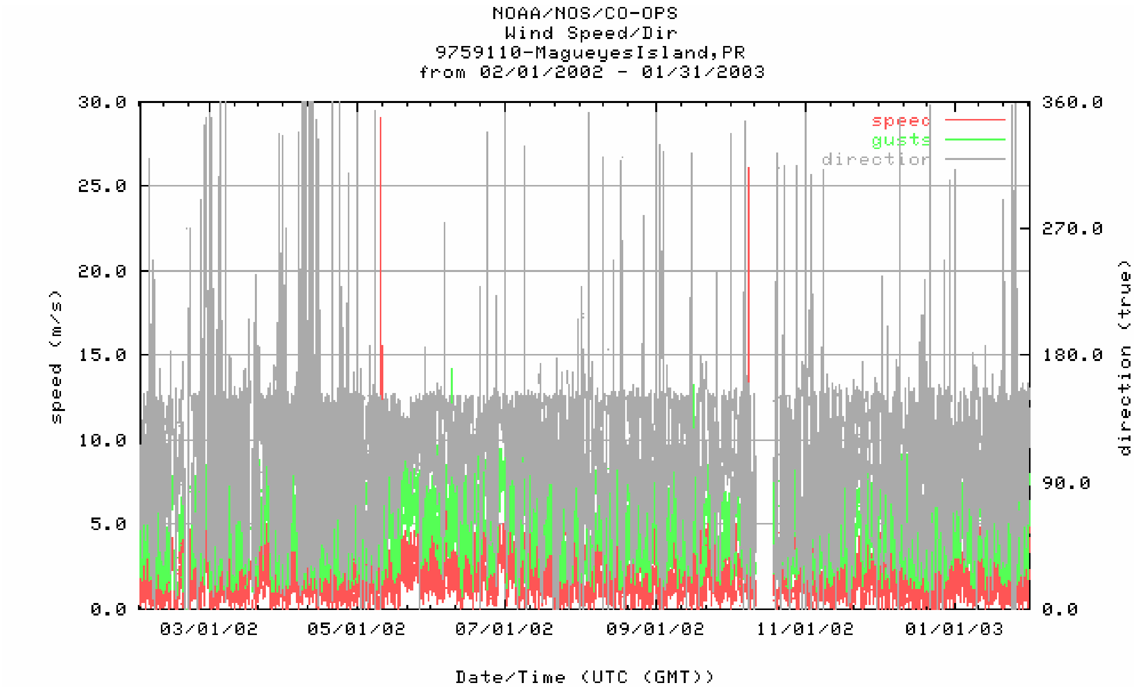

Figure 25. Average wind speed (m/s) and direction (true) during February 2002 to January 2003 in Magueyes Island Marine Laboratories, La Parguera, southwestern Puerto Rico (graph courtesy of NOAA/NOS/CO-OPS).

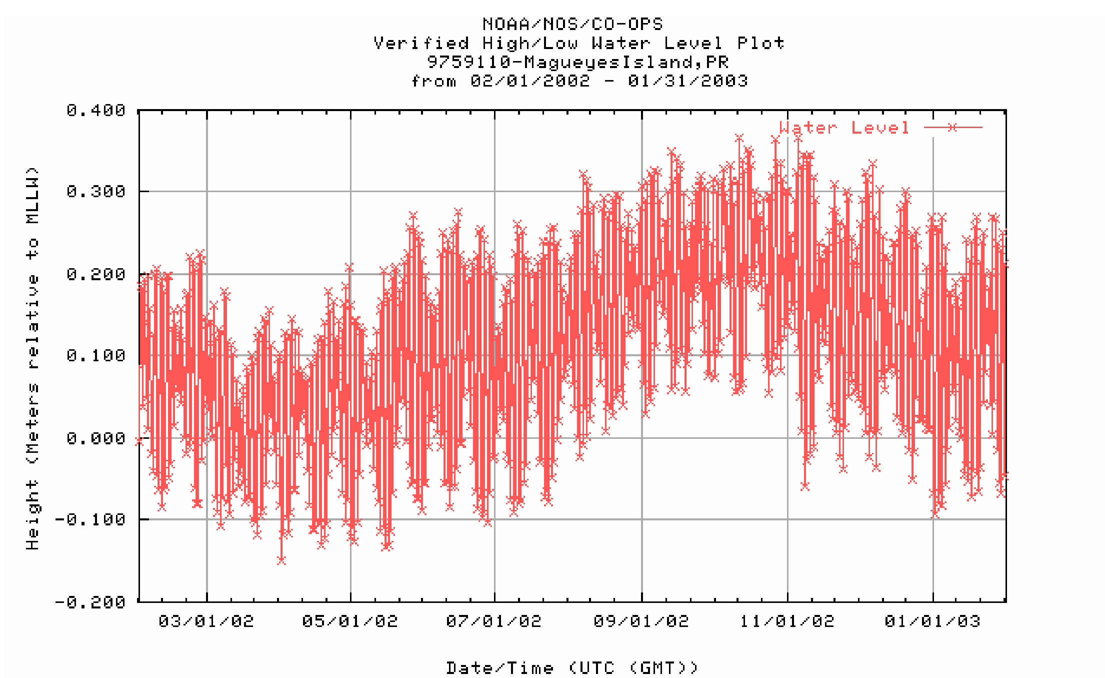

Figure 26. Water level (m) during February 2002 to January 2003 in Magueyes Island Marine Laboratories, La Parguera, southwestern Puerto Rico (graph courtesy of NOAA/NOS/CO-OPS).

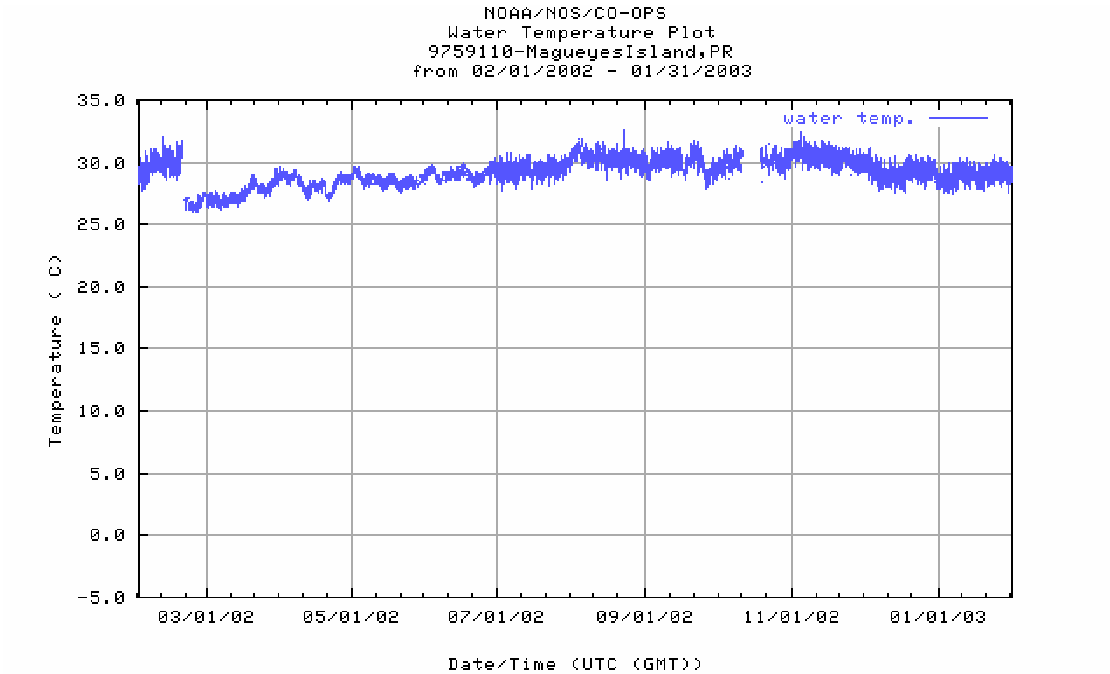

Figure 27. Average water temperature (°C) during February 2002 to January 2003 in Magueyes Island Marine Laboratories, La Parguera, southwestern Puerto Rico (graph courtesy of NOAA/NOS/CO-OPS).

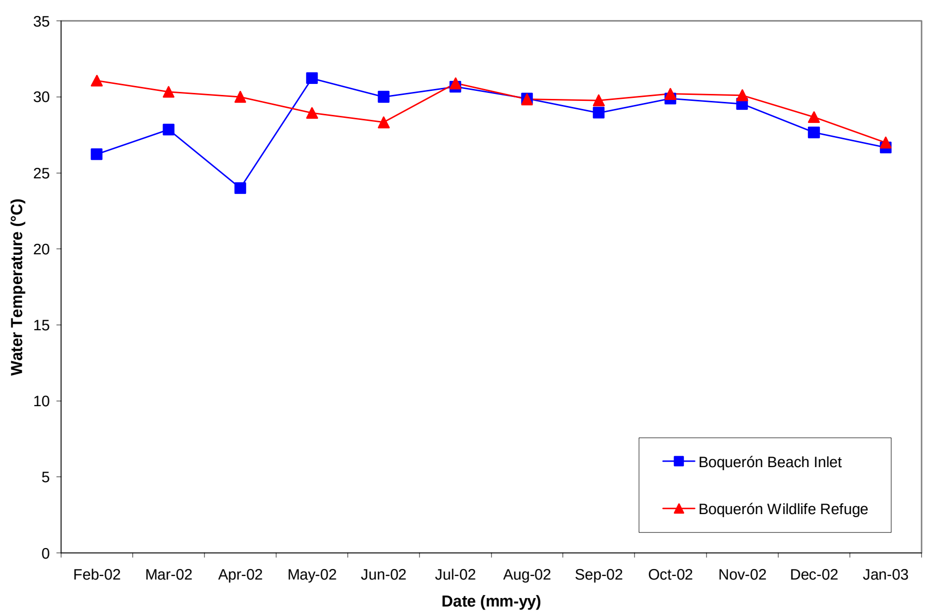

Figure 28. Average water temperature (°C) of sampling sites at Rincón Lagoon, Boquerón Commonwealth Forest, southwestern Puerto Rico.

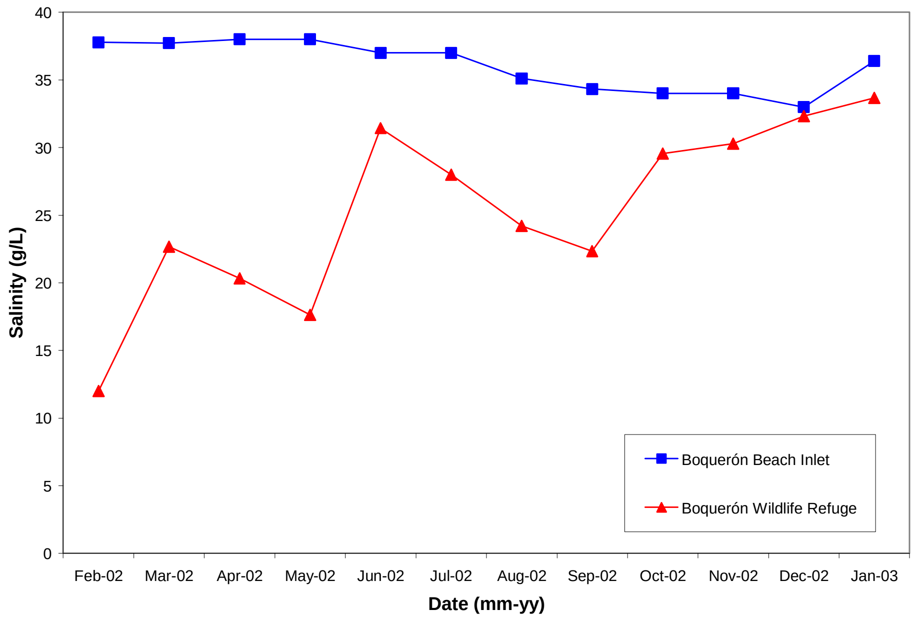

Figure 29. Average salinity (g/L) of sampling sites at Rincón Lagoon, Boquerón Commonwealth Forest, southwestern Puerto Rico.

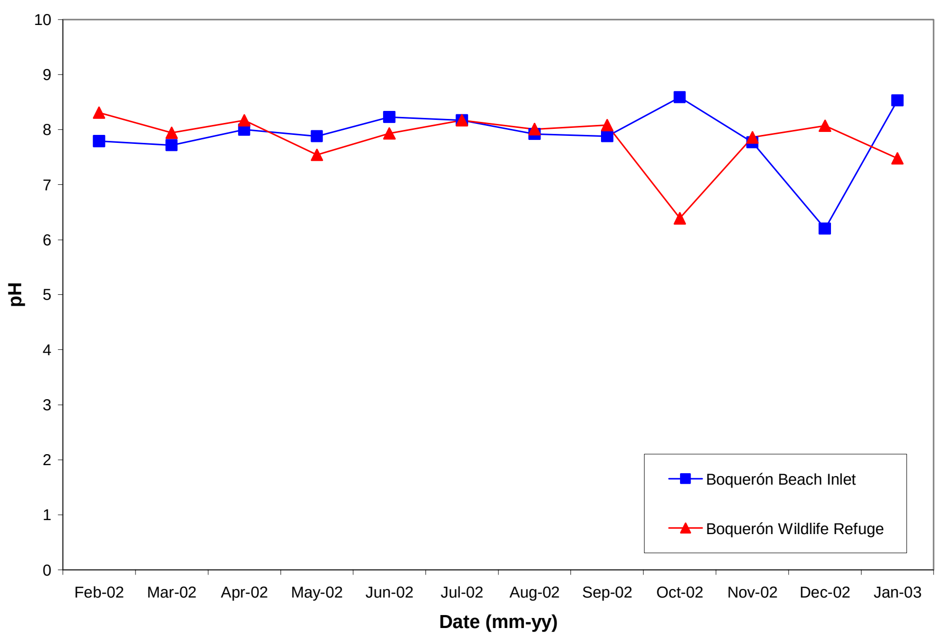

Figure 30. Average pH of sampling sites at Rincón Lagoon, Boquerón Commonwealth Forest, southwestern Puerto Rico.

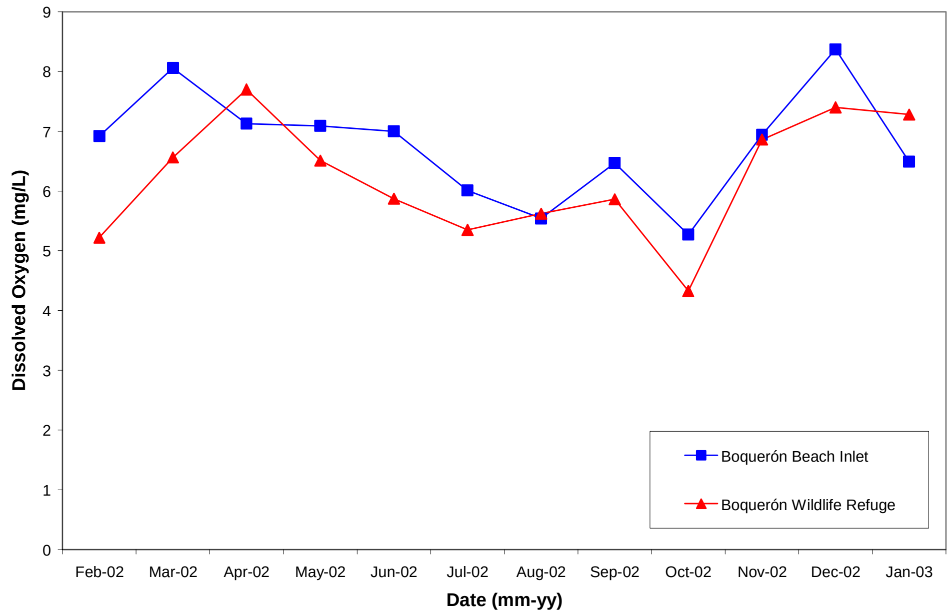

Figure 31. Average dissolved oxygen (mg/L) of sampling sites at Rincón Lagoon, Boquerón Commonwealth Forest, southwestern Puerto Rico.

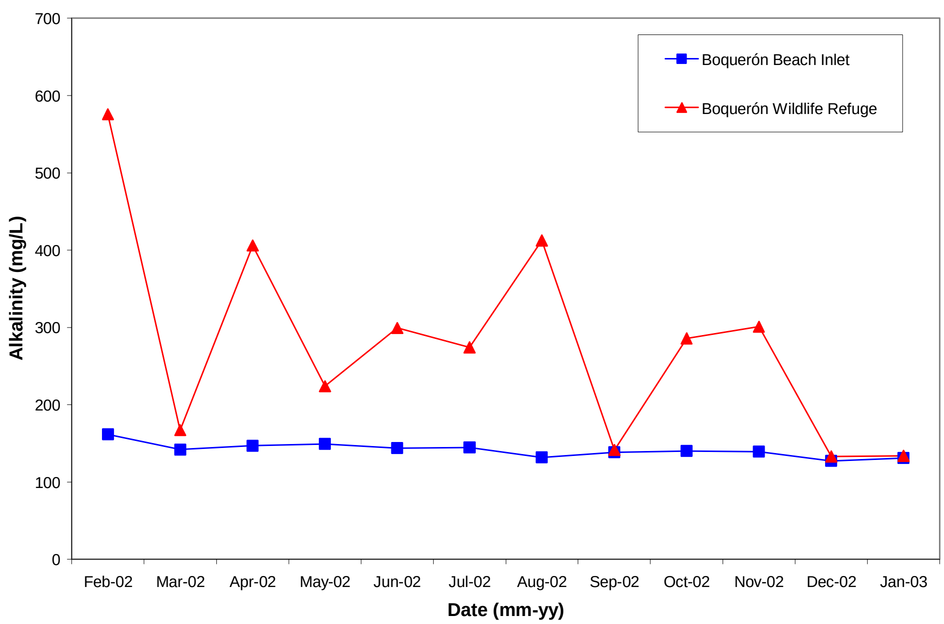

Figure 32. Average alkalinity (mg/L) of sampling sites at Rincón Lagoon, Boquerón Commonwealth Forest, southwestern Puerto Rico.

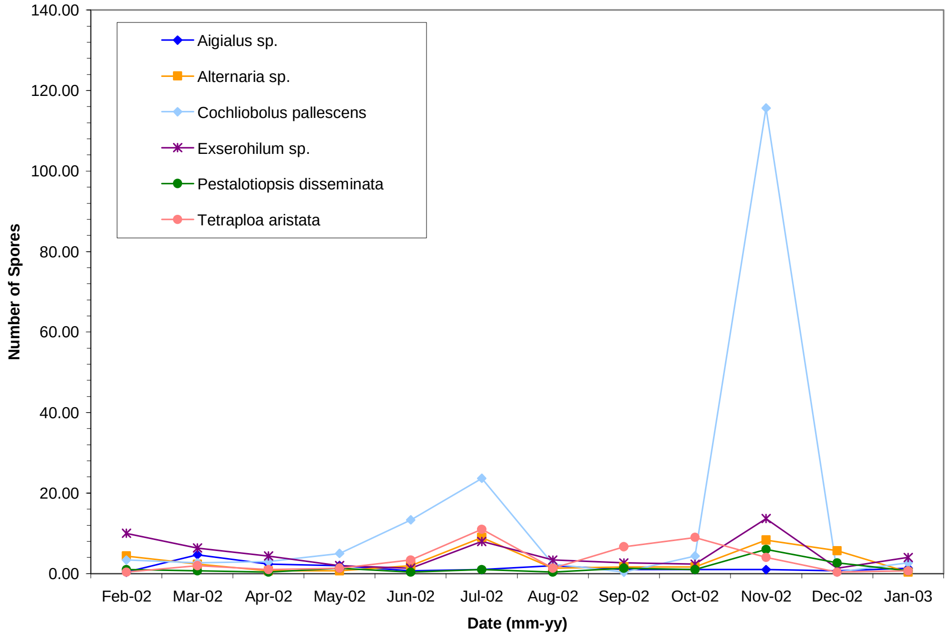

Figure 33. Number of fungal spores in sea foam per month during the year of sampling at Boquerón Beach Inlet, Rincón Lagoon, southwestern Puerto Rico.

