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LICHENOLOGICAL STUDIES IN PUERTO RICO: HISTORY AND CURRENT STATUS

JOEL A. MERCADO-DIAZ^{1,2} AND EUGENIO SANTIAGO-VALENTIN^{2,3}

Abstract. European scientists initiated lichenology in Puerto Rico in the 19th century. Activity of the discipline increased notably on the island during the first three decades of the 20th century, primarily by the field explorations and publications of the New York Botanical Garden scientists and associates (A. A. Heller, N. L. and E. G. Britton, L. W. Riddle), and by the work of Bruce Fink of Miami University in Ohio and collaborators (E. A. Vainio, A. Zahlbruckner). Another period of research activity began in the late 1950s and was initiated by Henry Imshaug of Michigan State University. By the last decades of the century, the first contributions of Puerto Rican lichenologists I. Landrón-Concepción and J. Muñiz-Acevedo were made. Because of these efforts, Puerto Rico is among the best documented islands of the Caribbean in terms of its lichen biota. In spite of contributions spanning over a century, the development of knowledge and local expertise is today slow-paced. Training students and the development of new taxonomic and collecting activities are fundamental to addressing shortcomings of the discipline and in laying the foundation for future work in the field. To allow further development of lichen studies in Puerto Rico, we have constructed an electronic checklist of all previously reported taxa (available at <http://lichensofpuertorico.herbario.upr.edu>), and a current bibliography on Lichenology for the island.

Keywords: Lichenology, Caribbean islands, tropical lichens, history of botany, Puerto Rico

In comparison to other groups of organisms, lichens often have not caught the attention of scientists working in tropical regions. Indeed, lichenology was not recognized by major funding agencies or organizations as a discipline of high relevance or as a priority for funding support (BSA, 1995). Until recently, there have been only a few trained lichenologists, concentrated mainly in Europe, working in the tropics. At the beginning of the 21st Century, taxonomic works (e.g., Aptroot et al., 2008; Lücking, 2008; Harris, 1995; Rivas-Plata et al., 2006; among others) had begun to fill part of the knowledge gap. However, ecological studies on lichens are still limited, particularly if compared

to other taxa such as the bryophytes (Merwin and Nadkarni, 2001). Years ago, Bruce Fink (Fig. 1), who was the first lichenologist to visit Puerto Rico, stated that “a large amount of work would be required yet for an approximately complete study of the lichen flora of Porto Rico and adjacent islands” (Fink, 1927). After 80 years, this notion of the status of lichenology on the Island still prevails. In order to advance lichen studies in Puerto Rico, we present a historical summary of lichenological activity in Puerto Rico and a checklist of the lichens reported for the island. The checklist was put together using published and unpublished reports and information from different herbaria

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databases. The literature on lichens of Puerto Rico is dispersed, including some important contributions that are unpublished or of limited distribution, the literature cited aims



FIGURE 1. Portrait of Bruce Fink (1861–1927) from December 27th, 1900. Photo courtesy of the Harvard University Herbaria Botany Libraries, Cambridge, MA.

to represent the most current bibliography on the subject today. We also evaluate the current status of knowledge, and highlight needs to further advance the discipline in Puerto Rico.

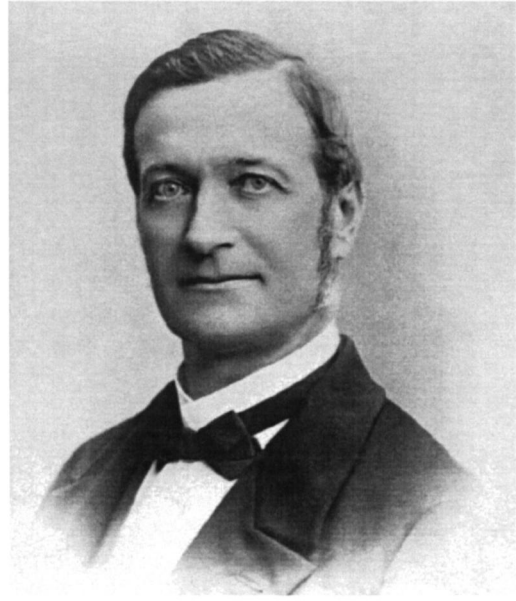


FIGURE 2. Undated portrait of Johannes (Jean) Müller Argoviensis (1828–1896). Photo courtesy of Hunt Institute for Botanical Documentation, Carnegie Mellon University, Pittsburg, PA.