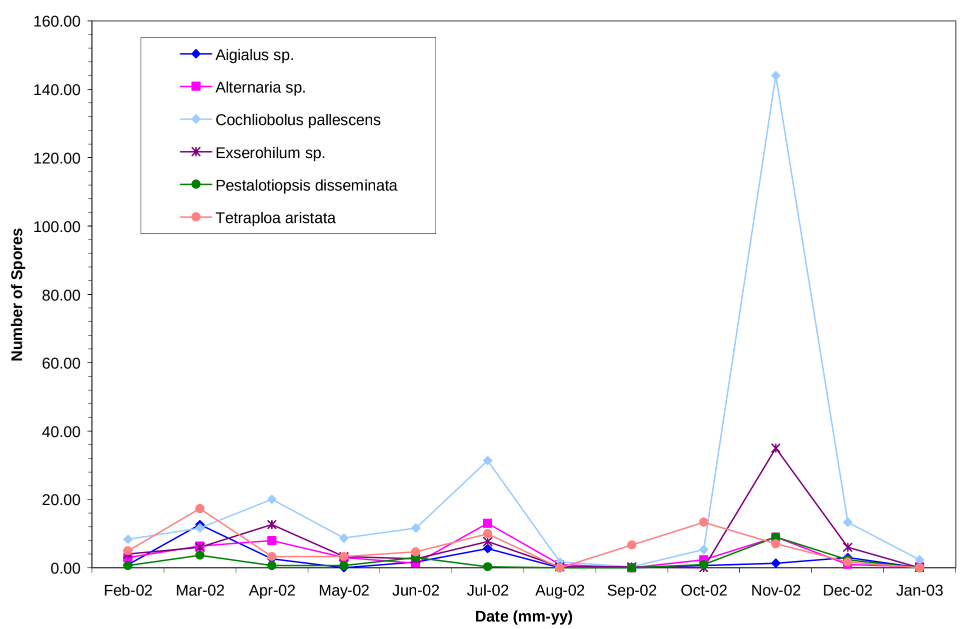

Figure 34. Number of fungal spores in sea foam per month during the year of sampling at Boquerón Wildlife Refuge, Rincón Lagoon, southwestern Puerto Rico.

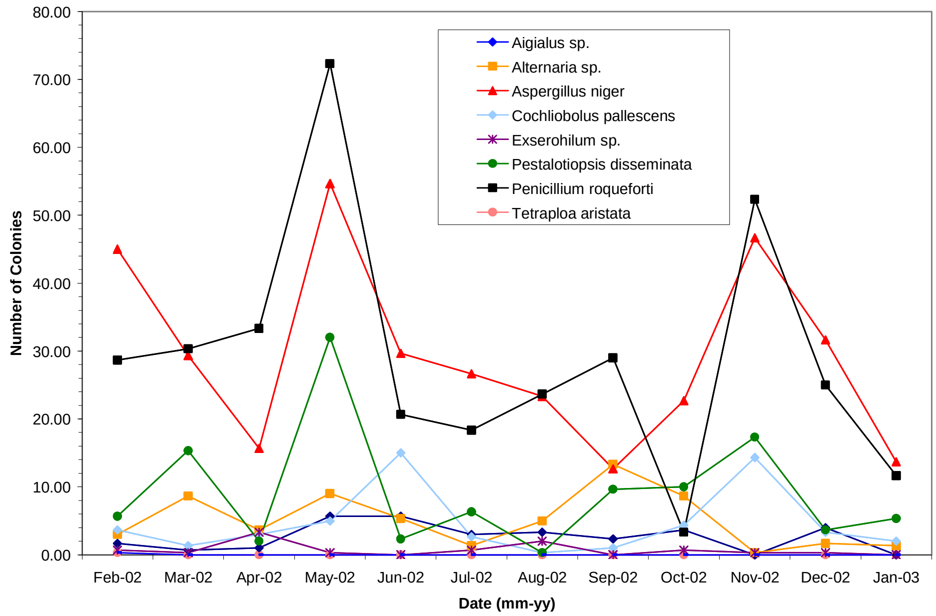

Figure 35. Number of fungal colonies in *Avicennia germinans* leaves per month during the year of sampling at Boquerón Beach Inlet, Rincón Lagoon, southwestern Puerto Rico.

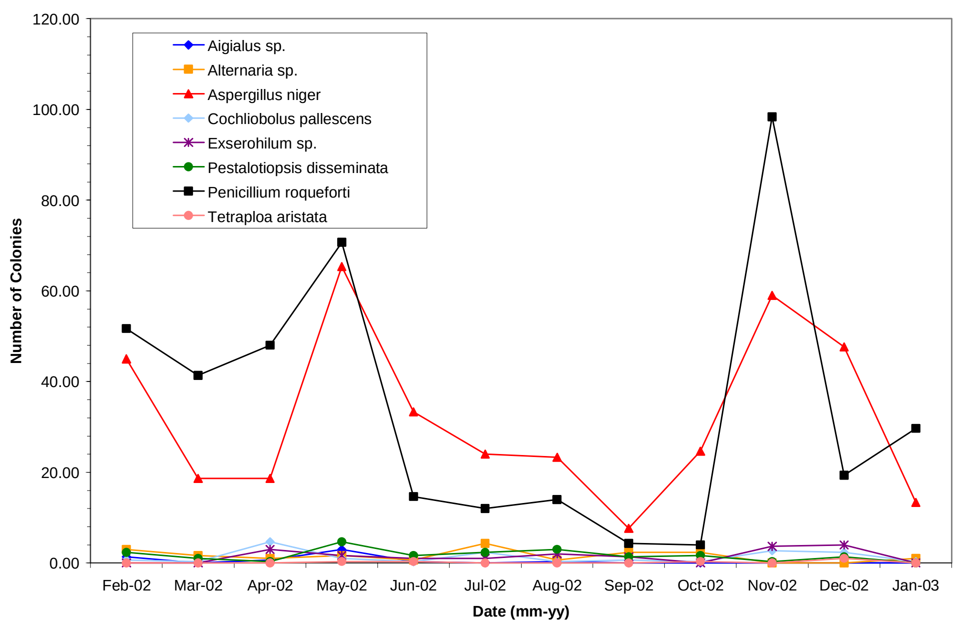

Figure 36. Number of fungal colonies in *Avicennia germinans* leaves per month during the year of sampling at Boquerón Wildlife Refuge, Rincón Lagoon, southwestern Puerto Rico.

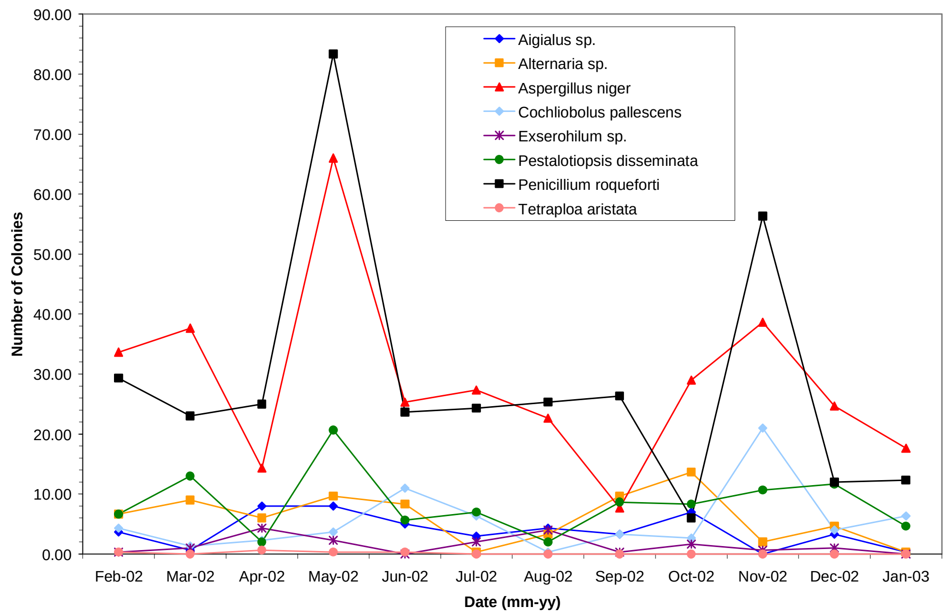

Figure 37. Number of fungal colonies in *Rhizophora mangle* leaves per month during the year of sampling at Boquerón Beach Inlet, Rincón Lagoon, southwestern Puerto Rico.

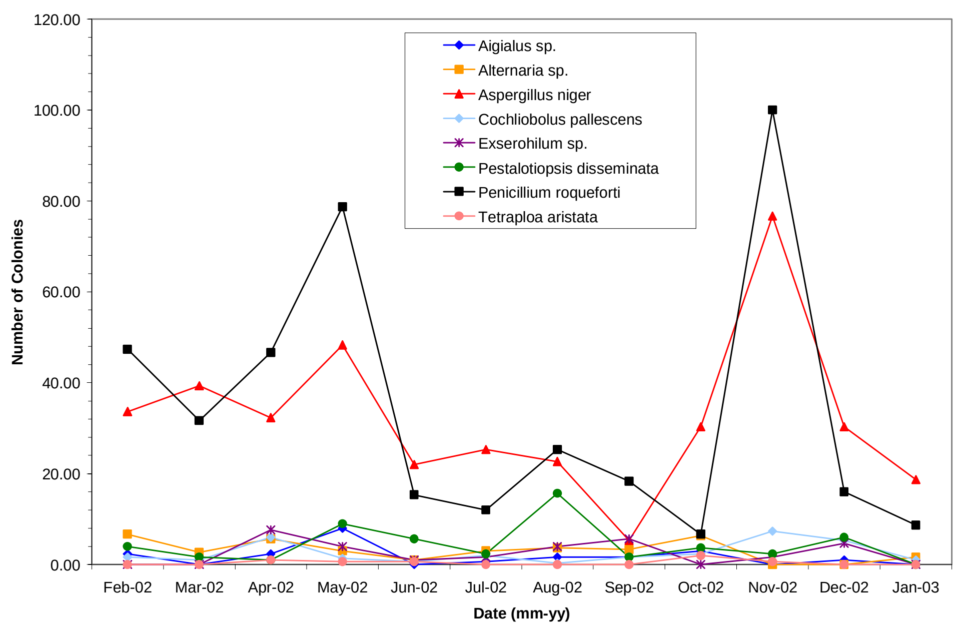

Figure 38. Number of fungal colonies in *Rhizophora mangle* leaves per month during the year of sampling at Boquerón Wildlife Refuge, Rincón Lagoon, southwestern Puerto Rico.

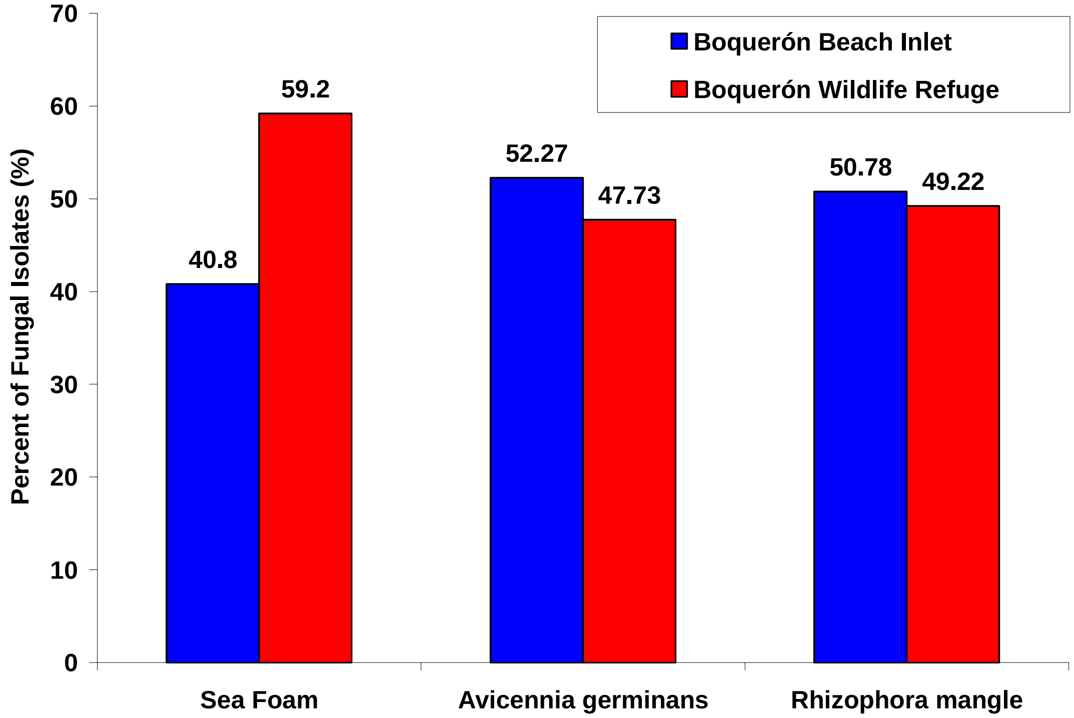

Figure 39. Total percentage of fungal isolates from substrates (sea foam, leaves of *Avicennia germinans*, and *Rhizophora mangle*) in the sampling sites at Rincón Lagoon, Boquerón Commonwealth Forest, Cabo Rojo, southwestern Puerto Rico.

CHAPTER 5

CHARACTERIZATION OF *CLADOSPORIUM OXYSPORUM* AND *C. SPHAEROSPORUM* USING POLYAROMATIC HYDROCARBONS (PAHs) AS THEIR SOLE CARBON SOURCE IN TROPICAL COASTAL SEAWATER

ABSTRACT

Two species of *Cladosporium* (*C. oxysporum* and *C. sphaerospermum*) were isolated from surface coastal seawater based on their ability to use the polyaromatic hydrocarbons (PAHs) naphthalene ($C_{10}H_8$) and phenanthrene ($C_{14}H_{10}$) as a sole carbon and energy source. Although both *Cladosporium* spp. are cosmopolitan species, both species are new records to mangrove forests of Puerto Rico. These two species may be of value in the bioremediation of natural oil spills or other contaminants in tropical environments.

RESUMEN

Se aislaron dos especies de *Cladosporium* (*C. oxysporum* y *C. sphaerospermum*) de agua de mar superficial costera basándose en su habilidad de usar los hidrocarburos poliaromáticos (PAHs) nafataleno ($C_{10}H_8$) y fenantreno ($C_{14}H_{10}$) como fuentes de carbono y de energía. Aunque ambos *Cladosporium* spp. son especies cosmopolitas, ambas especies son nuevos registros para los bosques de mangles de Puerto Rico. Estas dos especies pueden ser de valor en la bioremediación de derrames naturales de aceite u otros contaminantes en ambientes tropicales.

INTRODUCTION

Polyaromatic hydrocarbons or polycyclic aromatic hydrocarbons (PAHs) are formed primarily as products from the combustion of fossil fuels. The United States Environmental Protection Agency lists 16 PAHs as priority pollutants (Zaidi and Imam, 1999). In marine environments, due to their hydrophobic nature and low water solubility, PAHs are readily adsorbed by particulate matter and tend to accumulate in sediments (Means et al., 1980). Because of their toxic, mutagenic, or carcinogenic properties, high concentrations of PAHs are harmful to the marine biota and human health (Stegeman, 1977). In Puerto Rico, for example, PAHs pollution has induced nuclear mutations for chlorophyll deficiency in trees of *Rhizophora mangle* (Corredor et al., 1995).

The fate of most petroleum substances in the marine environment is ultimately defined by their transformation and degradation due to microbial activity (Bragg et al., 1994). Microorganisms are the primary means of degrading PAHs naturally. About a hundred known species of microorganisms (e.g., bacteria and fungi) are able to use oil components to sustain their growth and metabolism. In pristine areas, their proportions usually do not exceed 0.1 to 1.0% of the total abundance of heterotrophic bacterial communities; in polluted areas, however, this proportion increases to 1.0 to 10.0% (Atlas and Bartha, 1997). Most of the information on degradation of PAHs has being derived from pure cultures that were isolated from temperate environments (Kirk and Gordon, 1988; Cerniglia and Sutherland, 2001; Qi et al., 2002). Very little information is available on isolation of fungal strains capable of degrading PAHs in subtropical marine environments (Acevedo, 2001).

Kohlmeyer & Kohlmeyer (1979) and González et al. (1998) have classified members of the genus *Cladosporium* as facultative marine fungi. These fungi from freshwater or terrestrial areas are capable of growing in the marine environment. *Cladosporium oxysporum* and *C. sphaerospermum* are typically geophilic (soil loving) and cosmopolitan (deVries, 1952). In this paper, we report the identification and characterization of *C. oxysporum* and *C. spherospermum* (from Cabo Rojo and Guayanilla, respectively, coastal waters of southwestern Puerto Rico) two species that are capable of degrading PAHs naphthalene ($C_{10}H_8$) and phenanthrene ($C_{14}H_{10}$).

MATERIALS AND METHOD

Guayanilla Bay (GB) is located on the south coast of Puerto Rico about 35 km east of the island's southwestern corner (Figure 4). This bay was the site of one of the largest petrochemical complexes in the world until these were shut down in 1982 (Zaidi and Imam, 1999). Many studies have determined the fate of PAHs at this bay after closure of industrial complex (Zaidi et al., 2003). Bahía Sucia (BS) and Los Morrillos (LM) are part of the Boquerón Commonwealth Forest, Cabo Rojo, and were described by Tosterson et al. (1977) and Nieves-Rivera et al. (2001). On March 18, 1973, the tanker Zoe Colocotronis ran aground on a reef 4.8 km off La Parguera (southern Puerto Rico) releasing 1.01 million gallons of Venezuelan (Tijuana) crude oil on BS shores (Nadeau and Bergquist, 1977; Corredor et al., 1990).

Naphthalene (99% purity), phenanthrene (> 96% purity), and agarose type VII (low gelling temperature) were obtained from Sigma Chemical Co., St. Louis, and Noble agar from Difco Laboratories, Detroit. Seawater and sediment samples were collected from BS, GB, and LM bays, stored in a refrigerator and used within 2-3 weeks after collection of the isolates. Isolates were grown on sea water medium (SWM) (Bogart and Hemmingsen, 1992) and on malt extract agar (MEA) (Ho et al., 1999). Wet mounts were observed at 25-60 x and 100-1000 x with stereo and compound microscopes. Fungal isolates were deposited in the American Type Culture Collection, ATCC. Identification of *C. oxysporum* and *C. sphaerospermum* was based on deVries (1952), Ellis (1971), and Ho et al. (1999). In addition to the authorities cited, other descriptions in a number of other published works (e.g., Stevens (1981), de Hoog et al. (2000), Samson et al. (2000), Flannigan et al. (2001), Wang and Zabel (1990)) were useful.

RESULTS AND DISCUSSION

Characters of colonies and morphological structures of ATCC MYA-3068 and MYA-3069 on MEA (Figures 40A-G) were generally consistent with descriptions of C. *sphaerospermum* and *C. oxysporum* respectively, in both Ellis (1971) and Ho et al. (1999). MYA-3068 keys to *C. oxysporum* in Ho et al. (1999) and in Ellis (1971) *C. oxysporum* resembles *C. tenuissimum*, but the latter lacks the intercalary nodes. The defining character of this species, rather long conidiophores routinely approaching 500 μm in length and possessing intercalary conidiogenous nodes, was observed in culture. Conidia of MYA-3069 (NJRR-1) were intermediate in size between those described for *C. sphaerospermum* in Ellis (1971) and those in Ho et al. (1999). *Cladosporium sphaerospermum* has been isolated on extreme halophilic environments (Kis-Papo et al., 2001), in organic chemicals such as toluene (Weber et al., 1995), and after the fallout of Chernobyl (Zhdanova et al., 2000).

Isolates were grown on SWM and on MEA (Ho et. al. 1999). Characters of colonies and morphological structures of MYA-3068 and MYA-3069 on MEA (Figures 40A-G) were generally consistent with descriptions of *C. sphaerospermum* and *C. oxysporum* respectively, in both Ho et al. (1999) and Ellis (1971). Conidia of NJRR-1 were intermediate in size between those described for *C. sphaerospermum* in Ellis (1971) and those in Ho et al. (1999). Characters on SWM were indistinguishable from those on MEA with the exception of growth rate, which were faster in MEA (2 mm/week) versus the slower SWM (1 mm/week).

Cladosporium oxysporum Berk. & M.A. Curtis, 1869.

Colonies on MEA (Ho et al., 1999) 43-44 mm diameter in 10 days at ca. 25 °C, deep olive green, lighter and concentrically banded toward margin, surface almost velutinuous to flocculose. Reverse dark greenish black, lighter at margin. Conidiophores macronematous, olive, smooth, mostly ca. 300-900 x 3.5-4.5 µm (up to 7.5 µm at nodes), straight, mostly unbranched, with (0-) 1-5 conspicuously swollen internodes and a swollen apical node (Figures 40A-D). Conidia with 1-3 scars smooth, olive, mostly oval to elliptical, occasionally limoniform, mostly (3.5-) 4-6 x 2.5-3.5 µm, the larger conidia grading into ramoconidia (Figure 40E). Ramoconidia smooth, olive, elliptical to cylindrical with 3-5 scars; up to ca. 20 x 4 µm (Figure 40E). Scars protuberant, dark, on conidia, ramoconidia and conidiophores. Strain deposited as ATCC MYA-3068 (ÁMNR-7); seawater in *R. mangle* roots, Los Morrillos and Bahía Sucia, Cabo Rojo, Puerto Rico, 4 November 2002, Á. M. Nieves-Rivera.

Cladosporium sphaerospermum Penz., 1882.

Colonies on MEA (Ho et al., 1999) 25-26 mm and 36-37 mm on half strength V8 agar (½ V8, Stevens, 1981) at 10 days at circa 25°C; dark olive green, velvety, powdery, and reverse blackish green. Conidiophores olivaceous, macronematous, straight to flexous, 0-1 (-3) branched, intercalary or terminal, smooth, septate, up to ca. 160 µm long, usually circa 30 to 125 µm, up to 3 µm in diameter (slightly expanded at apices), not geniculate. Conidia in simple or branched chains, globose or subglobose to limoniform, mostly aseptate, moderately verrucose, olive, mostly 3.5-6.5 x 3.0-4.5 µm; abscission scars darkened, protuberant (Figures 40F-G). Ramoconidia subglobose to cylindrical, olive, typically aseptate, 7.5-17.5 (-25.0) x 3.5-4.5 µm wide (Figure 40G). Hyphae septate, olivaceous, smooth, up to 3 µm wide. Strain deposited as ATCC MYA-3069 (NJRR-1); seawater in *R. mangle* roots, María Langa Cay, Guayanilla Bay, Guayanilla, Puerto Rico, 31 January 2002, N. J. Rodríguez-Rodríguez.

Figures 40A-G show the arrangement of intact conidial chains on *C. oxysporum* and *C. sphaerospermum*. The top right and middle row show the variation in node placement and structure (an important character for identification of *C. oxysporum*). And the insert (Figure 40E) and bottom right figures (Figure 40G) show the conidia of *C. oxysporum* and *C. sphaerospermum*, respectively. Although both *Cladosporium* spp. are cosmopolitan species, they are new records for mangrove forests of Puerto Rico.

Coastal environments of Puerto Rico are prime repositories of PAHs because most industries as well as urban centers are located on the coast. For instance, for over 20 years GB was the location of one of the biggest concentrations of petrochemical industries in the world until it was shut down in 1982. Petrochemical industries and oil spills are the major source of organic pollutants which are of interest to this study. Although many studies have been conducted in areas along Puerto Rican coasts to determine the fate of pollutants by microbial degradation (Zaidi and Imam, 1999; Zaidi et al., 2003), few have been conducted by using fungal isolates (Acevedo, 2001). This study was baseline information on the conditions of GB and LM.

In conclusion, our particular interest was on the identifying potential bioremediation species that may be used in natural oil spills or other contaminant clean ups, which is a crucial part of environmental protection. The two species discussed above may play an important role in the future. However, we must discover, define, and experiment with additional naturally occurring species to ensure the protection of our tropical environments.

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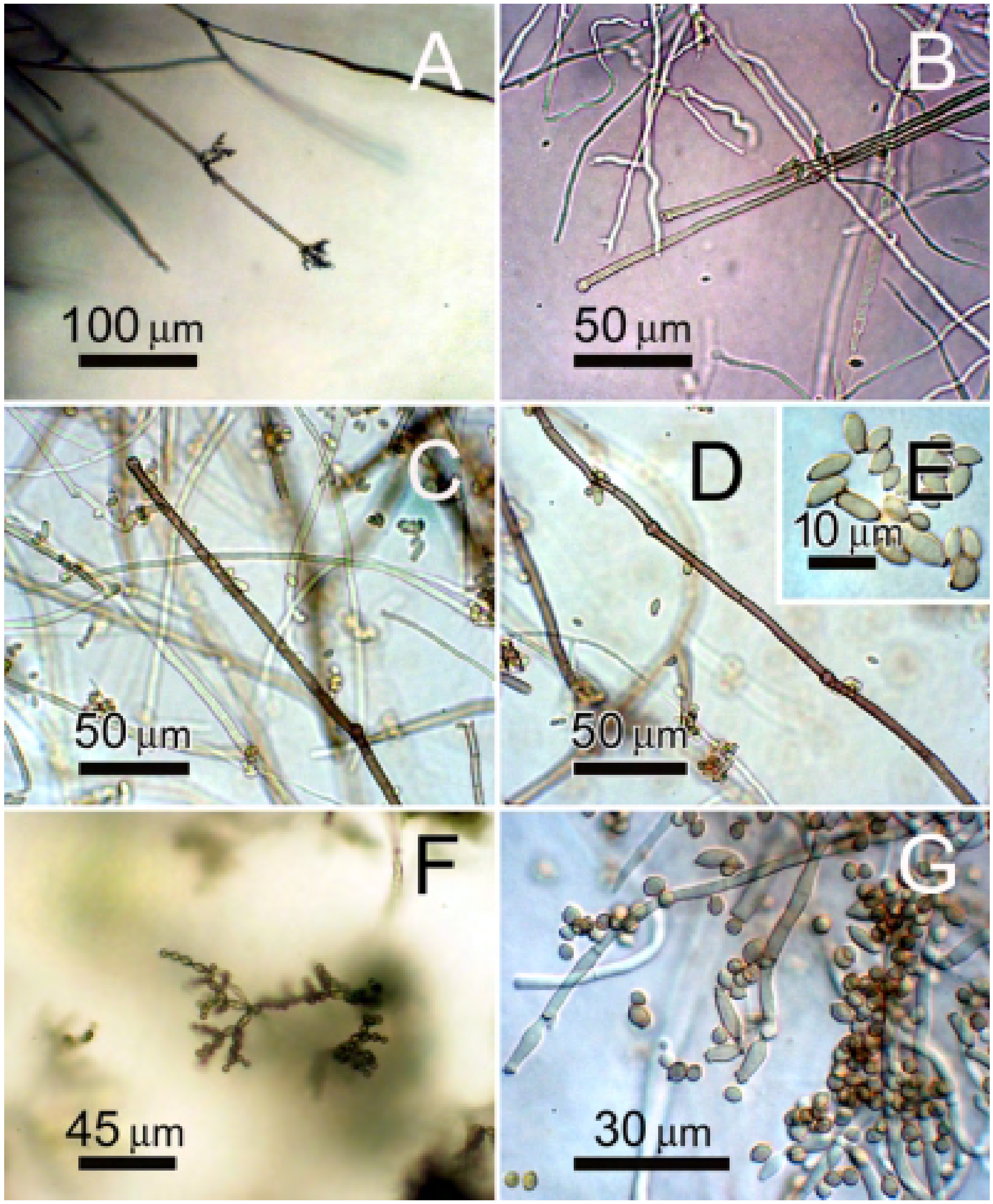

Figures 40A-G. Characteristic microscopic features of *Cladosporium oxysporum* (ATCC MYA-3068) and *C. sphaerospermum* (ATCC MYA-3069) from coastal seawater. A-D. Conidiophores of *C. oxysporum* on MEA. E. A group of oval to elliptical-shaped conidia and cylindrical ramoconidia of *C. oxysporum* at high magnification. F. Ramoconidia and conidia of *C. sphaerospermum* on ½ V8 agar. G. Conidiophores, ramoconidia, and conidia of *C. sphaerospermum* on MEA.

CHAPTER 6

SOOTY MOLD-PLANTHOPPER ASSOCIATION ON LEAVES OF THE BLACK MANGROVE *AVICENNIA GERMINANS* IN SOUTHWESTERN PUERTO RICO

ABSTRACT

Recent attention has been given to terrestrial and marine manglicolous fungi because of mangrove tree mortalities. However, this mycobiota in many Caribbean Islands is practically unknown. The halotolerant fungus *Asteridiella sepulta* (Ascomycota, Meliolaceae), which is one of many species that form sooty mould, has been isolated from leaves surfaces of *Avicennia germinans* in southwestern Puerto Rico. In this study of *A. germinans*, I found the planthopper *Petrusa marginata* (Homoptera, Flatidae) excretes a sugary honeydew upon which the dematiaceous mycelium of *A. sepulta* grows. Although *A. sepulta* has been previously collected on *A. germinans*, the association of the fungus and the planthopper in black mangrove had not been noted. *Asteridiella sepulta* produces a flat colony with a spongy subiculum on surfaces of leaves, twigs, and small branches of *A. germinans*.

RESUMEN

Se le ha dado una reciente atención a los hongos manglícolas terrestres y marinos a causa de las mortalidades de árboles de mangle. Sin embargo, en muchas islas Caribeñas esta micobiota es prácticamente desconocida. El hongo halotolerante *Asteridiella sepulta* (Ascomycota, Meliolaceae), considerado como una de las especies que forman la fumagina, ha sido aislado de la superficie de las hojas de *Avicennia germinans* en el suroeste de Puerto Rico. En este estudio de *A. germinans*, encontré que el saltahojas *Petrusa marginata* (Homoptera, Flatidae) excreta una secreción azucarada sobre la cual crece el micelio dematiáceo de *A. sepulta*. Aunque *A. sepulta* ha sido previamente colectado en *A. germinans*, la asociación del hongo con los saltahojas en el mangle negro es poco conocida.

Asteridiella sepulta produce una colonia plana con un subículo esponjoso sobre la superficie de las hojas, vástagos, y pequeñas ramas de *A. germinans*.

INTRODUCTION

A mangrove forest is a dynamic ecotone, or a transition zone, between the terrestrial and marine habitats. In its simplest sense, a mangrove is used as a generic term referring to a group of woody, halophylic plant formations that grow along sheltered tropical and subtropical coastlines (Tomlison, 1986). The mangroves are derived from a variety of plant taxa and they vary in their dependence upon littoral habitats (Lugo and Snedaker, 1974).

The black mangrove, *Avicennia germinans* (Avicenniaceae), is a small tree or shrub (about 3 to 12-m high) that grows in lagoons and coastal swamps in paleotropics and neotropics. It has been recorded in continental tropical America, Bermuda, The Bahamas, United States of America (From Florida to Texas), throughout the West Indies (except Dominica), including Trinidad, Tobago, and Curaçao (Martorell, 1976; Little et al., 2001). In Puerto Rico, *A. germinans* has been reported from the main island, Vieques, and Culebra (Martorell, 1976; Little et al., 2001). *Avicennia germinans* is very widely distributed along tropical and subtropical protected silty seashores and forming mangals in brackish water at mouths of rivers, usually with other mangrove species, but rarely forming monotypic stands (Jiménez and Lugo, 1985a; Tomlinson, 1986; Little et al., 2001). Except for *A. germinans*, the other mangrove species that occur in Puerto Rico are the red mangrove (*Rhizophora mangle*) (Rhizophoraceae), the white mangrove (*Laguncularia racemosa*), and the buttonwood (*Conocarpus erectus*) (Combretaceae) (Little et al., 2001).

Recent attention has been given to mangrove tree mortalities, which are caused by anthropogenic misuse and unfavorable environmental conditions (Jiménez and Lugo, 1985b; Anderson and Lee, 1995) as well as by fungal diseases (Jiménez and Lugo, 1985a; Wier et al., 2000), among other biotic and abiotic factors. Although terrestrial and marine manglicolous fungi have been extensively studied in various parts of the world (Johnson and Sparrow, 1961; Kohlmeyer and Kohlmeyer, 1979; Rollet, 1981; Hyde and Lee, 1995), in many Caribbean Islands these fungi are poorly known.

Previous mangrove fungal collections in Puerto Rico are summarized in Stevenson (1975), Acevedo (1987, 2001), Nieves-Rivera et al. (1998), Calzada (1999), Tattar et al. (1994), Wier et al. (1996, 2000), Minter et al. (2001), and Tattar and Wier (2002). Stevenson (1975) gave a summary of manglicolous fungi of Puerto Rico and the U.S. Virgin Islands. Acevedo (1987) reported 18 species of manglicolous fungi (ascomycetes and mitosporic fungi) from *R. mangle* in La Parguera. Nieves-Rivera et al. (1998) reported *Schizophyllum commune* and *Hypoxylon* Sect. *Hypoxylon* in *Avicennia nitida* (= *A. germinans*) and *Rhizophora mangle*, respectively, from Boquerón Wildlife Refuge. Calzada (1999) studied three phytopathogenic fungi (*Pestalotiopsis disseminata*), *Phoma eupyrena*, *Pterosporidium rhizophorae*) causing foliar diseases in *R. mangle* of La Parguera (Phosphorescent Bay and La Parguera Channels). Acevedo (2001) assayed marine fungi (e.g., *Didymosphaeria rhizophorae*, *Hydronectria tethys*, *Hypoxylon oceanicum*, *Lulworthia grandispora*, *Pestalotia* sp., *Xylaria* spp., as well as other undetermined species of ascomycetes and mitosporic fungi) by HPLC for biotransformation of phenanthrene in algal and mangrove (*R. mangle*) substrates; she found that marine fungi and notably algal endophytes (e.g., *Xylaria* spp.) are potentially useful organisms for bioremediation in marine environments. Minter et al. (2001) gave a summary of manglicolous fungi of the Caribbean, including Puerto Rico. Tattar et al. (1994), Wier et al. (1996, 2000), and Tattar and Wier (2002) documented the incidence of *Cytospora rhizophorae* as a plant pathogen in *R. mangle* in the southwestern coast of Puerto Rico.

Insects also have been found associated with mangrove plants. According to Martorell (1976), two species of insects collected on *A. germinans* in Puerto Rico are the cricket *Hygronemobius alleni* (Orthoptera, Grillidae) and the tree termite *Nasutitermes costalis* (Isoptera, Termitidae). Tattar and Wier (2002) reported the termites *N. costalis*, *Neotermes mona*, *Incisertermes nr. incisus* and *Procryptotermes corniceps* from *R. mangle* in southwestern Puerto Rico. Twenty-two species of ants (including *Azteca* sp. (Dolichoderinae), *Camponotus* spp. *Myrmelachista* spp. (Formicidae), *Crematogaster* spp., *Hylomyrma* sp., *Pheidole* spp., *Solenopsis* spp. (Myrmicinae), *Pachycondyla villosa* (Ponerinae), *Pseudomyrmex gracilis*, *Pseudomyrmex* sp. (Pseudomyrmecinae)) have been recorded from the Brazilian mangrove plants *Avicennia schaueriana*, *L. racemosa*, and *R. mangle* (Cortes-Lopes and Dos Santos, 1996). However, the recent reports of the gall midges *Actilasioptera* spp. (Gagné and Law, 1998) and *Meunieriella avicenniae* (Diptera, Cecidomyiidae) (Gagné and Etienne, 1998), the causative agents of the leaf gall in black mangroves, show that mangrove insect fauna is rather poorly known. Therefore, there has been no assessment on the effects insects have on these plants.

On February 5, 2001, while collecting manglicolous fungi, I observed a coating on the leaves of the black mangrove (*A. germinans*), with a black soot caused by mycelia giving the false impression of pollution caused by passing vehicles. After a careful examination under the dissecting microscope, the soot was found to be a mycelium produced by a fungus. This fungus was *Asteridiella sepulta* (Ascomycota, Meliolaceae). The type collection for *A. sepulta* is contained in voucher 6416, collected from *A. nitida* (= *A. germinans*) from Cataño, Puerto Rico, by A. A. Heller (Stevenson, 1975). The purpose of the present study is to record details of the sooty mould-planthopper association on leaves of the black mangrove in southwestern Puerto Rico.

MATERIALS AND METHODS

Locality

Leaves of *A. germinans* were collected at Los Morrillos (LM), (coordinates: 17° 57.215' N, 67° 11.867' W), which is part of the Boquerón Commonwealth Forest, Road 301, km 11.4, Barrio El Corozo, Cabo Rojo, Puerto Rico (Figures 2, 41, 42A). This forest is approximately 0 to 30 m above sea level and the general environment of the region is classified as a subtropical dry forest (Ewel and Whitmore, 1973). The rainy season in Puerto Rico ranges from May to June and August to September, with two rainfall peaks. Annual average rainfalls in the weather station located at Lajas Agricultural Experiment Station of the University of Puerto Rico-Mayagüez, are 1016 to 1270 mm (Ravalo et al., 1986).

According to 'CNN.com/weather', the annual average climatic conditions for Boquerón, Cabo Rojo, Puerto Rico from 2000 to 2002) were: air temperature, 28.0°C; relative humidity, 74.0%; wind, variable (mostly from ENE or SSE at < 5 to 30 km/hr; sunrise, 06:05 hr, sunset, 18:49 hr. In 'Atmos Carib— Caribbean Atmospheric Research Center' at University of Puerto Rico-Mayagüez Campus, the annual average climatic conditions for Magueyes Island Marine Laboratories (MIML) in La Parguera, Lajas, Puerto Rico from 2000 to 2001 were: air temperature, 26.6°C; atmospheric pressure, 1013.9 mb. Glynn (1973) conducted early meteorological observations in MIML. Therefore MIML was selected because it has the same xeric conditions and its proximity to the study site. The geologic formations of the study site are: Holocene's mangrove swamps (Qm) and beach deposits (Qb) (Volckmann, 1984; Torres-Figueroa, 1993). Soils of LM are classified as tidal flats (Tf), tidal swamps (Ts), coastal beaches (Co), and limestone rock lands (Lr) (USDA, 1993).