THE 19TH CENTURY

Sprengel's work (1820) is apparently the first that includes lichens collected in Puerto Rico and cites only two species: *Lecidea portoricensis* (syn. *Patellaria portoricensis* (Spreng.) Spreng.) and *Lecanora piperis* (syn. *Malcolmiella piperis* (Spreng.) Kalb & Lücking). A publication in 1886 by the Swiss botanist Johannes Müller Argoviensis (Fig. 2) (Müller, 1886) reports lichens from primarily tropical regions from around the World, but includes one record from Puerto Rico, *Arthonia pulcherrima* (syn. *Coniarthonia pulcherrima* (Müll. Arg.) Grube). The first work entirely devoted to Puerto Rican

lichens (Fig. 3), is that of Müller (1888). This publication was based on specimens collected by Paul Sintenis between 1885 and 1886, and reports 51 species collected from varied localities across the Island (Müller, 1888). As opposed to Sprengel (1820), Müller cites a locality and Sintenis' collection number for every cited species. An additional contribution by Mobius (1888), adds two more species of *Coenogonium* Ehrenb. to the island. Apparently, there was no official initiative from the Spanish crown (who ruled Puerto Rico until 1898) to study or document the lichens of Puerto Rico.

THE EARLY 20TH CENTURY

The end of the 1898 Spanish-American war marked a new period in the study of the natural history of the islands, especially in the former Spanish colonies of Cuba and Puerto Rico. American scientists and naturalists had a prominent presence on these and other islands just months after the end of the war. Lichenology

entered a new phase during the first portion of the 20th Century. One of the first botanists of the period who collected lichens in Puerto Rico was Amos A. Heller. His exploration for the newly founded New York Botanical Garden (NYBG) was funded by the New York millionaire Cornelius Vanderbilt (Harris, 1989).

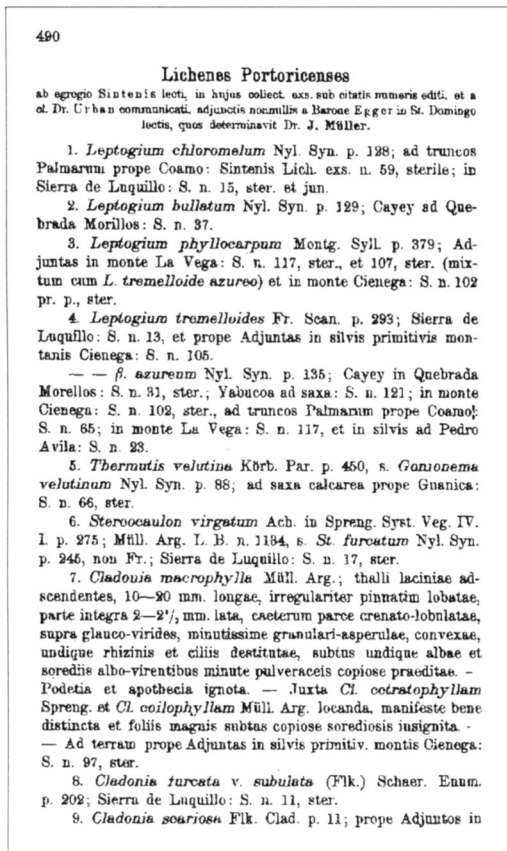


FIGURE 3. Cover page of the first report on lichens from Puerto Rico prepared by J. Müller in 1888, based on Paul Sintenis collections. Image courtesy of the U.S. Forest Service National Library.