Isolation of Sooty Mold

The author collected individual leaves of *A. germinans* August 3, 2001. Most of the leaves of *A. germinans* were collected close to roads and trails. These were photographed and the identity of the sooty mould was confirmed with Stevens (1916, 1917, 1927), Ciferri (1954), and Hughes (1976). Leaves were placed in wet chambers in Petri-dishes, following Calzada (1999). Distilled water was used in the wet chambers. The paraffin-sealed wet chambers were placed in light/dark at room temperature. Microscopic observations were made with a light microscope (Nikon Labophoto-2 Microscope). Drawings were made with a camera lucida. All voucher specimens are placed at the Center for Forest Mycology Research, in the process of curation before being deposited in the Herbarium of the Department of Natural Sciences, University of Puerto Rico at Río Piedras (UPRRP).

Insect Collection

The insect specimens collected in *Avicennia germinans* were preserved in 70%

ethanol and identified by various specialists (Drs. Arístides Armstrong, Ángel L. González, and Silverio Medina-Gaud of the Department of Crop Protection, University of Puerto Rico, Mayagüez). Planthopper identification was provided by Dr. Stuart H. McKamey (Smithsonian Institution in Washington, D.C.).

RESULTS

Asteridiella sepulta was found on the phylloplane (surface of living leaves, *sensu* Hughes, 1976) (Figure 42B) producing a flat, spongy subiculum colony of sooty mould on the front and back of the leaves, twigs, and small branches of *A. germinans* (Figures 42C-F). This sooty mould was found throughout the year on the leaves of *A. germinans*. It must be a halotolerant fungus to be able to grow on black mangrove leaves, which are often covered with salt crystals. *Asteridiella sepulta* also grew in the margins of the leaves and the stems, apparently following the path of running water after a rain, moist, dew, or by condensation (Figure 42D).

Diagnostic

Colonies circular, 1-7 mm in diameter, amphigenous, dense, easily secedent, well defined, sub-epiphyllous spots, single or confluent, black. Hyphae brown, sinous to tortuous, branching alternate or irregular, not opposite, at acute angles, forming a mat, densely reticulate and becoming almost solid (Figure 43A). Capitate hyphopodia alternate, more or less antrorse, usually straight, 23.0-24.3 µm long; stalk cell cylindric, 0.9-10.4 µm long; head cell globose to widely piriform, entire or rarely slightly rounded-angulose. Mucronate hyphopodia few, mixed with capitate, opposite or alternate, ampulliform with short neck. Setae none. Perithecia in loose central group, black, globose, rough, 165 µm in diameter; most surface cells are prolonged into translucent dark brown, obtusely conoid outgrowths, not striate (Figure 43A). Asci not seen. Spores dark brown, cylindric, obtuse, 4 septate, constricted, ends obtuse, smooth, thin-walled, 51.1-52.6 x 18.2-19.8 µm (Figure 43B).

Material Studied

Los Morrillos, Boquerón Commonwealth Forest, in coastal forest next to Parador Las Salinas, on living leaves of *A. germinans*, 1.5 m alt., 3 August 2001, Á. M. Nieves-Rivera, PR-935, 936, 937 (UPRRP); Los Morrillos, Boquerón Commonwealth Forest, in the shores of a hypersaline lagoon, next to old bridge, on living leaves of *A. germinans*, 0.5 m alt., 3 August 2001, Á. M. Nieves-Rivera, PR-938 (UPRRP); Guánica Dry Forest, in coastal forest next to Parador Copa Marina, on living leaves of *A. germinans*, 1.5 m alt., 7 August 2001, Á. M. Nieves-Rivera, PR-939, 940 (UPRRP).

Distribution

Sooty mould mycelia develops in the front and back of the leaves, petioles, twigs, and branches (Reynolds, 1976) (Figures 44A-B, 45A). The range of the area covered by sooty moulds extends about 2.0 x 1.5 km in *A. germinans* of LM. However, the fungus dissemination seems to depend on the planthopper *Petrusa marginata* (Homoptera, Flatidae) and *A. germinans* distribution along the coastline. Previous collections of *A. sepulta* in Puerto Rico were reported by Stevens (1916, 1917, 1927) as *Irenina* (*Meliola*) *sepulta*, Chardón (1920) as *Meliola sepulta*, Toro (1925) as *Irene sepulta*, in the Dominican Republic by Ciferri (1954) as *Meliola* (*Irenina*) *sepulta*, and Trinidad by Dennis (1970) as *A. sepulta*. Stevenson (1975) summarized *A. sepulta* distribution to be found in *A. germinans* forests of Puerto Rico, the Dominican Republic, and Sierra Leone (Africa).

Insects

The planthopper *P. marginata* has been previously reported in Puerto Rico by Osborn (1935), Caldwell and Martorell (1950), and Maldonado-Capriles and Medina-Gaud (1985); however, *A. germinans* has not been recorded as host plant for this insect in Puerto Rico. Many planthopper exuviae, exocuticles, and immature (nymphs) were also detected on the leaves of *A. germinans*. *Petrusa marginata* has become a pest in plantations of coffee *Coffea arabica*, coco-plum *Chrysobalanus icaco*, jasmine *Jasminum* sp. (Maldonado-Capriles and

Medina-Gaud, 1985), and the sea grape *Coccoloba uvifera* (Figures 45B). *Petrusa marginata* (*Oremis* (*Petrusina*) *marginata* of Osborn, 1935) has been collected on *Lantana* sp. and *Cordia* sp. at Ensenada, Aguirre, and other points throughout the island (Osborn, 1935). Caldwell and Martorell (1950) reported *P. marginata* from Monserrat, B. W. I., to Mona Island, Puerto Rico. *Petrusa marginata* is very common along coastal areas and also present in suitable habitat up to 762 m especially along the south coast of Puerto Rico (Caldwell and Martorell, loc. cit.). During our study, few other insects were collected by the senior author on *A. germinans*, including the common bee *Apis mellifera* (Hymenoptera, Apidae), the green lacewing *Chrysopa* sp. (Neuroptera, Chrysopidae), the leaf gall midge *M. avicenniae*, the ants *Solenopsis* spp. (Hymenoptera, Formicidae), the cricket *H. alleni*, the tree termite *N. costalis*, and three spiders of the Group Aranae.

DISCUSSION

Sooty moulds are usually associated with the liquid excrement of sucking insects, known as 'honeydew' is a common occurrence on many trees (Auclair, 1963). Undigested sucrose in honeydew makes an excellent growth medium for dark-spored fungi (Tattar, 1989). However, sooty moulds also have been found on plants not infested with insects which produce honeydew, living and dead vegetation, on the surface of rocks, and the forest floor (Hughes, 1976).

In Puerto Rico sooty moulds caused by *Capnodium* spp., *Trimmatostroma* sp. (Figures 44A-B), and other undetermined fungal species are found in honeydew excretions of aphids and scale droppings on tea (*Camellia sinensis*), sour orange (*Citrus aurantium*), orange (*C. sinensis*), coffee (*C. arabica*), mango (*Mangifera indica*), sea grape (*Coccoloba uvifera*), white mangrove (*L. racemosa*) or ornamental plants (*Anthurium* sp., *C. icaco*, *Gardenia* sp., *Ixora* sp., *Jasminum* spp.) (Figure 45A). The mycelial mats of these fungi are easily removed by peeling off the surface from the leaf where they are found, usually revealing a clean, intact plant surface (Reynolds, 1976). Maldonado-Capriles and Medina-Gaud (1985) refer to sooty mould in Spanish as "hongo de hollín".

The presence of saprophytic sooty mould *A. sepulta* does not initially infect the leaves of *A. germinans*, but covers the leaf surfaces only after the honeydew of *P. marginata*. Planthoppers, like aphids, feed on the leaves of both deciduous hardwoods and evergreens (Tattar, 1989). They excrete excess sucrose in a honeydew excrement (Auclair, 1963). We suspect this fungus-leaf covering does not adversely affect photosynthesis because of the healthiness in leaves examined (leaves were green, robust, and intact), and its similarity to cases of myxomycete-grass associations (Nieves-Rivera, 2000). However, a heavy accumulation of sooty mould can prevent photosynthesis (Tattar, 1989).

The covering of the leaves by the fungus looked like "soot," giving the false impression of pollution caused by passing vehicles. The "soot" was found to be fungal mycelia which had expanded over the foliar surface to cover, in some cases, 25 to 98% of the leaf, similar to the percentages reported in pecan leaves by Tedders and Smith (1976), and Wood et al. (1988). Coating by *A. sepulta* was not detected on other mangroves species, such as *R. mangle* and *C. erectus*. In his study of the genus *Meliola* in Puerto Rico, Stevens (1917) reported *Meliola laguncularíae* and *M. nigra* on the white mangrove *L. racemosa* in Puerto Rico. However, other black mangrove populations in different locations around Puerto Rico have been observed with sooty moulds, for example, the mangals located in Magueyes Island, La Parguera mangrove channels, Bahía de Jobos estuary in Salinas, Las Cabezas de San Juan Natural Reserve in Fajardo, Caño Corazones in Mayagüez, Guayanilla and Ponce coasts (Nieves-Rivera, unpubl. data).

Sooty moulds, like myxomycetes (Nieves-Rivera, 2000) are saprobes and their fruiting bodies may cover portions of the plant, but apparently do not infect them. The plasmodium (in the case of myxomycetes) does not affect the leaf by reducing its photosynthesis or respiration as true fungi do (for example, powdery mildews (Mignucci and Boyer, 1979)) (Nieves-Rivera, 2000). Although sooty moulds are not considered of economic importance, Maldonado-Capriles and Medina-Gaud (1985) recommended the use of Diazinon AG-500, Cygon 2.67 or Endosulfan 50 PH to control *P. marginata*, thus controlling the sooty mould. However, the use of commercial pesticides and insecticides might best be avoided because of the resultant pollution, the use of entomopathogenic fungi for planthopper and leafhopper biocontrol (Soper, 1985) might be more prudent.

In conclusion, sooty mould-planthopper occurrence on black mangrove leaves is another example of fungus/insect interaction, that does not appear to be detriment. However, if a black mangrove forest were to be stressed from changes in climate, attack by borers in high incidence or other negative anthropogenic impact, a heavy incidence of sooty mould could exacerbate the stress and lead to decline. Therefore, the continued study of sooty mould on *A. germinans* is merited.

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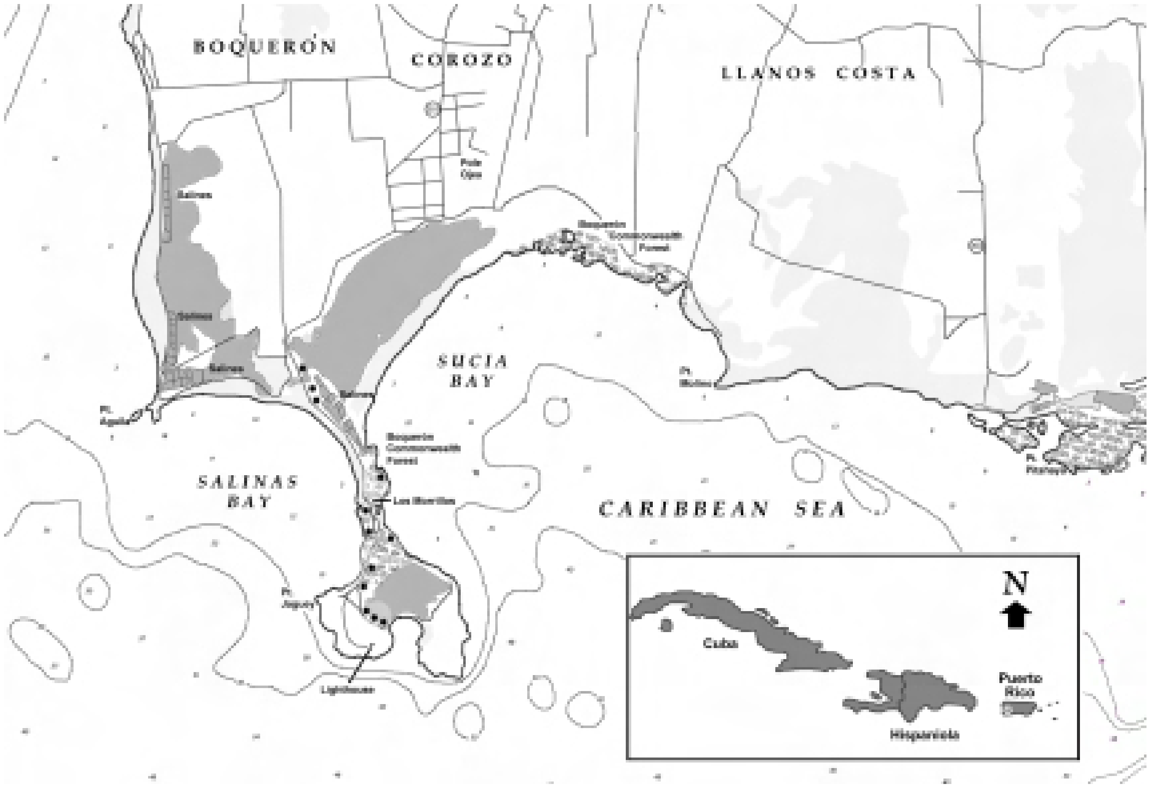
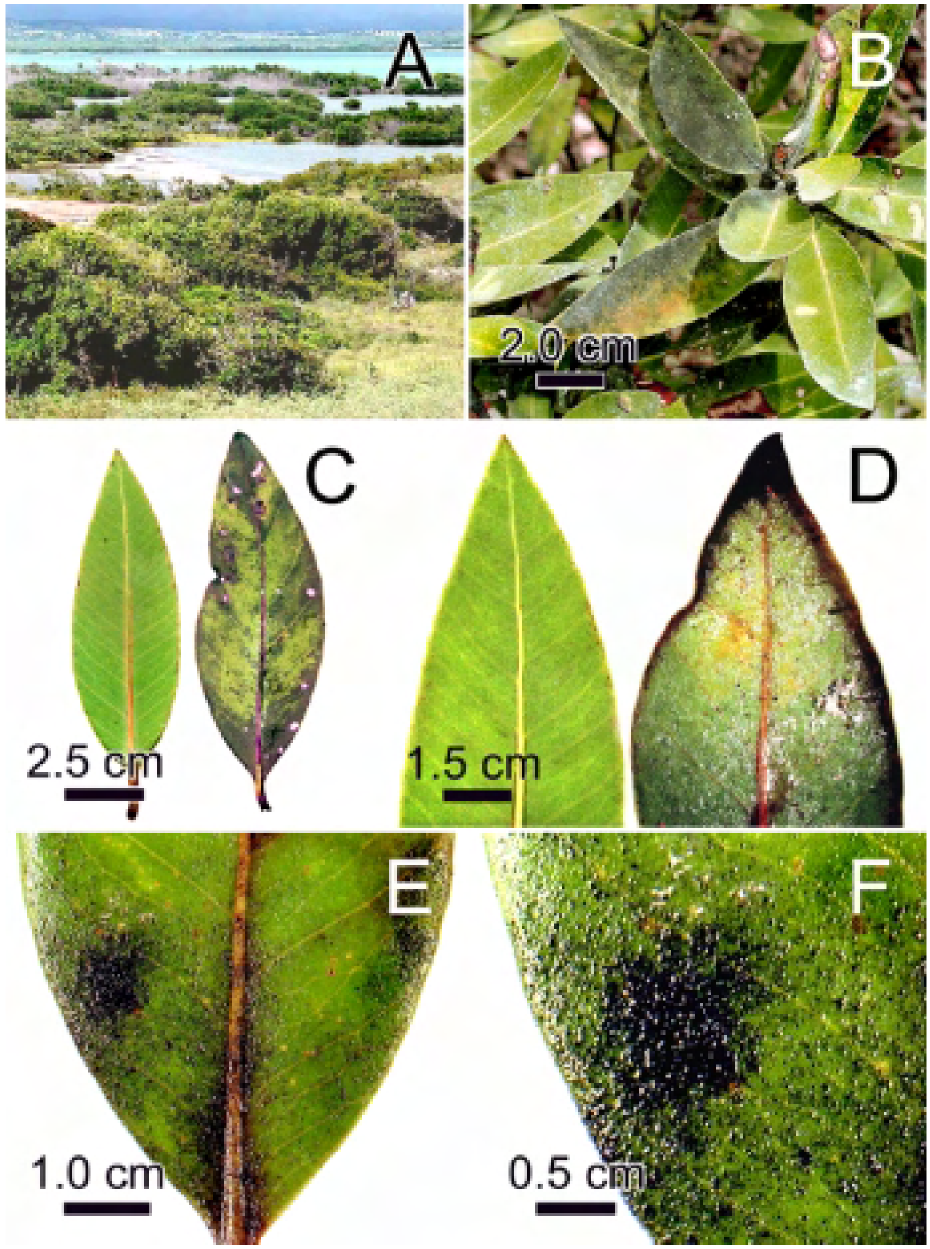
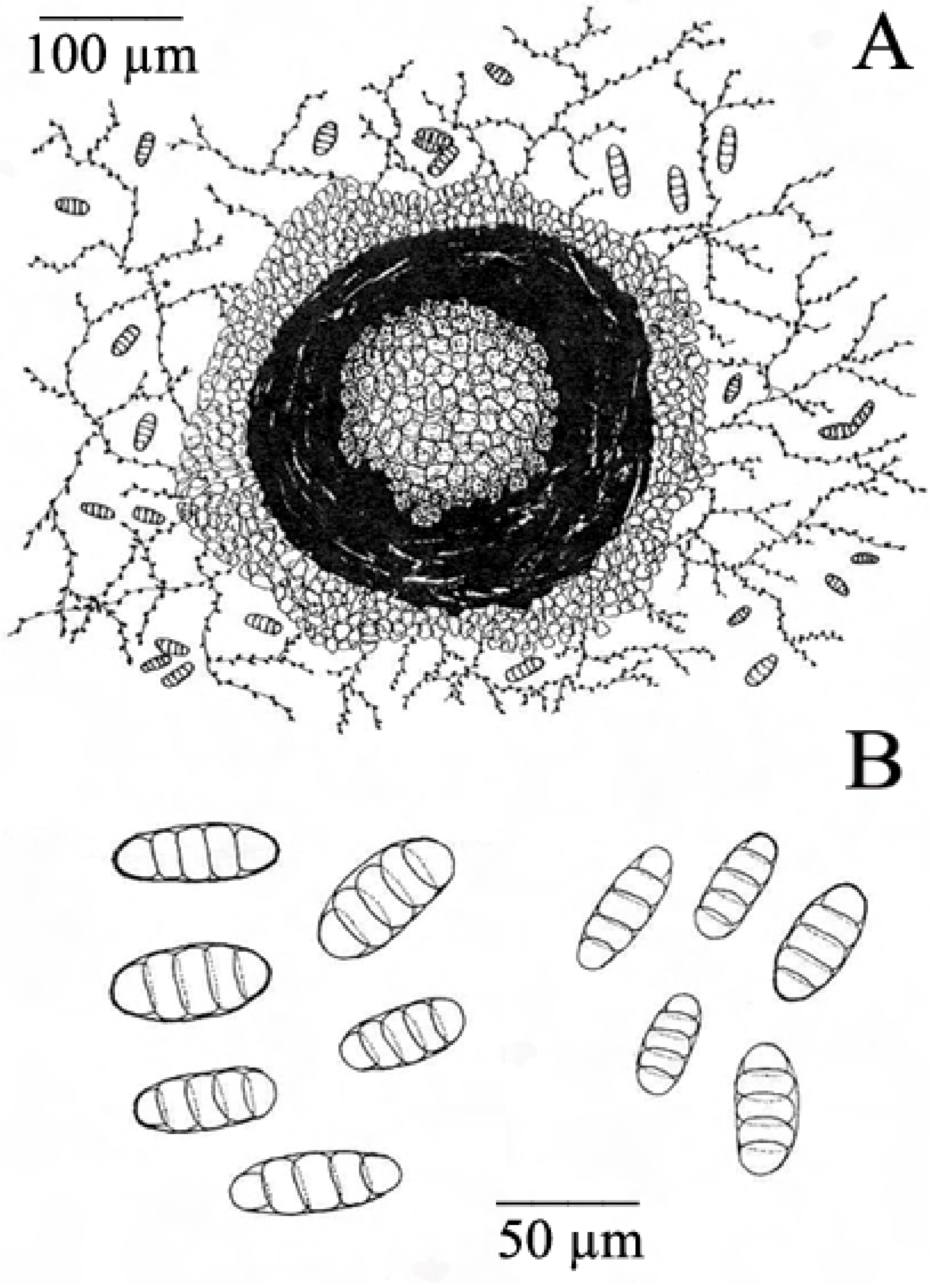


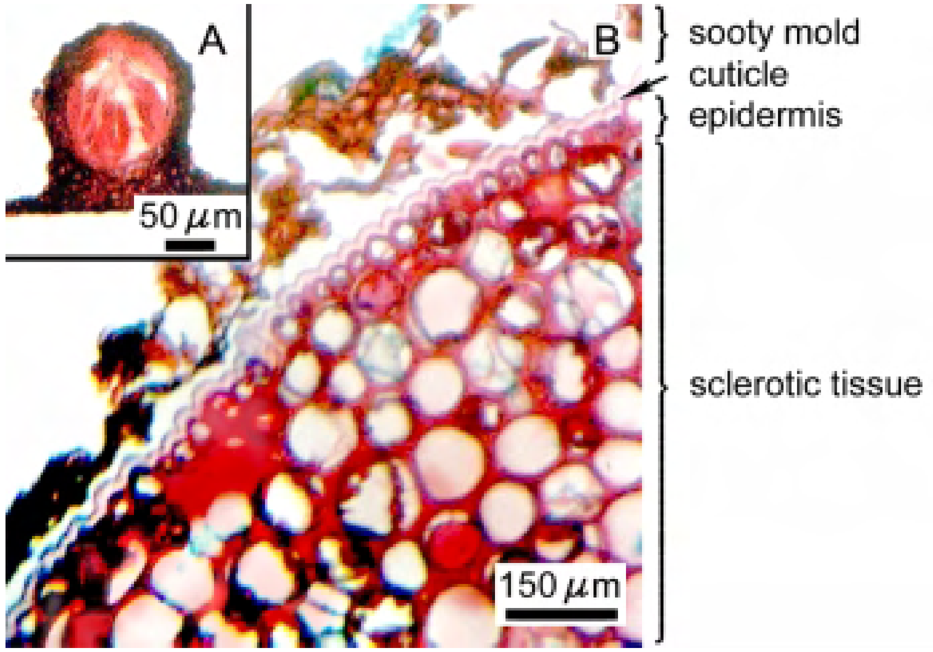
Figure 41. A. Map of the southwestern end of Puerto Rico, showing Cabo Rojo municipality collection areas (*).



Figures 42A-F. A. View of Los Morrillos, Boquerón Commonwealth Forest, Cabo Rojo, Puerto Rico. B. Growth *in situ* of sooty mould (*Asteridiella sepulta*) on an upper surface of leaf of the black mangrove *Avicennia germinans*. C-D. Leaves of black mangrove *Avicennia germinans*, with a clean surface (left) and *Asteridiella sepulta* infested surface (right). E-F. Growth of *Asteridiella sepulta* on the lower surface of the front of the leaf of *A. germinans*, associated with infestation of the planthopper *Petrusa marginata*. Photos taken at Los Morrillos, Boquerón Commonwealth Forest.



Figures 43A-B. *Asteridiella sepulta*. A. Hyphae with perithecium and young ascostroma bearing hyphal appendages, on leaves of the black mangrove *Avicennia germinans* (Cabo Rojo, Puerto Rico). B. Spores.



Figures 44A-B. Example of the sooty mold, *Trimmatostroma* sp. A. Perithecium or ascoma with asci and ascospores inside. B. Dematiaceous hyphal subiculum (sooty mold) on twig of the sapodilla (níspero) *Manilkara zapota* (Mayagüez, Puerto Rico).

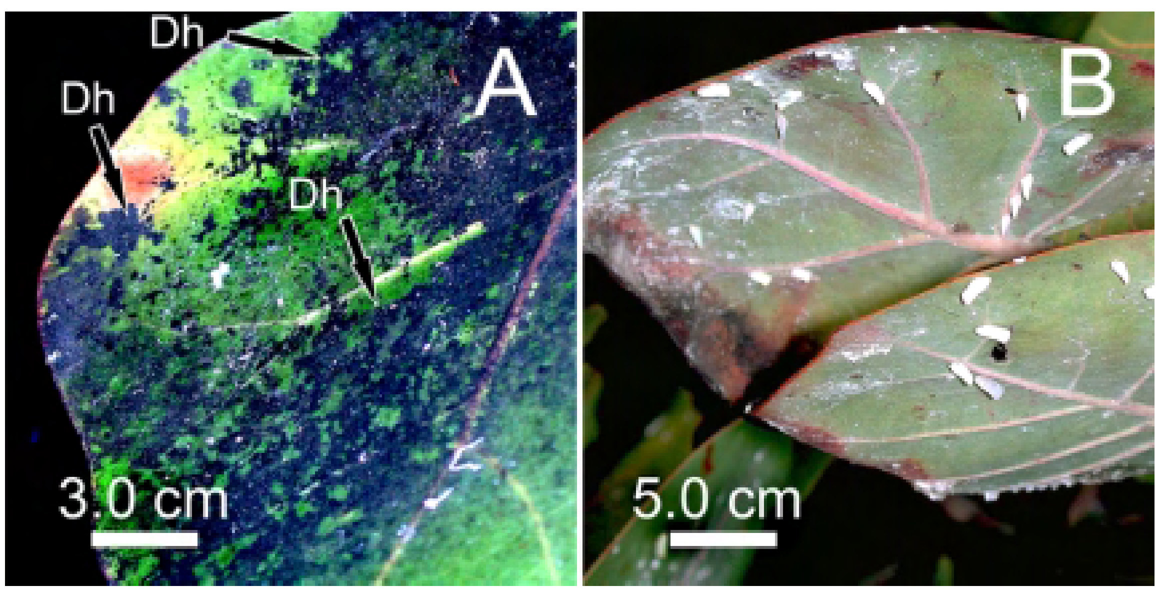


Figure 45A-B. Sea grape *Coccoloba uvifera*, showing sooty mold (A) and with an infestation of *Petrusa marginata* on lower surface (B). A. Dematiaceous hyphae (Dh) and young ascostroma of *Asteridiella sepulta* and *Trimmatostroma* sp., on leaves of the black mangrove *Avicennia germinans* surface. Photograph taken at Playa Jobos, Isabela, Puerto Rico.

CHAPTER 7

MANGLICOLOUS BASIDIOMYCETES OF SOUTHWESTERN PUERTO RICO AND SOUTHWESTERN FLORIDA (U.S.A.)

ABSTRACT

Field surveys of the Boquerón Commonwealth Forest, Boquerón Wildlife Refuge, and Magueyes Island in southwestern Puerto Rico, and the Aquatic Preserves of southwestern Florida from July 2001 throughout 2003, yielded 59 specimens of manglicolous basidiomycetes that were catalogued and taxonomically examined. All the specimens were identified to taxa by observation of morphological and microscopic characters, and compared with specimens from the U.S. National Fungus Collections at Maryland (BPI), University of Puerto Rico at Río Piedras (UPRRP), The New York Botanical Garden at Bronx (NY), and University of Oslo at Blindern (O) herbaria. They represented 8 families, 12 genera, and 14 taxa. Basidiomycetes grew on dead bark and wood of *Rhizophora mangle*, *Avicennia germinans*, and *Laguncularia racemosa*. *Coriolopsis floccosa*, *Phellinus merrillii*, and *Tyromyces* cf. *chioneus* are new records for Puerto Rican mangroves and *Phlebia* sp. is a new record for Florida mangroves.

RESUMEN

Los reconocimientos de campo en el Bosque Estatal de Boquerón, el Refugio de Vida Silvestre de Boquerón e Isla Magueyes en el sudoeste de Puerto Rico, y en las Reservas Acuáticas del sudoeste de la Florida durante julio de 2001 y a través de 2003, produjeron 59 especímenes de basidiomicetos manglícolas que fueron catalogados y examinados taxonómicamente. Todos los especímenes fueron identificados a especies mediante la observación de los caracteres morfológicos y microscópicos, junto con la comparación de especímenes de los herbarios de las Colecciones Nacionales Fúngica de los EEUU en

Maryland (BPI), Universidad de Puerto Rico en Río Piedras (UPRRP), el Jardín Botánico de Nueva York en el Bronx (NY), y la Universidad de Oslo en Blindern (O). Estos representaron 8 familias, 12 géneros y 14 taxones. Los basidiomicetos crecieron en corteza muerta y madera de *Rhizophora mangle*, *Avicennia germinans* y *Laguncularia racemosa*. *Coriolopsis floccosa*, *Phellinus merrillii* y *Tyromyces* cf. *chioneus* son registros nuevos para los mangles de Puerto Rico y *Phlebia* sp. fue un registro nuevo para los mangles de la Florida.

INTRODUCTION

Until recently, there have been few mycological studies on the manglicolous basidiomycetes of the Caribbean region, although information on their occurrence would be of considerable value for biologists and conservationists. Previous reports summarized in Kohlmeyer (1969) recorded eight manglicolous basidiomycetes (*Fomes avicenniae*, *Phellinus gilvus*, *Psathyrella* sp., *Schizophyllum commune*, *Trametes rhizophorae*, *Tulasnella bifrons*, *T. pacifica*, and *T. violacea* from *Avicennia* sp., *Rhizophora mangle* or *Hibiscus tiliaceus* (Reichardt, 1870; Baccarini, 1916; Olive, 1957; Cooke 1961; Kohlmeyer, 1969). Kohlmeyer (1969) also collected two basidiomycetes, *F. avicenniae* and *P. gilvu*s from the Heeia Swamp, Oahu, Hawaii, on *R. mangle*. Lee and Baker (1973) reported three basidiomycetes from *R. mangle* roots (*Fomes* sp., *Polyporus cinnabarinus*, and *Psathyrella* sp.).

The neotropical occurrence of manglicolous basidiomycetes were reported from Brazil (Sotão et al., 1991; Almeida Filho et al., 1993; Campos and Cavalcanti, 2000; Sotão et al., 2002), Lesser Antilles (Pegler, 1983a; Minter et al., 2001), Panama (Gilbert and Sousa, 2002), Puerto Rico (Stevenson, 1975; Lodge, 1996a; Nieves-Rivera et al., 1998; Minter et al., 2001) and Venezuela (Dennis, 1970). Minter et al. (2001) survey of Caribbean fungi recorded 11 taxa of manglicolous basidiomycetes for Puerto Rico (e.g., *Gloeophyllum striatum*, *Pleurotus djamor*, *Pleurotus* sp., *Polyporus fulvocinereus*, and *Tyromyces* sp. on *R. mangle*; *Phellinus* sp. and *Trametes villosa* on *Conocarpus erectus*; *Coriolopsis* sp., *Inonotus* *porrectus*, and *Phellinus* sp. on *Laguncularia racemosa*; and *S. commune* on *Laguncularia* sp.). More recently, the manglicolous fungi surveys by Poonyth et al. (2000) and Schmit and Shearer (2003) summarized what is known about worldwide fungal species and their mangrove hosts, and recorded about 30 species of manglicolous basidiomycetes (e.g. *Crepidotus krieglsteiner*, *P. gilvus*, *Psathyrella rhizophorae*, *Pycnoporus cinnabarius*, *S. commune* on *R. mangle*, and *Dacrymyces intermedius* on *H. tiliaceus*). We note here the occurrence of 14 basidiomycetes from mangrove coastal forests of southwestern Puerto Rico and 4 basidiomycetes for southwestern Florida (U.S.A.); this marks the second formal documentation of manglicolous basidiomycetes for Puerto Rico, and the sixth neotropical occurrence of manglicolous basidiomycetes.

MATERIALS AND METHOD

The Puerto Rican study areas were located at the Boquerón Commonwealth Forest (BCF, 18°01'N, 67°10'W, secondary road PR-307, next the town of Boquerón, Barrio Boquerón, Cabo Rojo), Boquerón Wildlife Refuge (BWR, 18°01'N, 67°09'W, secondary road PR-301, near to the town of Boquerón, Cabo Rojo), and Magueyes Island Marine Laboratory (MIML, 17°58'N, 67°02'W, secondary road PR-304, close to the town of La Parguera, Barrio La Parguera, Lajas), all at mean sea level, southwestern Puerto Rico (Figures 2 and 3). The general environment of the region is classified as a subtropical dry forest (Ewel and Whitmore, 1973). Further details on climatology, geology, and edaphic formations of BCF, BWR, and MIML are discussed in Glynn (1973), Vázquez (1983), Toro and Colón (1986), Winter et al. (1998), and Nieves-Rivera et al. (2002). *Rhizophora mangle* occasionally forms thick coastal woodland in BCF and in the rest of the southwestern coast of Puerto Rico (Cintrón et al., 1978; Lugo, 1989; Vázquez and Kolterman, 1998).

The Aquatic Preserves of Southwest Florida (APSF) are located SE of Venice, at the Gulf of Mexico (Figures 46A-B). The APSF have over 2,574 km of coastline, a network of barrier islands and mangals providing more than 907 km^2 of bays, lagoons, and other water bodies sheltered from the open gulf. Southwest Florida contains the highest density of aquatic preserves in the state. Most of the coastal waters here are contained within aquatic preserves. The eight aquatic preserves in this region are: (1) Lemon Bay; the Charlotte Harbor Aquatic Preserves, which include (2) Cape Haze, (3) Charlotte Harbor/Gasparilla Sound, (4) Matlacha Pass and (5) Pine Island Sound; (6) Estero Bay; (7) Rookey Bay; and (8) Cape Romano/Ten Thousand Islands. The collection sites at APSF were: Punta Gorda (26°47'N, 82°04'W), Cape Coral (26°45'N, 82°04'W), and Cape Haze (26°54'N, 82°10'W). The Punta Gorda site was at sea level and was flooded with each tide. The Cape Coral and Cape Haze sites were on berms approximately 0.5 m above sea level. The general environment of the region is classified as a subtropical dry forest. APSF normally receive 1,376 mm on average of precipitation each year. The driest months are November, December and April with precipitation is less than 50 mm. Wildfires are common in late spring, since April is dry and hot, and sometimes-rainy season does not begin in June. In these cases, the fire season can also extend into June (unpublished data). Further details on climatology, geology, and edaphic formations of APSF are discussed in Davis (1940), Craighead (1971), and Kangas and Lugo (1990). *Avicennia germinans* forms thick coastal woodland in APSF and in the rest of the southwestern coast of Florida (Davis, 1940; Craighead, 1971; Kangas and Lugo, 1990).

As a result of three field surveys to the BCF, BWR, and MIML in southwestern Puerto Rico and the Aquatic Preserves of southwest Florida from July 2001 through 2003, 59 specimens of manglicolous basidiomycetes were catalogued and taxonomically examined, using the works of Cooke (1961), Dennis (1970), Gilbertson and Ryvarden (1986, 1987), Pegler (1983a, b), and Larsen and Cobb-Poulle (1990). Each taxon newly recorded for Puerto Rico and Florida is marked with an asterisk at the head of the specific name. To study the material, microscopical observations were made from slides mounted in 5.0% KOH, Meltzer reagent or lactophenol, following Largent et al. (1977). All the specimens were identified by observation of morphological and microscopic characters, along with comparison with specimens from the U.S. National Fungus Collections at Maryland (BPI), University of Puerto Rico at Río Piedras (UPRRP), The New York Botanical Garden at

Bronx (NY), and University of Oslo at Blindern (O) herbaria.

RESULTS

Manglicolous basidiomycetes represented 8 families, 12 genera and 14 taxa. Basidiomycetes occurred on host trees *R. mangle* (11 species), *A. germinans* (2 species) and *L. racemosa* (2 species). *Coriolopsis floccosa*, *Phellinus merrillii*, and *Tyromyces* cf. *chioneus* were new records for Puerto Rican mangroves, and *Phlebia* sp. was a new record for Florida mangroves.

Crepidotaceae

Crepidotus uber (Berk. & M.A. Curtis) Sacc., Syll. Fung. 5: 878. 1887.

(Figures 47A-E)

Material studied: PUERTO RICO. Cabo Rojo: Boquerón Commonwealth Forest, next to Puerto Real, boardwalk that passes through a mangrove forest and reaches the lagoon on the Boquerón-Guaniquilla mangrove forest, on *Rhizophora mangle* on bark and dead wood, also on rotting aerial roots, and upright tree trunks, position aboveground 0.3 to 1.5 m, 14-IV-2003, *Á. M. Nieves-Rivera* (BPI 843767).

Remarks: *Crepidotus uber* (BPI 843767), the main character that distinguishes this form from the type species *Crepidotus mollis* is the lack of encrusting-pigmented hyphae on the cutis, an epicutis undifferentiated from the underlying context, and a gelatinized layer reaching the surface (Pegler, 1983a). In general, *C. uber* appears to be widespread in the tropics and subtropics and sequencing data suggest that it may be a complex of species; microscopically it is indistinguishable from *C. uber* from Madagascar (Mary Catherine Aime, unpublished data). *Crepidotus uber* has been collected from Bonin Island, Dominica, and Guadeloupe in the Lesser Antilles (Pegler, 1983a).

Coprinaceae

Psathyrella sp.

(Figures 48A-B)

Material studied: PUERTO RICO. Cabo Rojo: Boquerón Wildlife Refuge, on *R. mangle* leaf litter, position aboveground 0.1 m, 13-III-1995, *Á. M. Nieves-Rivera* (UPRRP *PR-641.1*).

Remarks: This taxon grew on decayed plant material (leaf litter of *R. mangle* and *Thespesia populnea*, and blades of *Thalassia testudinum*)

Lentinaceae

Lentinus crinitus (L.: Fr.) Fr., Syst. Orb. Veg. 77. 1825. [= *Lentinus swartzii* Berk. (Lodge, 1996)]

(Figure 48C)

Material studied: PUERTO RICO. Cabo Rojo: Boquerón Wildlife Refuge, on *R. mangle* fallen trunk, position aboveground > 1 m, 15-III-2002, *Á. M. Nieves-Rivera* (BPI 863546).

Remarks: This extremely common species has a basidioma which is extremely variable and difficulty is experienced in delimiting the species (Pegler, 1983a, b). *Lentinus crinitus* is found single or gregarious on moist dead hardwoods logs or stumps.

Coriolaceae

Coriolopsis badius (Cooke) Murrill, Bull. Torrey Bot. Club 34: 466. 1907.

Material studied: UNITED STATES. Florida: Aquatic Preserves of Southwest Florida, Cape Coral, on *Avicennia germinans* dead wood, position aboveground > 1 m, 5-I-2003, *T. A. Tattar* (BPI 843741); Cape Haze, on *A. germinans* dead wood, position aboveground > 1 m, 20-X-2002, *T. A. Tattar* (BPI 843742).

Remarks: This species is common in the Caribbean. *Coriolopsis badius* had a position aboveground from 25 cm to 2 m and also grew on *Conocarpus erectus* dead wood.

**Coriolopsis floccosa* (Jungh.) Ryv., Genera Polyp. Syn. Fung. 5: 316. 1991.

(Figure 48D)

Material studied: PUERTO RICO. Lajas: Magueyes Island, on *R. mangle* bark, position aboveground < 2 m, 14-IV-2003, *Á. M. Nieves-Rivera* (O *PR-979*).