Heller collected lichens in all three of his trips to Puerto Rico in 1899, 1900, and 1902–1903 (Santiago-Valentín, 2005). The plant and lichen material Heller and other NYBG associates provided motivated Nathaniel L. Britton, the Garden Director, to turn his attention to Puerto Rico (Sastre-D.J. and Santiago-Valentín, 1996a). Two factors that might have influenced NYBG's interest in Puerto Rico were that Nathaniel's wife, the bryologist Elizabeth G. Britton, was fluent in Spanish and her family owned sugar plantations in Cuba (R. C. Harris, pers. comm.). Consequently, the Brittons, along with other associates and friends, carried out 16 expeditions to Puerto Rico during the period of 1906–1933 (Sastre-D.J. and Santiago-Valentín, 1996a). Two major outcomes of this activity were the establishment of the NYBG tropical exploration program and the initiation of the Scientific Survey of Puerto Rico and

the Virgin Islands, the latter under the New York Academy of Sciences (Sastre-D.J. and Santiago-Valentín, 1996b). These explorations produced considerable collections of plants, but also of lichens and other cryptogams.

Although Elizabeth G. Britton had special interest in cryptogams, particularly in bryophytes, the first publication including lichens from Puerto Rico resulting from NYBG efforts was prepared by the lichenologist Lincoln Ware Riddle (Fig. 4; Britton, 1915). Riddle was professor of cryptogamic botany at Wellesley College from 1917 to 1919, who later became assistant professor and associate curator of the cryptogamic herbarium at Harvard University, positions he held for only one year before his death in 1921 (Osterhout et al., 1921). This publication focused on collections by Britton and collaborators from Puerto Rico's offshore islands, Mona and Desecheo (Britton, 1915). Riddle identified 26 species, 24 of which were included in the 1915 publication (Britton, 1915). Since this is the first description of the lichen biota made for any area of Puerto Rico,



FIGURE 4. Undated portrait of Lincoln Ware Riddle (1880–1921). Photo courtesy of the Harvard University Herbaria Botany Libraries, Cambridge, MA.

we present Riddle's observations:

The exploration of Mona Island has yielded 42 numbers of lichens, 40 collected by Dr. N. L. Britton, Messrs. J. F. Cowell, and W. E. Hess, and 2 collected incidentally by Dr. F. L. Stevens. These 42 numbers represent 26 species in condition for determination.

The species growing on the limestone rocks constitute the most striking and interesting part of the collection. These include four species of *Omphalaria*, a species of *Collema*, and a species of Dermatocarpaceae, which is, unfortunately, sterile and, therefore, not further determinable. The omphalarias are all little known species. *O. polyglossa* Nyl. [*Digitothyrea polyglossa* (Nyl.) P.P. Moreno & Egea], collected from limestone rocks in Cuba by Charles Wright, and not otherwise known, is apparently common on Mona Island, as it is represented by two numbers, each with several well developed specimens. There occur also *O. lingulata* Tuck., previously known from Cuba and Bermuda; a sterile *Omphalaria* related to *O. wrightii* Tuck., but apparently not identical; and one other species of the genus, probably new. It has not yet been possible to identify the species of *Collema*, and that may also prove to be new. Curiously enough, none of these calciphile species has yet been detected among the material collected in Porto Rico.

In marked contrast to the rock-lichens, the bark-inhabiting lichens are all common species, widely distributed in Tropical America. The genus *Trypethelium* is best represented, with the species *T. eluteriae* (four numbers), *T. ochroleucum*, and its variety *palescens*, and *T. mastoideum* [*Bathelium mastoideum* Afzel. ex Ach.] (two numbers). There are also such characteristic species as *Graphis afzelii* [*Dyplolabia afzelii* (Ach.) A. Massal.], *Melanotheca cruenta* [*Pyrenula cruenta* (Mont.) Vain.], *Pyxine picta* [*Dirinaria picta* (Sw.) Schaer. ex Clem.], *Physcia alba* and *P. speciosa* [*Heterodermia japonica* (M. Satô) Swinscow & Krog], *Parmelia sulphurata* [*Parmotrema sulphuratum* (Nees & Flot.) Hale] and

P. tinctorum [*Parmotrema tinctorum* (Despr. ex Nyl.) Hale], and *Ramalina complanata* and *R. montagnei*. Probably owing to the comparatively unfavorable conditions on Mona Island, the foliose and fruticose lichens are mostly small specimens, not well-developed. [L.W. Riddle (excerpt from Britton, 1915: 35-36)].