Remarks: Spores of this species were non-amyloid in Melzer's reagent. *Coriolopsis floccosa* cause white rot in *R. mangle*.

Gloeophyllum striatum (Sw.: Fr.) Murrill, Bull. Torrey Bot. Club 32: 370. 1905.

Material studied: PUERTO RICO. Cabo Rojo: Boquerón Commonwealth Forest, next to Puerto Real, boardwalk that passes through a mangrove forest and reaches the lagoon on the Boquerón-Guaniquilla mangrove forest, on *R. mangle* bark, position aboveground 0.5 to 2.0 m, 19-IV-2003, *Á. M. Nieves-Rivera* (BPI 843744).

Remarks: *Gloeophyllum striatum* has also been found on *R. mangle* decay wood in the Boquerón Wildlife Refuge in Cabo Rojo.

Hexagonia hydnoides (Fr.: Sw.) M. Fidalgo, Mem. N. Y. Bot. Gdn. 17: 69. 1968.

(Figure 48E)

Material studied: UNITED STATES. Florida: Aquatic Preserves of Southwest Florida, Punta Gorda, on *Laguncularia racemosa* dead wood, position aboveground 50 cm, 20-X-2002, *T. A. Tattar* (BPI 843745); position aboveground 1 m, 20-X-2002, *T. A. Tattar* (BPI 843746).

Remarks: Specimen (BPI 843746) is young. This species is common in the Caribbean and is found especially in xeric localities. It has been found growing on *R. mangle* dead wood in Boquerón Wildlife Refuge in Cabo Rojo.

Pycnoporus sanguineus (L.: Fr.) Murrill, Bull. Torrey Bot. Club 31: 421. 1904.

(Figure 48F)

Material studied: PUERTO RICO. Cabo Rojo: Boquerón Commonwealth Forest, next to Puerto Real, boardwalk that passes through a mangrove forest and reaches the lagoon on the Boquerón-Guaniquilla mangrove forest, on *R. mangle* dead wood, position aboveground 50 cm, 19-IV-2003, *Á. M. Nieves-Rivera* (UPRRP *PR-984.2*).

Remarks: *Pycnoporus sanguineus* is the one of causative agents of the white rot of dead hardwoods. This species has hyphal contents in some areas of tramal tissue strongly dextrinoid in Melzer's reagent. *Pycnoporus sanguineus* is widely distributed throughout the subtropical and tropical regions of the world.

**Tyromyces* cf. *chioneus* (Fr.: Fr.) Karst., Rev. Mycol. 3: 17. 1881.
(Figure 48G)
Material studied: PUERTO RICO. Cabo Rojo: Boquerón Commonwealth Forest, next to Puerto Real, boardwalk that passes through a mangrove forest and reaches the lagoon on the Boquerón-Guaniquilla mangrove forest, on *R. mangle* bark, position aboveground 60 cm, 19-IV-2003, *Á. M. Nieves-Rivera* (UPRRP *PR-984.3*).
Remarks: This cosmopolitan species is found single or gregarious on dead hardwoods and occasionally on conifers. *Tyromyces* sp. has been previously collected from *Rhizophora* sp. (Sotão et al., 2002).

Hymenochaetaceae
Phellinus cf. *gilvus* (Schw.) Pat., Essai Taxon. Hyménon., p. 97. 1900.
Material studied: UNITED STATES. Florida: Aquatic Preserves of Southwest Florida, Punta Gorda, on *L. racemosa* dead wood, position aboveground 50 m, 20-X-2002, *T. A. Tattar* (BPI 843747).
Remarks: Basidioma badly eaten by insects and shows almost no pores left. This species also has been collected on *A. germinans*.

**Phellinus merrillii* (Murrill) Ryv., Norw. J. Bot. 19: 234. 1972.
Material studied: PUERTO RICO. Lajas: Magueyes Island, on *R. mangle* bark and dead wood, position aboveground 1.2 to 3.0 m, 8-V-2003, *Á. M. Nieves-Rivera* (O *PR-985*).
Remarks: *Phellinus merrillii* was originally described from the Philippine Islands. The globose, pigmented spores, lustrous context, and lack of setae characterized *P. merrillii*.

Meruliaceae

**Phlebia* sp.

(Figures 18A-B)

Material studied: UNITED STATES. Florida: Aquatic Preserves of Southwest Florida, Cape Haze, on *R. mangle* bark on dead aerial roots, position aboveground 25 cm, April 2003, *T. A. Tattar* (O *FL-9*).

Remarks: This species has a very striking color (bright orange towards center with white margins) and very large spores; it was sent to Dr. Kurt Hjortstam for further study. A similar specimen (UPRRP *PR-982*) also growing on *R. mangle* dead bark and decay wood was collected from Boquerón Commonwealth Forest in Cabo Rojo. *Phlebia acanthocystis* was reported from mangroves *Bruguiera gymnorrhiza* and *Rhizophora mucronata* in Japan (Maekawa et al., 2003).

Schizophyllaceae

Schizophyllum commune Fr.: Fr., Syst. Mycol. 1: 330. 1831.

Material studied: PUERTO RICO. Lajas: Magueyes Island, on *R. mangle* bark, position aboveground 0.5 to 3.0 m, 5-XI-1998, *Á. M. Nieves-Rivera* (BPI 843748).

Remarks: This species is commopolitan. *Schizophyllum commune* has been seen on a liana in *R. mangle* canopy at 5.0 m in height in Magueyes Island. Causes wood rot and is pathogenic to humans.

Dacrymycetaceae

Dacryopinax spathularia (Schw.) G. W. Martin, Lloydia 11: 116. 1948.

(Figure 48H)

Material studied: PUERTO RICO. Cabo Rojo: Boquerón Commonwealth Forest, on *Rhizophora mangle* decay wood, sometimes in bark, position aboveground 0 to 1.2 m, 13-III-1995, *Á. M. Nieves-Rivera* (BPI 843743).

Remarks: BWR specimens of *D. spathularia* were also found on *R. mangle* wood subjected once or twice a year to brackish water, with an annual surface salinity range of 7 to 31 g/L (unpublished data).

DISCUSSION

When compared with the assemblage of taxa reported from the Caribbean Islands, the Florida records were lower in basidiomycete diversity (e.g., *Coriolopsis badius*, *Hexagonia hydnoides*, *Phellinus* cf. *gilvus*, *Phlebia* sp.). In general, all basidiomycetes collected showed a tendency of dominant species adapted to coastal surroundings and a few limited unreported species demonstrate an interesting local distribution of basidiomycetes in both collection sites. Although many of these basidiomycetes have been reported previously from Puerto Rico (Stevenson, 1975; Lodge, 1996a; Nieves-Rivera et al., 1999; Lodge et al., 2000; Minter et al., 2001), their presence on *R. mangle*, *A. germinans*, and *L. racemosa* suggests that mangroves, although usually neglected as a potential substrate for basidiomycetes, may support a larger assemblage of species than indicated by the previous published records.

The basidiomycetes of the forests in Puerto Rico, especially the Agaricales are poorly known, and 15 to 25% is undescribed taxa (Lodge, 1996b). For instance, Lodge (1996b) mentioned that 30 taxa of Entolomataceae found by Dr. Timothy J. Baroni (State University of New York at Cortland) in Puerto Rico were not previously listed by Stevenson (1975). Examples such as these shows that much remains to be learned and it will be a monumental task to produce a reasonably complete mycobiota for Puerto Rico. Therefore, it would seem important to continue studying such habitats, in order to contribute to the conservation and knowledge of the biodiversity of basidiomycetes of Puerto Rico.

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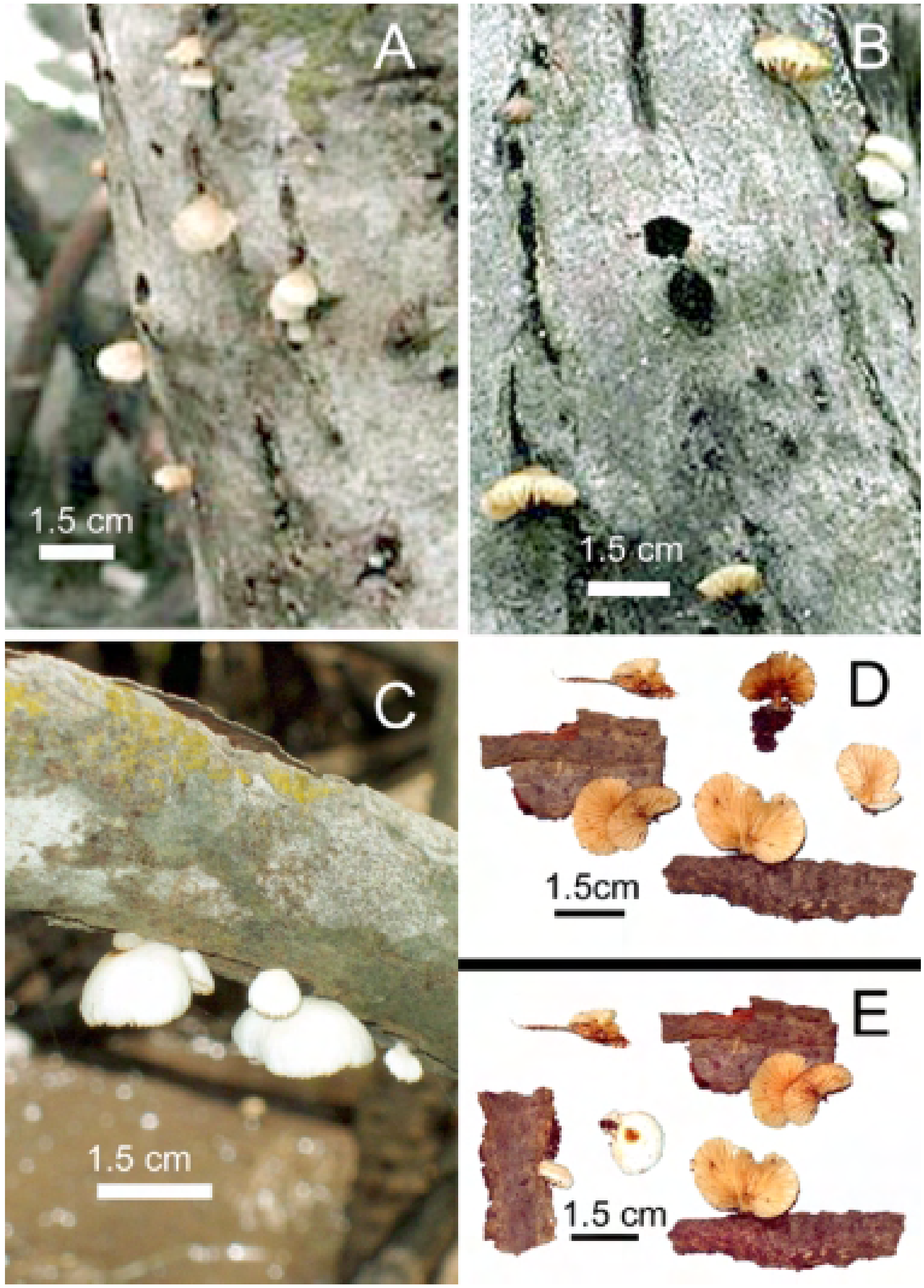
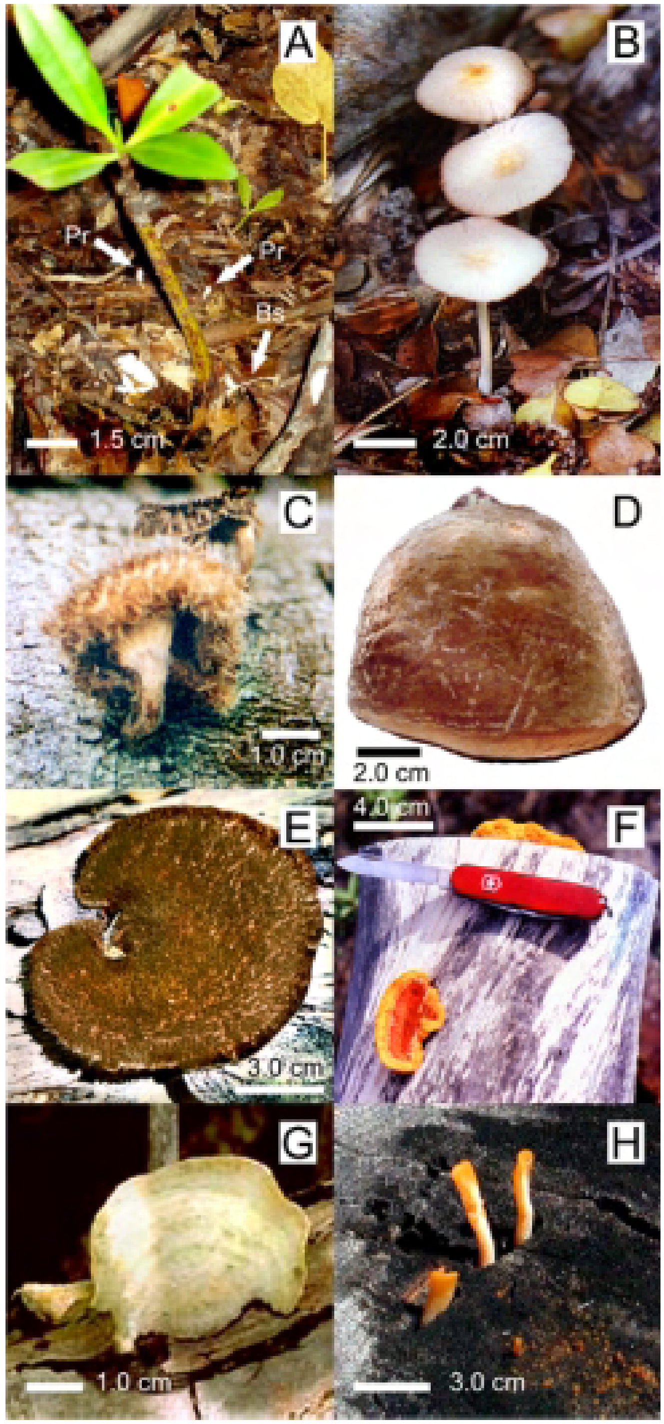
Figures 46A–B. Forests of *Avicennia germinans* and *Rhizophora mangle* of the Aquatic Preserves of Southwest Florida, located southwestern of Venice, at the Gulf of Mexico, Florida (U.S.A.). A. Pneumatophores and trees of *Avicennia germinans*. B. Aerial roots, buttresses, and trees of *Rhizophora mangle*.



Figures 47A–E. Manglicolous basidiomycete collected on southwestern Puerto Rico. A–B. *Crepidotus uber* on dead upright *Rhizophora mangle* tree trunk (A–B, young basidioma) and branch (C–E, mature basidioma).



Figures 48A–H. Further manglicolous basidiomycetes collected on southwestern Puerto Rico and Florida (U.S.A.). A–B. *Psathyrella* sp. (Pr = primordium; Bs = basidioma) on *Rhizophora mangle* leaf litter. C. *Lentinus crinitus*. D. *Coriolopsis floccosa*. E. *Hexagonia hydnoides*. F. *Pycnoporus sanguineus*. G. *Tyromyces* cf. *chioneus* on *R. mangle* wood. H. *Dacryopinax spathularia* on *R. mangle* wood.

CHAPTER 8

THE OCCURRENCE OF *STEMONITIS SPLENDENS* (MYXOMYCOTA: STEMONITALES) ON *RHIZOPHORA MANGLE*

ABSTRACT

The myxomycete *Stemonitis splendens* is reported on the red mangrove, *Rhizophora mangle*. This is the first report of this myxomycete on mangroves in the Caribbean region and the fifth report of a myxomycete from *R. mangle*. Although *S. splendens* was reported previously from Puerto Rico, its presence on *R. mangle* suggests that mangroves, although usually neglected as a potential substrate for myxomycetes, may support a larger assemblage of species than indicated by the few published records.

RESUMEN

Se informa el mixomiceto *Stemonitis splendens* en el mangle rojo, *Rhizophora mangle*. Este es el primer informe de este mixomiceto en mangles en la región del Caribe y el quinto informe de un mixomiceto en *R. mangle*. Aunque *S. splendens* se informó previamente para Puerto Rico, su presencia en *R. mangle* sugiere que los mangles, usualmente despreciados como sustrato potencial para los mixomicetos, pueden sostener una gran asociación de especies que la indicada por los pocos registros publicados.

INTRODUCTION

The myxomycetes in Puerto Rico are still poorly known, although a number of reports exist (a summary of previous work was included in Novozhilov et al., 2001). The genus *Stemonitis* (Myxomycota, Stemonitales) includes a number of common and widespread species, some of which are fairly distinctive. The single most important distinguishing feature of this genus is the presence of a reticulum (also known as surface net), a structure lacking in the morphologically similar genus *Comatricha*. This reticulum, which develops just beneath the peridium and is connected to the tips of the branches of the capillitium, forms a well-defined netlike covering over the surface of the spore mass (Stephenson and Stempen, 1994). Other features used to distinguish *Stemonitis* from other members of the Stemonitales are differences in stipe structure and ontogeny, as well as the origin of the capillitium (Stephenson and Stempen, 1994). The type species of the genus is *Stemonitis fusca*.

We found *Stemonitis splendens* Rostafinski on a red mangrove (*Rhizophora mangle*) in a forest site at Cabo Rojo, Puerto Rico (Nieves-Rivera and Darrah, 2002). This marks the first Caribbean record and the fifth published report of the occurrence of a myxomycete on red mangrove. The first species reported was *Arcyria cinerea*, which was collected on June 4, 1968 in the Heeia Swamp, Oahu, Hawaii, on a branch of *R. mangle* (Kohlmeyer, 1969). Jan Kohlmeyer gave the material to Constantine J. Alexopoulos who identified the specimen and deposited it in the University of Texas Myxomycete Collection (UTMC), under herbarium number 1922 (J. Kohlmeyer, personal communication, 2003). Later, Lee and Baker (1973) reported *Arcyria virescens*, *Ceratiomyxa* sp., and *Physarum* sp. from living roots of *R. mangle* above the tidal line at the same locality. *Arcyria cinerea* and *A. virescens* were the only myxomycetes included in the Schmit and Shearer (2003) survey of mangrove-associated fungi and fungal-like organisms. The occurrence of myxomycetes on mangroves appears to be rare.

MATERIALS AND METHOD

The study area is located at the Boquerón Commonwealth Forest (BCF), adjacent to the town of Boquerón, Barrio Boquerón, Cabo Rojo, southwestern Puerto Rico, in a secondary road (PR-307) at km 17.9, at 18°01’68.5”N, 67°10’49.8”W, at mean sea level, on 29 May 2002 (Figure 2). The region is classified as a subtropical dry forest (Ewel and Whitmore, 1973). Further details on climatology, ecology, geology, and edaphic formations of BCF are discussed in Vázquez (1983), Toro and Colón (1986), and Nieves-Rivera et al. (2002). *Rhizophora mangle* occasionally forms thick coastal woodland in BCF and in the rest of the southwestern coast of Puerto Rico (Cintrón et al., 1978; Lugo, 1989; Vázquez and Kolterman, 1998).