Collecting trips to Puerto Rico were few between 1916–1921, primarily because of World War I (Sastre-D. J. and Santiago-Valentín, 1996a). The main contributions of the period are three works on the lichen biota of other Caribbean islands (Riddle 1918, 1920, 1923) that include material from Puerto Rico. The first is a report on the lichens of St. John and St. Thomas that document three new species for Puerto Rico. These determinations were based on collections made by Britton and associates in 1915 (Riddle, 1918). Riddle's second publication was included in the work of Britton and C. F. Millspaugh, *The Bahama Flora*, and includes 11 new species, and one from the 1918 publication (Riddle, 1920). The third publication on the lichens of Isla de Pinos (Isla de la Juventud), Cuba, mentions 7 species collected in Puerto Rico (Riddle, 1923). Four of these were reported in 1920, and the rest are new records for the Island. Lincoln W. Riddle was an important figure in the history of lichenology, not only of Puerto Rico, but of the Caribbean region. His work resulted in about 100 new species for the islands.

An initiative independent of that undertaken by the NYBG was that of the lichenologist Bruce Fink, Head of Botany at Miami University in Ohio (Wylie, 1928). Fink visited Puerto Rico between November of 1915 and January of 1916, with the objective of assessing the mycological flora of the island (Fink, 1918; Stevenson, 1975). Fink's activities included collections from different parts of Puerto Rico, yielding approximately 2300 specimens of lichenized fungi (primarily ascomycetes emphasizing the families Graphidaceae and Arthoniaceae) and non-lichenized fungi. A detailed account of this visit is found in Fink (1918); however, no new records were reported. Beginning in 1927, four publications (Fink, 1927; Vainio, 1929; Zahlbruckner, 1930; Hedrick, 1930) focused on the lichens from Puerto Rico. Fink (1927) is of the utmost

importance because besides describing 36 new species in the family Graphidaceae, it provides an historical account on lichenological activities in Puerto Rico up to that date. Fink distributed unidentified specimens to colleagues for help in the determinations, sending 162 of the most difficult material to the most renowned lichenologists of that time, including the Finnish lichenologist Edvard August Vainio (the "Father of Brazilian lichenology"), and the Austrian lichenologist Alexander Zahlbruckner (Pišút, 2002). Of these 162 numbers, Vainio received 52 specimens (22 determined as new species; Vainio, 1929) and Zahlbruckner received 110 (22 determined as new species; Zahlbruckner, 1930). The last article of the series initiated by Fink was published by Joyce Hedrick Jones, Fink's assistant at Miami University, after Fink's death (25 new species determined by Fink and collaborators; Hedrick, 1930). Fink's collection was sold to the University of Michigan-Ann Arbor in 1929 (P. Rogers, pers. comm.). In addition, Hedrick Jones prepared a manuscript entitled *Lichens of Porto Rico and the Virgin Islands*, which was intended to be part of Volume VII, Part 4 of the Scientific Survey of Porto Rico and the Virgin Islands, but remains unpublished. This manuscript includes

a complete list of Fink's collection, as well as collections made in Puerto Rico and other Caribbean islands by NYBG associates: 710 species and subspecies, representing 110 genera in 41 families. Of these, 555 species are reported for the main island of Puerto Rico, Mona, Desecheo, or Culebra Island. Why this work was never published as part of the Scientific Survey is unknown; it might have been because of the lack of funds during the Great Depression and the final years and death of the Brittons in 1934 (R. C. Harris, pers. comm.).