RESULTS AND DISCUSSION

Stemonitis splendens Rostafinski, *Sluzowce (Mycetozoa) Monografia* 195, 1874.
(Figure 49A-B)

Description.–Sporangia 12-15 mm high, clustered and usually forming a large colony, densely crowded or agglutinated, stipitate, cylindric, rigid and more or less erect, or flexuous, obtuse to acuminate at the apex, dark purplish brown (Figures 495A-B). Sporotheca cylindrical, deep purplish brown, obtuse, more or less erect but flexuose towards the apex, 0.5 mm in diameter. Stipe 3-4 x 0.1-0.2 mm, slender, lustrous, conspisuously flared at the base, arising from a widely expanded, silvery to somewhat purplish hypothallus. Columella reaching nearly to the sporangial apex, attenuate, often coiled and tortuous toward the tip, dark reddish brown. Capillitium open-meshed and arising from the columella by relatively few major branches, sometimes with membranous junctions; surface reticulum fairly robust, smooth, with irregular, rounded to polygonal meshes, mostly 30-90 µm in diameter, incomplete or absent in agglutinated fruitings, brown. Spores 7-9 µm in diameter, globose, thin-walled, faintly verrucose (warted), lilaceous brown by transmitted light, dark purplish black in mass.

Habitat.–Gregarious or solitary on decayed fallen trunk (25 cm in diameter) of *R. mangle* (0.5 m above ground).

Material Studied.–PUERTO RICO: Boquerón Commonwealth Forest, adjacent to Puerto Real, boardwalk that passes through a mangrove forest and reaches the lagoon on the Boquerón-Guaniquilla mangrove forest, < 1 m alt., 29-V-2002, UARK #17308.

Remarks.–*Stemonitis splendens* (UARK #17308) is a common species, often occurs in large fruitings (as in Figure 49B) and has sporangia with conspicuous large-meshed surface net and nonreticulate spores (Stephenson and Stempen, 1994). The specimen was deposited in the herbarium (UARK) of the University of Arkansas in Fayetteville, Arkansas.

Although *Stemonitis splendens* Rostafinski was reported previously from Puerto Rico (Novozhilov et al., 2001) and the Caribbean in general (Stevenson, 1975; Minter et al., 2001; Camino et al., 2003), its presence on *R. mangle* suggests that mangroves, although usually neglected as a potential substrate for myxomycetes, may support a larger assemblage of species than indicated by the few published records. Therefore, it would seem important to continue studying such habitats, in order to contribute to the conservation and knowledge of the biodiversity of myxomycetes of Puerto Rico.

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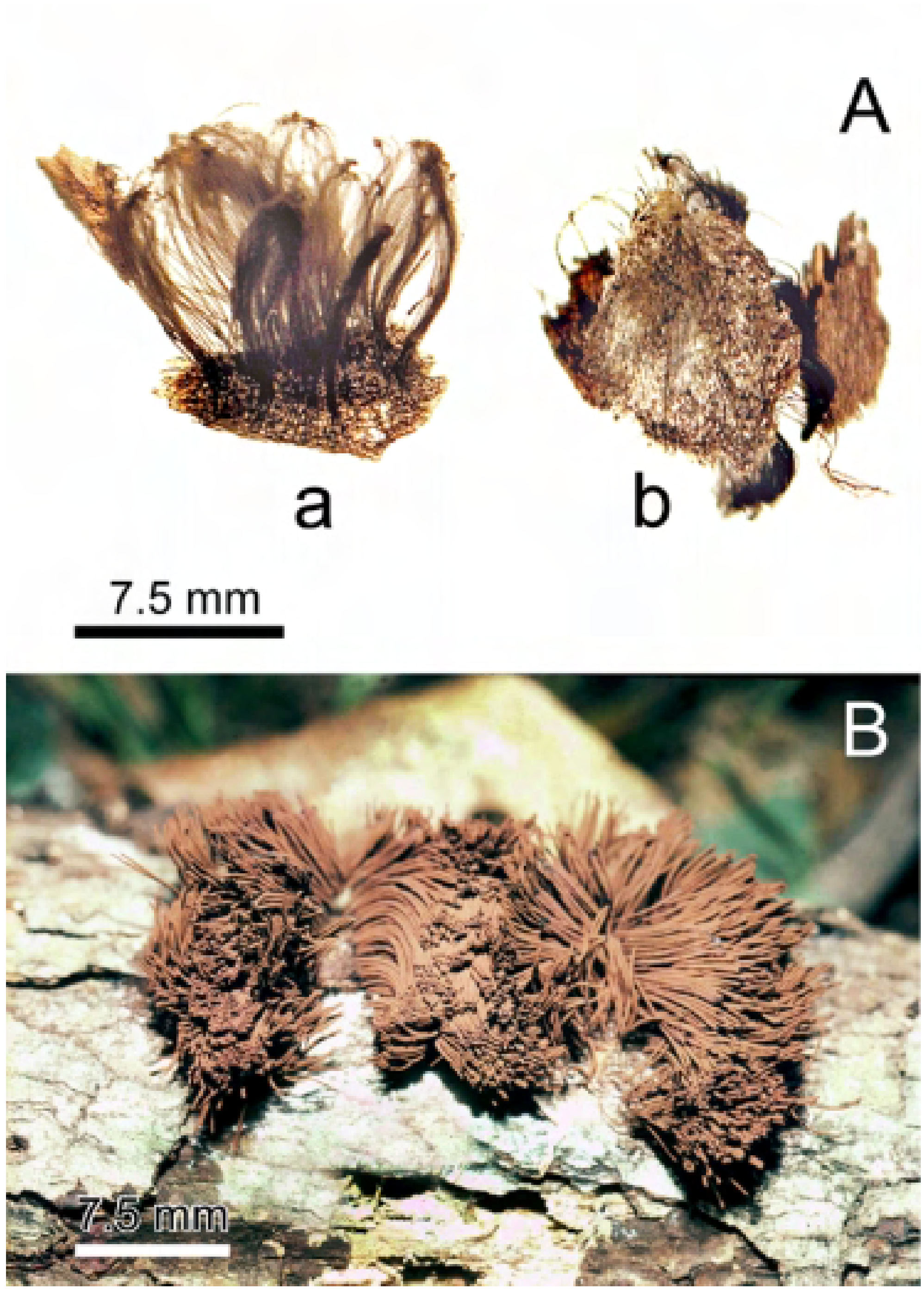

Figures. 49A-B. A. Sporangia of *Stemonitis splendens* (UARK #17308; a = side view, b = bottom view) collected on *Rhizophora mangle*, Boquerón Commonwealth Forest, Cabo Rojo, Puerto Rico, West Indies. B. Fruiting of *Stemonitis splendens* in New Zealand.

CHAPTER 9. GENERAL DISCUSSION

In this study, I have provided historical background and added some new records to the body of information that is available for the study of coastal fungi, including marine, estuarine, and mangrove-associated fungi in Puerto Rico. The techniques used in this study, although basic or simple, are currently used in taxonomic and physiological studies. In this part of this study, I would like to identify gaps in our current knowledge where future research should focus and propose novel areas for research in marine mycology in Puerto Rico.

From previous studies, the methodology employed for the isolation and culturing of fungi from marine and estuarine habitats has progressed little since the 1960's. Also, conclusions regarding the biodiversity and distribution of coastal fungi are often made without the aid of statistical analysis. Most beginning mycologists have the general tendency to identify large numbers of taxa or to force collections into existing species concepts. However, over time, Puerto Rican mycologists have developed greater sophistication.

The substrates surveyed in Puerto Rico included vascular plant material, sand grains, sandy soils, algae, and few terrestrial and aquatic animals, which tend to support a rich fungal diversity within coastal environments. However, many more substrates deserve further study such as marine flora (e.g., phytoplankton. algae, seaweeds, cryptogams) and fauna (e.g., zooplankton, calcareous mollusks, crustacean exoskeletons, sea birds, marine mammals). Other habitats that deserve more attention are hypersaline lagoons and brines, estuaries, pelagic waters, deep sea; such habitats might support physiologically-adapted fungi which may be of interest to biotechnology. Another applied research field is the pollution of the seas and the mutations in fungal populations, and the capability of such fungal isolates to withstand and biotransform harmful chemicals (e.g., PAHs) into less detrimental ones. Fungi in coastal environment such as parasites, commensals, and endophytes warrant further attention, as do understudied groups as the lower fungi and other fungal-like organisms (e.g., myxomycetes, oomycetes).

The oomycete *Halophytophthora* sp. has been isolated from leaf samples. This earliest group of fungal-like organisms decomposes senescent leaves and are quickly replaced by marine higher fungi. Frequent inhabitants of leaves are the mitosporic fungi and it is common to find geophilic species at early stages of incubation, for instance, *Cladosporium* spp. and *Pestalotiopsis* spp. Species of *Penicillium* and *Trichoderma* spp. occurred at advanced stages of leaf decomposition.

Most of the species coastal fungi found in this research are cosmopolitan. They are common saprophytes in aquatic habitats (marine, estuarine and freshwater habitats), forest timber, grow on sandy soil, and form mycorrhizal associations with both exotic and native plants. In general, they also are well represented in xerophytic and non-xerophytic areas. This study documents the large numbers of taxa found in the coasts of Puerto Rico, taking into account all surveys available (published and unpublished) of coastal fungi. For example, the terrestrial coast mycobiota (e.g., basidiomycetes) shows adaptability to xeric environments because they tend to form epigeous basidiocarps avoiding sun exposure, minimizing loss of water content. Moisture is a limiting factor in their collection; therefore, rainy seasons are the best time for collecting them. The climate of southwestern Puerto Rico has been described as subtropical dry, with scanty rain and strong winds from the southeast. In general, there are two distinct rainy seasons in Puerto Rico, one in May-June, the other in August-November. Summer and autumn months tend to be more or less rainy, while winter and spring months are usually drier.

The evaluation of biodiversity is becoming an extremely important part in the conservation of the environment and the naming of biological species depends on good systematics. The southwestern coast of Puerto Rico includes endemic and extirpated species of flora and fauna, interesting geological features, important archaeological sites, and spectacular landscapes unlike those found in many other coasts of Puerto Rico. These features are the product of the unique situation of this island-small size, belongs to the Antillean island arc, volcano-oceanic origin, relative isolation, and the degree of protection caused by remoteness from populated lands.

Islands located at a considerable distance from large land masses such as continents will be reached by a relatively small number of organisms that are well adapted to dispersal over long distances (e.g., seabirds, insects, beach plants, algae, pollen, fungal spores). However, organisms less suited for such dispersal will reach islands less frequently, perhaps blown during a hurricane, transported on the feet or in the digestive tract of a bird, or on an ocean-going raft of vegetation.

A database of coastal fungi would be needed for comparison of all known species, including aquatic and terrestrial fungi. This database would be integrated into an internet or compact disk-read only memory (CD-ROM) medium where data can be conveniently updated and accessed. The consideration of the use of DNA sequence analysis and morphology characterization of sexual and asexual structures are nowadays the tools of choice for the study of fungal identification.

In conclusion, there is no doubt that data on the existing biodiversity must be recorded prior to the evaluation of any changes in the mycobiota. Without at least a preliminary inventory of the fungi in Puerto Rico, it is nearly impossible to assay what is novel (e.g., new species or records). It seems important to continue studying such habitats, in order to contribute to the conservation and knowledge of the biodiversity of fungi and fungal-like organisms of Puerto Rico.

CHAPTER 10. GENERAL CONCLUSIONS

1. Most fungi and fungal-like organisms collected or isolated in mangroves of southwestern Puerto Rico are cosmopolitan. They are common saprophytes, parasites, endophytes, and filoplanes in coastal forest timber or grow on leaves and wood.
2. A high number of fungal taxa (604 spp.) was found among coastal fungi of Puerto Rico, when compared with previous reports from other coastal forests (i.e., Belize, Cuba, Mexico), but similar to that recorded in the Lesser Antilles (i.e., Guadeloupe, St. Croix). However, one must keep in mind that coastal mycology surveys are novel in the Caribbean.
3. Abrupt changes in the ecosystems of southwestern Puerto Rico, particularly deforestation of coastal forests (mangroves), may cause the decrease of native organims that depend on naturally occurring associations, such as fungi.
4. Evaluation of the existing biodiversity must be recorded prior to the evaluation of any changes in mycobiota. Mangroves, usually neglected as a potential substrate for fungi, supported a larger assemblage of species than indicated by the literature.

CHAPTER 11. RECOMMENDATIONS

1. To continue to study the biodegradation and bioremediation qualities of the *Cladosporium* species (*C. sphaerospermum* and *C. oxysporum*) and native strains of marine and terrigenous fungi by using HPLC or any other biochemical techniques to determine if these species in fact metabolize PAHs.
2. To survey other mangrove-associated plants (e.g., *Acrostichum* spp., *Batis maritima*, etc.) for fungi and fungal-like organisms and compare their biodiversity, taxonomic composition, population ecology, molecular biology, and phylogeny.
3. To more exhaustively survey manglicolous fungal-like organisms, endophytes, mycosis of marine fauna, and marine phytopathology of Puerto Rico, which are by no means exhausted. Future collections may produce some new records.
4. To conduct mycological research in Puerto Rico in the pelagic, shelf, benthic, and deep sea areas (e.g., Puerto Rico's Trench).

APPENDIXES

APPENDIX 1

AQUATIC FUNGI FROM ESTUARIES IN PUERTO RICO. I. MOUTH OF THE MANATÍ RIVER

ABSTRACT

Aquatic fungi were isolated from sea foam, leaf litter, beach sand, and drift wood from an estuary known as "La Boca" (river mouth) of the Manatí River in Barceloneta, northern Puerto Rico. Observations of the baits (sterilized balsa wood) and incubated organic debris revealed the presence of 28 species of aquatic fungi, 13 of which belong to the ascomycetes and 15 to the mitosporic fungi. The species *Arenariomyces triseptatus*, *Astrosphaeriella* aff. *mangrovei*, *Corollospora* cf. *colossa*, *C. filiformis*, *Halosphaeria* sp., *Kirschsteiniothelia* sp., *Torpedospora radiata* (Ascomycota), *Brachiosphaera tropicalis*, *Campylospora* sp., and *Clavatospora bulbosa* (Mitosporic fungi) were the most common in the samples. Eleven species are new records for Puerto Rico and six fungal isolates could not be identified.

RESUMEN

Se aislaron hongos acuáticos de la espuma de mar, hojarasca, arena playera y madera a la deriva de un estuario conocido como "La Boca" (boca de río) del Río Manatí en Barceloneta, al norte de Puerto Rico. Las observaciones de los cebos (madera de balsa esterilizada) y material orgánico incubado revelaron la presencia de 28 especies de hongos acuáticos, de los cuales 13 pertenecen a los ascomicetos y 15 a los hongos mitospóricos. Las especies *Arenariomyces triseptatus*, *Astrosphaeriella* aff. *mangrovei*, *Corollospora* cf. *colossa*, *C. filiformis*, *Halosphaeria* sp., *Kirschsteiniothelia* sp., *Torpedospora radiata* (Ascomycota), *Brachiosphaera tropicalis*, *Campylospora* sp. y *Clavatospora bulbosa* (Hongos Mitospóricos) fueron las más comunes en las muestras. Once especies son nuevos registros para Puerto Rico y se aislaron seis hongos que no pudieron ser identificados.

INTRODUCTION

Fungi occur widely in the oceans, seas, and estuaries as parasites in marine plants or animals or as saprobes on timber, algae, sea grasses, protozoans, corals, sea foam, and other substrata (Kirk et al., 2001). The distribution of fungi in the seas and estuaries has been studied in several Caribbean localities, including (1) Belize (Kohlmeyer and Volkmann-Kohlmeyer, 1987a; Minter et al., 2001), (2) Cuba (Capó-de Paz, 1986a, b; Minter et al., 2001; González et al., 2003), (3) Lesser Antilles (Kohlmeyer and Kohlmeyer, 1971; Fell and Master, 1975; Stevenson, 1975; Kohlmeyer, 1981; Kohlmeyer and Volkmann-Kohlmeyer, 1987b, 1988; Minter et al., 2001), (4) Mexico (González et al., 1998, 2000, 2001; Minter et al., 2001), (5) Puerto Rico (Rossy-Valderrama, 1956; Meyers, 1957; Kohlmeyer, 1968; Carvajal-Zamora, 1971; Hernández-Vera, 1972, 1975, 1980; Stevenson, 1975; Galler-Rimm, 1982; Hernández-Vera and Almodóvar, 1983, 1984; Acevedo, 1987, 2001; Valdéz-Collazo et al., 1987; Kohlmeyer and Volkmann-Kohlmeyer, 1987c; Calzada, 1988; Lodge, 1996; Minter et al., 2001; Nieves-Rivera et al., 2002), and (6) Venezuela (Dennis, 1970; Minter et al., 2001). Although aquatic fungi have been extensively studied worldwide, in many Caribbean islands the estuarine and marine mycobiota is poorly known. Most estuarine and marine collections are in some cases sporadic and interrupted by many years. The purpose of this study was to report the incidence of aquatic fungi in marine foam from a river mouth (estuarine conditions) in Puerto Rico, a subtropical island located between 18°00’–18°30’ N, 65°35’–67°15’W, in the northeastern Caribbean Sea. Fifteen of the samples were Mitosporic fungi, the most common group in the samples, and 13 were ascomycetes, eleven species are new records for Puerto Rico.

MATERIALS AND METHOD

On 25 November 1998, intertidal foam and sand were collected from the Manatí River (also known as “Río Grande de Manatí”). Samples were baited in the laboratory with pieces of sterilized balsa wood 10 cm long. Washed-up beach debris (leaf litter and drift wood) also was collected for incubation, following the methods described by Kohlmeyer and Kohlmeyer (1979).

A sandy beach of the Manatí River mouth, also known as “La Boca” or “Boca” (Spanish for mouth), located next to road PR-684 in the Barceloneta municipality, about 36 km west (18°28’81.8” N and 66°32’09.2” W) of San Juan, was selected as study site (Figure 50). The Manatí River is about 64 km long, rises in Cordillera Central just north of Barranquitas, flows northwest, past Ciales to the Atlantic Ocean 6.4 km northwest of Manatí. Mean annual precipitation is less than 1,650 mm and mean annual temperature is 25.3° C (Ravalo et al., 1986, Anonymous, 2003). The climate is described as that of the subtropical dry life zone (Ewel and Whitmore, 1973). Surface seawater salinity ranges from 19 to 31 g/L, with temperatures of 27 to 31°C, a pH of 7.4 to 8.7, a total alkalinity of 87 to 116 mg/L, and a dissolved oxygen (DO) value of 7.2 to 8.6 mg/L (Nieves-Rivera, unpublished data, 2003). At the collection site, the river mouth beach sand composition is dominated by dark minerals, volcanic rock fragments, quartz, and feldspar (Morelock et al., 1985). The geomorphology of La Boca was studied by Lobeck (1922), Wood et al. (1975), Morelock et al. (1985), and Barreto-Orta (1997).

The Manatí River estuary has been found to be highly stratigraphic, with little or no mixture in the interphase between fresh- and seawater (Carvajal-Zamora, 1977). The sea wedge extends five to six km up river. The intrusion of seawater into the river usually causes a decrease in DO, which is related to a high microbiological activity and chemical demand in the sea wedge and in sediments; this decrease in DO creates anoxic conditions during the year (Carvajal-Zamora, 1977). Slightly high phosphate (PO_4^{3-} = 0.08 to 0.12 µM) and nitrate (NO_3^{2-} = 16.72 µM) values have been detected in near shore surface waters, especially near the Manatí River mouth, probably because of agricultural runoff (Wood et al., 1975: Station PMA-3A at 0 m depth). Carvajal-Zamora (1977) found that the concentrations of heavy metals and nutrients in the sediments of the Manatí River were greater in the estuarine part than in the riverine portion.