Collecting efforts and studies of lichens in Puerto Rico were relatively slow between the early 1930s to the mid 1950s. However, during that period, over a dozen new species were described in the following genera: *Teloschistes* Norman (Hillmann, 1930), *Nesolechia* A. Massal. (Keissler, 1933), *Usnea* Dill. ex Adans. (Motyka, 1938), *Cladina* (Nyl.) Nyl. (des Abbayes, 1939; Santesson, 1942) *Cladonia* P. Browne (Evans, 1947), *Mazosia* A. Massal., *Strigula* Fr., *Raciborskiella* Hoehn., *Porina* Müll. Arg., *Psorotheciopsis* Rehm, *Gyalectidium* Müll. Arg., *Echinoplaca* Fée, *Tricharia* Fée, *Catillaria* A. Massal., *Byssoloma* Trevis. (Santesson, 1952), and *Buellia* De Not. (Imshaug, 1955).

LATE 1950'S TO THE PRESENT

In 1957, lichenologist Henry A. Imshaug, Professor of Botany and Assistant Curator of the Herbarium at Michigan State University (MSC) published a catalogue of West Indian lichens (Imshaug, 1957; Fryday and Prather, 2001). This catalog was based on an extensive revision of the publications then available. In it, 1751 species are reported for the Caribbean islands and of these, 248 occurred in Puerto Rico. The major merit of the publication is that Imshaug was especially cautious with nomenclature problems. He avoided creating new names in the catalog because a "...*nomen novum* should never be published without taxonomic studies," (Imshaug, 1957). Another major strength of the catalog is its thorough bibliography that can be considered a complete literature compilation on the lichen biota of Puerto Rico and the Caribbean up to 1957. Finally, Imshaug's catalog includes brief summaries of the collecting and research activities on each island. Six years after its publication, Imshaug collected in

Puerto Rico, from June 27th–30th, 1963. He collected 118 specimens from seven localities around the cloud forest (or elfin woodland) of the Caribbean National Forest (now named El Yunque National Forest). These specimens are deposited at the Herbarium of Michigan State University (A. M. Fryday, pers. comm.). In his field notebook (deposited at MSC), Imshaug includes a brief entry on the ecology of the area: "Notes on Puerto Rico: Conspicuous lack of lichens in elfin woodland which covers upper slopes, ridges and summits in Luquillo Mts. No lichens even in crowns of trees. Mossy trunks do not even have *Lobarias* or *Stictas*. Only rarely is a *Peltigera* found. *Selaginella* seems to replace *Stictaceae* when one compares this with Jamaica. The *Selaginella* even divides dichotomously as do the *Stictaceae*." After Imshaug's visit to Puerto Rico and before 1970, only two articles were published that added information regarding the lichens of the island; these are the works by Hale (1959) on *Parmelia*

Ach., and by Herre (1960) on *Usnea* Dill. ex Adans. Two new records were documented for Puerto Rico in these articles, one in each genus.

In 1970, mountain forest tracts at El Verde Experimental Station were subject of nuclear irradiation experiments by the University of Puerto Rico Nuclear Center (Gannutz, 1970). These experiments, supported by the U.S. Atomic Energy Commission, were in part performed to understand the ecological and environmental consequences of radiation exposure in tropical forests. One of the studies assessed the effects of ionizing radiation on the lichens of a tropical rainforest community (Gannutz, 1970). This study provided support for the general idea held by scientists at the time, that crustose lichens were more resistant to radiation than other types of lichens. The study reported ten new records for the lichen biota of Puerto Rico.

In 1972, Ismael Landrón-Concepción, a Puerto Rican native and student of Henry Imshaug, presented his dissertation, *The lichen genus Ramalina Ach. in the West Indies with notes on its role in the vegetation of Puerto Rico*, for a Ph.D. in Botany at Michigan State University (Landrón-Concepción, 1972). Landrón-Concepción is the first Puerto Rican with formal training in lichenology. In addition, his work is the only one to date addressing the biology and natural history of a genus of lichen in the Caribbean. The work emphasizes the species of *Ramalina* in Puerto Rico and the presence of members of the genus in different habitats on the island. Additionally, Landrón-Concepción offers a series of distributional maps for *Ramalina*. Although this dissertation was not published, hardcopies are available at the General Library and Natural Sciences Library of the University of Puerto Rico in Río Piedras.

In 1984, Jose Muñiz-Acevedo completed a Master's thesis—also unpublished—on the lichens of Puerto Rico, at the University of Puerto Rico at Mayaguez (Muñiz-Acevedo, 1984). This work compares the lichen flora of three Commonwealth forests of western Puerto Rico (Maricao [lower montane forest on serpentinite], Guajataca [subtropical moist forest on karst], and Susúa [subtropical dry forest on serpentinite]), and looks into the possible relationship between lichen life forms and environmental factors in these forests.

Muñiz-Acevedo also assessed how the substrate rugosity of the photophyte is related to the ecological distribution of crustose lichens. Besides the ecological questions addressed, an important component of his thesis is the identification of nine species previously not known for Puerto Rico. A hardcopy of the thesis is available at the University of Puerto Rico, Mayagüez Campus General Library.

An important contribution to the study of the lichen biota of Puerto Rico is the *Working keys to the lichen-forming fungi of Puerto Rico* by Richard Harris of the New York Botanical Garden (Harris, 1989). This work is also relevant to the study of lichens in the tropics since, according to the author, it was the first attempt to treat all the lichen-forming fungi for any tropical region (Harris, 1989). These keys were prepared for a tropical lichen workshop held at Maricao, Puerto Rico May 21–31, 1989, organized by the bryologist Inés Sastre-De Jesús, who was then a professor at the Catholic University of Ponce. This work comprises a set of taxonomic keys for 640 species, although the author points out that not all families were completed due to lack of time. In this regard, Harris mentions that there are around 50–100 additional species represented in a set of specimens not evaluated for this work. While this would give a total of 700–750 species for the island, Harris indicates that due to the lack of information, it would be difficult to estimate what percentage of the total number of lichens in Puerto Rico this number of species represents (Harris, 1989). The work also includes a summary on lichen studies in Puerto Rico. Later, Harris prepared a second volume of taxonomic keys for the lichens of Florida (Harris, 1995) in which he reports additional records for Puerto Rico.

There are a number of other works published during the last 14 years that contain records of Puerto Rican lichens (e.g., Breuss, 1999; Lücking, 2008; Lücking et al., 2009). Among them, only one (Breuss, 1999) gives a closer look to the Island. The monograph by Lücking (2008) deserves to be mentioned since it reports more than 30 species of foliicolous lichens for Puerto Rico. The other publications are taxonomic works of broader geographical scope, but include material from the island. For more information on these works, please refer to Mercado-Díaz (2009).

Finally, an online checklist of species for the Island was published in 2007 (Feurerer, 2007) and, although somewhat rudimentary at

present, it is an initiative worth citing given that knowledge on the Puerto Rican lichen biota had, until this time, been unavailable online.

PUERTO RICAN LICHENS IN HERBARIA

Herbaria with the largest lichen collections from Puerto Rico are those of Michigan State University (MSC), the University of Michigan (MICH), and the New York Botanical Garden (NY). The MSC herbarium comprises more than 3100 specimens collected by Imshaug in 1963 and by Landrón-Concepción between 1967 and 1968 (A. M. Fryday, pers. comm.). According to their database, of these 3100 specimens, only about 140 have been identified to species level. The University of Michigan herbarium, incorporating Bruce Fink's personal collection, comprises 1880 numbers from Puerto Rico (P. Rogers, pers. comm.) of which 103 are type specimens. Around 442 species are represented in this collection. The total number of specimens and the number of species represented in NY is unknown, but Harris (R. C. Harris, pers. comm.) estimates that NY's collection from Puerto Rico may be of approximately 3000 to 3500 specimens, including specimens collected by the Brittons and associates, a set of specimens from Fink's collection, and specimens collected by Richard Harris and the bryologist William Buck, as well as duplicates from other collectors. Other U.S. herbaria with collections of Caribbean lichens that might comprise specimens from Puerto Rico include that of the Field Museum of Chicago

(F), Farlow Herbarium (FH), and the Academy of Natural Sciences of Philadelphia (PH). The relatively large representation of Puerto Rican lichens in herbaria supports the idea that a thorough evaluation of these collections would give a better picture of the lichen diversity of Puerto Rico.