The procedure used in the present study for collection and preservation of marine foam on the sandy beach follows Kohlmeyer and Kohlmeyer (1979); their illustrated keys are described elsewhere (Kohlmeyer and Volkmann-Kohlmeyer, 1991; Hyde and Sarma, 2000). For the isolation and identification of aquatic hyphomycetes, we followed Santos-Flores and Betancourt-López (1997). Voucher specimens (slides) of all species were deposited at the University of Puerto Rico at Río Piedras herbarium (UPRRP).

RESULTS AND DISCUSSION

A total of 28 fungi were found, 13 of which belong to the ascomycetes and 15 to the mitosporic fungi (Table VIII; Figures 51A-H). The species *Arenariomyces triseptatus* (Figure 51A), *Astrosphaeriella* aff. *mangrovei* (Figure 517B), *Corollospora* cf. *colossa* (Figure 51C), *C. filiformis* (Figure 51D), *Halosphaeria* sp., *Kirschsteiniothelia* sp. (Figure 517E), *Torpedospora radiata* (Figure 51F) (Ascomycota), *Brachiosphaera tropicalis* (Figure 51G), *Campylospora* sp., *Clavatospora bulbosa* (Figure 51H) (Mitosporic fungi) were the most common in the samples. Few marine ascomycetes were isolated; this scarcity was probably due to the selectivity of the isolation method employed and the time of sampling. Ascomycetes and mitosporic fungi (mostly aquatic hyphomycetes) were found mixed in foam, leaf litter, and sand of the La Boca beach. Eleven species are new records for Puerto Rico, and six fungal isolates could not be identified (Table VIII).

Along with ascospores of marine fungi, conidia of 10 species of aquatic hyphomycetes were detected: *Anguillospora* cf. *longissima*, *Articulospora tetracladia*, *Brachiosphaera tropicalis*, *Camposporidium* sp., *Campylospora* sp., *Diplocladiella scalaroides*, *Lemonniera pseudofloscula*, *Triscelophorus acuminatus*, *Triscelophorus* sp., and *Tubeufia cylindrothecia* (Santos-Flores and Betancourt-López, 1997) (Table VIII). *Camposporidium* sp. conidia resembled *Camposporidium* spp. reported from Río Sonadora and Quebrada Jiménez nears the El Verde LTER Field Station, Puerto Rico (Hamilton, 1973). Some specimens of *B. tropicalis* showed a translucent halo around the central cell

(Figure 51G); while others *B. tropicalis* were typical. Aquatic hyphomycetes are not uncommon in estuarine habitats (Johnson and Sparrow, 1961; Kohlmeyer and Kohlmeyer, 1979). For example, Kirk (1969) reported two lignicolous aquatic hyphomycetes (*Clavatospora stellatacula* and *Tetraploa aristata*) adapted to seawater conditions in the Chesapeake Bay.

Conidia of six terrigenous mitosporic fungi also were isolated from sea foam samples. These were: *Curvularia* sp., *Fusarium* sp., and conidia of four unknown species, as listed in Table VIII. The unknown spores (also referred to as *Ignotus* by Acevedo, 1987, 2001) are described as dematiaceous, aseptate or septate, ranging in sizes, aleuriospore, dictyospore, phragmospore, lenticular with or without apical pore. These terrigenous species are apparently common to marine and estuarine habitats. Acevedo (1987) found 25 species of mitosporic fungi in sand, from the reefs and an offshore island (Isla Cuevas) from La Parguera, southwestern Puerto Rico. These mitosporic fungi were: *Alternaria* sp., *Aspergillus* spp., *Cephalosporium* sp., *Cladosporium* spp., *Curvularia* spp., *Diplodia* spp., *Fusarium* spp., *Helminthosporium* spp., *Penicillium* spp., *Scopulariopsis* sp., *Trichoderma* spp., and Mycelia Sterilia (Acevedo, 1987).

In this survey, we did not recover any species that were potentially pathogenic to humans, a finding different to that of González et al. (2000) (Table IX). The assemblage of species reported by González et al. (2000) also differs greatly from that recorded in the present study due to methodology and bait used. González et al. (2000) isolated a total of 17 keratinophilic fungi, 13 of which were hyphomycetes and four ascomycetes. González et al. (2001) reported a larger collection throughout Mexico; therefore, their checklist contains 47 ascomyetes, 14 mitosporic fungi, and one basidiomycete (Table IX). In the Cuban survey, González et al. (2003) reported 29 marine fungi (25 ascomycetes and four mitosporic fungi), 19 of which were new records (Table IX). In contrast, our collection from a single locality produced 15 mitosporic fungi and 13 ascomycetes (Table IX).

Most of the species collected are arenicolous (*Arenariomyce*s cf. *majusculus*, *A. triseptatus*, *Corollosopora* cf. *colossa*, *C. filiformis*, *C.* cf. *pseudopulchella*; see Kohlmeyer and Kohlmeyer, 1979). Marine ascomycetes (*Arenariomyces triseptatus*, *Lulworthia* sp., *Torpedospora radiata*) have been recorded previously from Belize (Kohlmeyer and Volkmann-Kohlmeyer, 1987a), Cuba (González et al., 2003), Mexico (González et al., 2000, 2001), Puerto Rico (Nieves-Rivera and Santos-Flores, unpublished data, 2004), and St. Croix (Kohlmeyer and Volkmann-Kohlmeyer, 1988) (Table IX). *Halorosellinia oceanica*, *Lulworthia* sp., and *Torpedospora radiata* are lignicolous or algicolous species (Kohlmeyer and Kohlmeyer, 1979; Acevedo, 2001). All species isolated in this survey are saprobes living in parts of angiosperms, plant debris, or in the blades of seagrasses.

Fifteen of the samples were Mitosporic fungi, the most common group in the samples, and 13 were ascomycetes. Eleven species are new records for Puerto Rico. The species we found are most similar to those from previous studies in Puerto Rico (Carvajal-Zamora, 1971; Hernández-Vera, 1972, 1975, 1980; Stevenson, 1975; Hernández-Vera and Almodóvar, 1983, 1984; Acevedo, 1987, 2001; Calzada, 1988; Lodge, 1996; Minter et al., 2001) (Table VIII).

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Table VIII. Summary of the aquatic fungi (obligate and facultative marine fungi sensu Kohlmeyer, 1974) recovered from samples of sea foam, leaf litter, and wood in the mouth of the Manatí River, northern Puerto Rico.

Fungus	Substrate[1]
ASCOMYCOTA	
Arenariomyces cf. *majusculus* Kohlm. & Volkm.-Kohlm.*	F, S
A. triseptatus Kohlm.	F, S
Astrosphaeriella aff. *mangrovei* (Kohlm. & Vittal) Aptroot & K.D. Hyde*	F, L, W
Chaetomastia cf. *typhicola* (Karst.) Barr*	F, S
Corollospora cf. *colossa* Nakagiri & Tokura *	F
C. filiformis Nakagiri, in Nakagiri & Tokura*	F
C. cf. *pseudopulchella* Nakagiri & Tokura*	F
Coronopapilla aff. *mangrovei* (K.D. Hyde) Kohlm. & Volkm.-Kohlm.*	F, W
Halosphaeria cucullata (Kohlm.) Kohlm.*	F, S
Halosphaeria sp.	F, S
Kirschsteiniothelia sp.*	F
Kretzschmariella culmorum (Cooke) Y.M. Ju & J.D. Rogers	F
Lindra sp.	F, S
Lulworthia sp.	F, S
Torpedospora radiata Meyers	F
Unknown sp. 1	F, S
Unknown sp. 2	F
MITOSPORIC FUNGI	
Anguillospora cf. *longissima* (Sacc. & P. Syd.) Ingold	F, L, S
Articulospora tetracladia Ingold	F
Brachiosphaera tropicalis Nawawi, in Descals	F
Camposporidium sp.	F
Campylospora sp. (s. str. Santos-Flores & Betancourt-López, 1997)	F, L, W
Clavatospora bulbosa (Anastasiou) Nakagiri & Tubaki*	F, S
Curvularia sp.	F, L, W
Diplocladiella scalaroides G. Arnaud	F, L
Fusarium sp.	F, L, W
Lemonniera pseudofloscula Dyko, in Descals, J. Webster & Dyko	F, L
Triscelophorus acuminatus Nawawi	F, S
Triscelophorus sp.	F
Tubeufia cylindrothecia (Seaver) Höhn.*	F, S

Unknown sp. 1	F, W
Unknown sp. 2	F, L
Unknown sp. 3	F
Unknown sp. 4	F, W

[1] Substrate: F = sea foam; L = leaf littter; S = beach sand; W = wood.
* = New record for Puerto Rico.

Table IX. Summary of the aquatic fungi (obligate and facultative marine fungi sensu Kohlmeyer, 1974) recovered from the Caribbean.

Kohlmeyer & Volckmann-Kohlmeyer (1987a) [Belize]	**Kohlmeyer & Volckmann-Kohlmeyer (1988) [St. Croix]**
ASCOMYCOTA	ASCOMYCOTA
Aigialus grandis	_Aigialus grandis_
Aniptodera chesapeakensis	_A. parvus_
*_Arenariomyces triseptatus_	_Arenariomyces parvulus_
Ascocratera manglicola	*_A. triseptatus_
Belizeana tuberculata	_Ascocratera manglicola_
Biatriospora marina	_Belizeana tuberculata_
Caryosporella rhizophorae	_Caryosporella rhizophorae_
Chadefaudia corallinarum	_Ceriosporopsis halima_
Corollospora maritima	_Dactylospora haliotrepha_
C. pulchella	_Didymosphaeria enalia_
Dactylospora haliotrepha	_D. rhizophorae_
Didymosphaeria enalia	_Halosphaeria quadricornuta_
D. rhizophorae	_H. salina_
Halosarpheia abonnis	_Hydronectria tethys_
H. fibrosa	_Keissleriella blepharospora_
Halosphaeria cucullata	_Leptosphaeria australiensis_
H. quadricornuta	_Lignicola laevis_
H. salina	_L. tropica_
Hydronectria tethys	_Lindra marinera_
Keissleriella blepharospora	_L. thalassiae_
Leptosphaeria australiensis	_Lophiostoma mangrovis_
L. avicenniae	_Lulworthia grandispora_
Lignicola laevis	*_Lulworthia_ sp.
L. tropica	_Massarina thalassiae_
Lindra marinera	_M. velatospora_
L. thalassiae	_Ophiodeira monosemeia_
L. thalassiae var. _crassa_	_Passeriniella savoryellopsis_
Lophiostoma mangrovis	_Swampomyces armeniacus_
Lulworthia grandispora	*_Torpedospora radiata_
L. kniepii var. _curalii_	_Trematosphaeria lignatilis_
*_Lulworthia_ sp.	BASIDIOMYCOTA
Massarina thalassiae	_Halocyphina villosa_
Mycosphaerella pneumatophorae	_Nia vibrissa_
M. salicorniae	MITOSPORIC FUNGI
Swampomyces armeniacus	_Cytospora rhizophorae_

**Torpedospora radiata*
Trematosphaeria lignatilis
BASIDIOMYCOTA
Halocyphina villosa
Nia vibrissa
MITOSPORIC FUNGI
Cytospora rhizophorae
Humicola alopallonella
Periconia prolifica
Rhabdospora avicenniae
Trichocladium achrasporum
Varicosporina ramulosa
Zalerion cf. *varium*

González et al. (2001) [Mexico]
ASCOMYCOTA
Antennospora quadriconuta
A. salina
Arenariomyces parvulus
A. trifurcatus
**A. triseptatus*
Ceriosporopsis halima
Corollospora angusta
C. gracilis
C. maritima
C. pseudopulchella
C. pulchella
Etheirophora blepharospora
Halosphaeriopsis mediosetigera
Hydronectria tethys
Leptosphaeria australiensis
L. avicenniae
Lignicola tropica
Lindra crassa
L. marinera
L. thalassiae
**Lulworthia* sp.
Mycosphaerella pneumatophorae
M. salicorniae
Paraliomyces lentiferus
Remispora galerita

Humicola alopallonella

González et al. (2000) [Mexico]
MITOSPORIC FUNGI
Aspergillus auricomus
A. fumigatus
A. terreus
Fusarium semitectum
F. solani
Gymnascella dankaliensis
Gymnoascus sp.
Scopulariopsis brumptii

González et al. (2003) [Cuba]
ASCOMYCOTA
Antennospora quadriconuta
Arenariomyces parvulus
A. trifurcatus
**A. triseptatus*
Ceriosporopsis halima
Corollospora armoricana
C. cinnamomea
C. gracilis
C. maritima
C. pseudopulchella
C. quinqueseptata
Falcatispora cincinnatula
Lignicola leavis
L. tropica
Lindra marinera
L. obtusa
L. thalassiae
Lulworthia grandispora
L. fucicola
L. kniepii
**Lulworthia* sp.
Neptunella longirostris
Pontogeneia cubensis
Savoryella lignicola
**Torpedospora radiata*

**Torpedospora radiata*
Verruculina enalia
BASIDIOMYCOTA
Nia vibrissa
MITOSPORIC FUNGI
Cirrenalia pseudomacrocephala
Cytospora rhizophorae
Periconia prolifica
Tricocladium achrasporum
T. alopallonellum
Varicosporina ramulosa

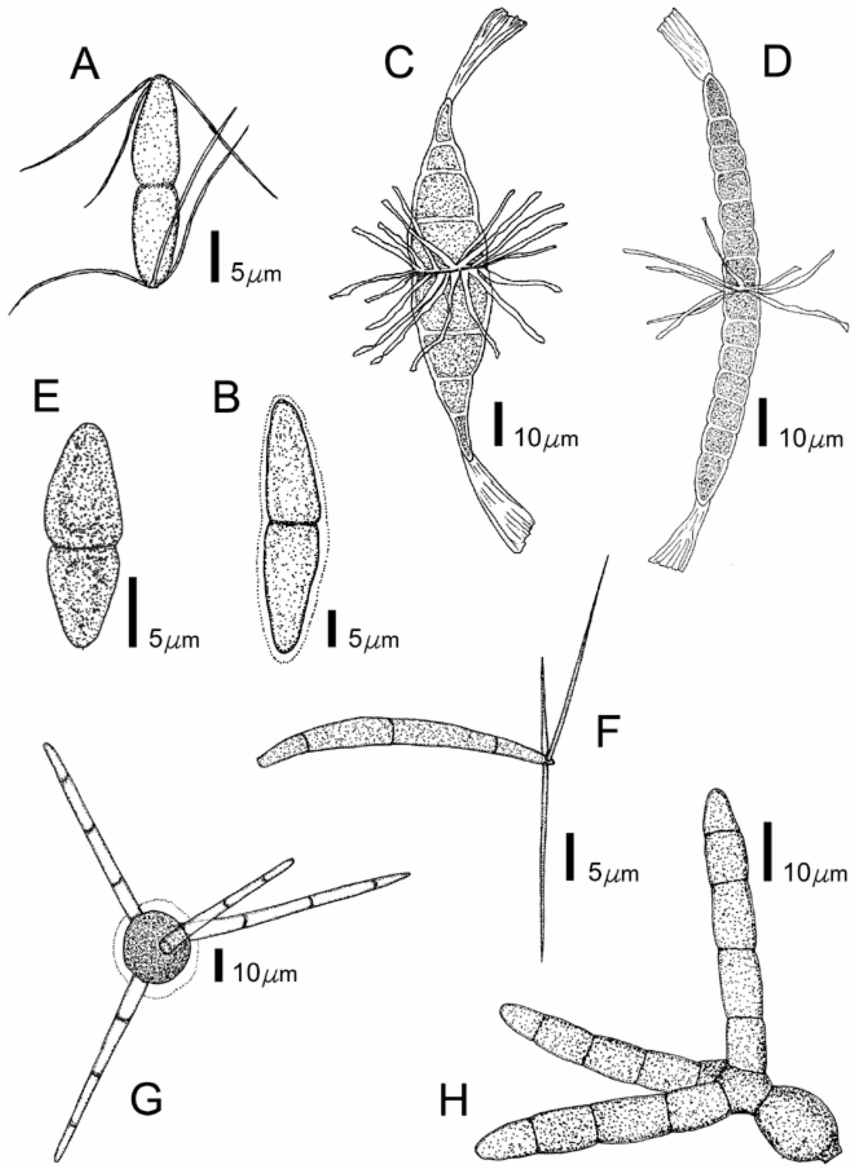
MITOSPORIC FUNGI
Cirrenalia basiminuta
Tricocladium alopallonellum
Varicosporina ramulosa
Zalerion varium

Nieves-Rivera and Santos-Flores (present study) [Puerto Rico]
ASCOMYCOTA
Arenariomyces cf. *majusculus*
**A. triseptatus*
Astrosphaeriella aff. *mangrovei*
Chaetomastia cf. t*yphicola*
Corollospora cf. *colossa*
C. filiformis
C. cf. *pseudopulchella*
Coronopapilla aff. *mangrovei*
Halosphaeria cucullata
Halosphaeria sp.
Kirschsteiniothelia sp.
Kretzschmariella culmorum
Lindra sp.
**Lulworthia* sp.
**Torpedospora radiata*
MITOSPORIC FUNGI
Anguillospora cf. *longissima*
Articulospora tetracladia
Brachiosphaera tropicalis
Camposporidium sp.
Campylospora sp.
Clavatospora bulbosa
Curvularia sp.
Diplocladiella scalaroides
Fusarium sp.
Lemonniera pseudofloscula
Triscelophorus acuminatus

Triscelophorus sp.
Tubeufia cylindrothecia

* = Marine fungi isolated in common from the Caribbean.

Figure 50. Collection of sea foam samples from the mouth of Manatí River, north central coast of Puerto Rico.



Figures 51A-H. Aquatic fungi isolated from samples collected of the mouth of Manatí River, northern Puerto Rico. Ascospores: A. *Arenariomyces triseptatus*. B. *Astrosphaeriella* aff. *mangrovei*. C. *Corollospora* cf. *colossa*. D. *Corollospora filiformis*. E. *Kirschsteiniothelia* sp. F. *Torpedospora radiata*. Conidia: G. *Brachiosphaera tropicalis*. H. *Clavatospora bulbosa.*

APPENDIX 2

BIBLIOGRAPHY ON COASTAL AND MARINE BIOLOGY IN PUERTO RICO, WITH SPECIAL EMPHASIS ON MARINE MYCOLOGY

INTRODUCTION

This bibliography on coastal and marine biology is primarily mycological in orientation. A bibliography on marine mycology in Puerto Rico, with special emphasis on manglicolous fungi is updated to 31 December 2004. A total of 1,085 citations or references are included. Due to recent interest in marine mycology, coastal mycology (including terrestrial and estuarine fungi, and lichenized fungi), paleomycology, and general oceanography (biological, geological, chemical, and physical oceanographies), it is our intention to present this bibliographic recompilation for the benefit of future generations of marine mycologists and oceanographers (professional and non-professional) alike. Although many of the references included in this bibliography might give the impression of not being related to Puerto Rico, in some cases the references reported one or more collections or isolations from the island. This bibliography also includes handbooks and key papers (e.g., Matsushima's works, 1971 to 2001) that are very helpful for initial studies on aquatic hyphomycetes, higher marine fungi, filamentous fungi or fungal like organisms (e.g., myxomycetes, oomycetes). Also included are a few studies of marine biology, geology, chemistry, and physics, including several marine pollution and marine zoologically-oriented studies. Although literature searches for these latter subjects have not been exhaustive, we have tried to add relevant papers with extensive bibliographies whenever possible. We also have made an effort to include marine mycology-based unpublished theses for which we have searched diligently in the various libraries of the University of Puerto Rico (basically the Mayagüez and Río Piedras Campuses) and other unpublished reports such as those by the Puerto Rico Department of Natural and Environmental Resources.

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