Ironically, the four formally established herbaria in Puerto Rico (UPR, UPRRP, MAPR, and SJ) have very small lichen collections. The three main herbaria of the University of Puerto Rico—Río Piedras (UPRRP), Jardín Botánico (UPR), and Mayagüez (MAPR)—hold approximately 50, 400, and 250 numbers respectively. Although, to the best of our knowledge, the botanist George Proctor collected lichens on the island, the Herbarium of the government of Puerto Rico at the Department of Environmental and Natural Resources (SJ), the depository of Proctor's collection, holds no lichen specimens (J. Sustache, pers. comm.). Dr. Ismael Landrón-Concepción keeps a personal lichen herbarium, however, the number of specimens it holds is unknown. Specimens are collected frequently by the first author of the present work and deposited at the Herbarium of the UPR Botanical Garden (UPR). Identifications of these specimens are done at least to the genus level.

NEEDS AND FUTURE DIRECTIONS

The lichen flora of Puerto Rico is not yet fully documented (R. C. Harris, pers. comm.) and it is imperative that studies continue. In order to address this issue, the first author of the present work compiled a preliminary checklist of species based on information contained in herbaria and published papers (Mercado-Díaz, 2009). Based on this compilation, Mercado-Díaz found 781 species that are well-documented, a number very close to estimates made by Harris, mentioned previously in this work. The checklist reports a total of 1181 species of lichenized and lichenicolous fungi, of these, 400 are in need of further study and support the possibility that the total number of species for Puerto Rico could exceed 781 species.

Efforts must be made to organize and revise the taxonomy of some of the existing collections as well as enriching the local herbaria of Puerto Rico. The lichen biota of Puerto Rico is composed of several poorly-known and probably rare, endemic elements that have not been adequately represented in local herbaria. An example is *Cladonia robusta* Ahti, which is confined to the white siliceous sands of the Laguna Tortuguero in northern Puerto Rico. Although most of the area is legally protected, intrusion of ATV vehicles and wandering hunters pose a threat to this species (Mercado-Díaz, personal observ.). Similarly, a prerequisite for the successful documentation of lichen species and for continued taxonomic

efforts on the island, is the training of new lichenologists. No institution from abroad has launched active study efforts on the lichens of Puerto Rico, as was the case in the past. Although botany is a fairly active discipline in Puerto Rico, lichenology is not. No higher-education institution on the island offers courses or formal training in lichenology. Both major campuses of the University of Puerto Rico (Río Piedras and Mayagüez), and the Universidad del Turabo have Ph.D.-level mycologists, but lichenology is not within their line of research. Similarly, the U.S. Forest Service is active in mycological research in Puerto Rico, but not in lichenology.

Some ecological aspects of lichens in Puerto Rico were once addressed (Gannutz, 1970; Landrón-Concepción, 1972; Muñiz-Acevedo, 1984), but were not continued. Other issues regarding composition, function, and interactions of lichens in our natural ecosystems

remain obscure. Knowledge applicable to conservation is a pressing priority since Puerto Rico is confronting a serious challenge in preservation of its natural areas. Urban sprawl, deforestation, lack of public policies on management, and pollution stand as threats faced by the island's natural biota.

The training of students, the development of new collections, and the support of new research projects require the acquisition of bibliographical resources—journal subscriptions, historical literature, current lichen treatments of other regions, etc.—all of which are lacking in Puerto Rican institutions. Due to the need for updated inventories, the well-known utility of lichens as indicators of environmental stress, and given the present lack of coherent conservation policies in Puerto Rico, it becomes obvious that it is urgent to nurture lichenology as a discipline particularly in Puerto Rico.

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