Final Report

Floristic Assessment of the Northern Karst Belt of Puerto Rico: Phase Three

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Introduction

The Floristic Inventory and Assessment of Puerto Rico (FIAPR) is being conducted in order to improve the conservation of native plants on the island of Puerto Rico. While it was initiated in order to contribute to an ongoing study of the Northern Karst Belt in Puerto Rico by the International Institute of Tropical Forestry in Río Piedras, Puerto Rico, it has wider conservation and scientific implications. The FIAPR builds upon eleven years of floristic research by The Institute for Regional Conservation (IRC) in South Florida, and foresees the development of an analog publication to *Rare Plants of South Florida: Their History, Conservation, and Restoration* (Gann et al. 2002) for Puerto Rico. The FIAPR is different from most plant conservation programs in that it is comprehensive and collects information on and assesses the conservation status of the entire flora of the region, rather than a sub-set of the flora, such as narrow endemics. The FIAPR also allows for the assessment of the flora of the sub-region comprising the Northern Karst Belt, including its role in conserving the native plant species of Puerto Rico.

Information compiled during the FIAPR are organized in the FIAPR Database, housed at IRC's offices in Miami, Florida. CD versions of the database were published in 2002 & 2004. The development of the FIAPR Database also allows for the creation of a website application modeled after IRC's Floristic Inventory of South Florida Database Online, which can be viewed at www.regionalconservation.org. Website design is complete and a working model of the structure is scheduled to be placed on the web on October 2, 2006. A launch of a beta version of the FIAPR Database Online is scheduled for launch on December 1, 2006.

Work on the FIAPR and the Floristic Assessment and the Northern Karst Belt of Puerto Rico has been conducted by IRC in cooperation with the USDA International Institute of Tropical Forestry (IITF) in Río Piedras, Puerto Rico through its State and Private Forestry Program. IITF has provided three rounds of funding for this project, beginning in 2001: phase one was completed in 2002; phase two was completed in 2004; phase three was initiated in the June, 2004 and was completed in June, 2006. While all funds made available for the project were expended by the end of June, 2006, work on the project has continued to this date. Data reported below in results for the end of phase one were documented in Gann & Bradley (2002); data reported for the end of phase two were documented in Gann & Bradley (2004).

Methods

Scientific Names of Plants

The development of the FIAPR Database began with the databasing of a preliminary list of the Puerto Rican flora derived from Liogier & Martorell's *Flora of Puerto Rico and Adjacent Islands* (2000). After all plant names were entered into an Accepted Names table from this resource other taxonomic sources were reviewed in order to supplement or make changes to this base list. A literature search was conducted to find newly published plant records for Puerto Rico and these were added to the database. The online USDA PLANTS database, http://plants.usda.gov/, was used extensively (2001 version), as was Kartesz (1994). If both of these references used a different name than one used by Liogier & Martorell (2000) then that name was changed. Names in the Orchidaceae generally followed Ackerman (1995). Authorities using each name for Puerto Rico

were recorded. Synonyms have also been entered and are stored in a Synonyms table. In 2005, Franklin Axelrod (University of Puerto Rico, Río Piedras) provided a draft copy of his manuscript, A Systematic Vademecum to the Vascular Plants of Puerto Rico. This work has been reviewed along with the USDA PLANTS database (USDA, NRCS 2006) for the pteridophytes, gymnosperms, and monocots and some additional name changes have been made; further name changes and additions to the list of synonyms are planned following further review. Work on the dicots is now in progress.

False, Doubtful and Reported Names

Significant work was done in phase two to identify names that were falsely or doubtfully attributed to the Flora of Puerto Rico or are from unsubstantiated reports, and this work continued in phase three. Ancillary data are not provided for these names except for comments explaining why these designations have been given, and native range in some cases.

Ancillary Data

Liogier & Martorell (2000) was used as a baseline for other types of data for each plant taxon, including global range, nativity, and current status in Puerto Rico. Other sources were used to supplement these baseline data and as sources for other data fields, including plant habit, substrate, and perennation. Valuable sources include the Descriptive Flora of Puerto Rico and Adjacent Islands by Liogier (1985-1997), Botany of Porto Rico and the Virgin Islands by Britton & Wilson (1923-1930), Ackerman (1995), Little & Wadsworth (1964), Little et al. (1974), Proctor (1989), and the USDA PLANTS database. Baseline data were augmented with information from herbarium labels. Agency lists of plants were also added; listing by the US Fish & Wildlife Service (USFWS) was obtained from the Federal Register; data from the Puerto Rican Department of Natural and Environmental Resources (DRNA) was provided via a computer printout of critical elements tracked by the Natural Heritage Division and provided to us July 12, 1999. Each taxon was also attached to a HighTax table with data on plant families and groups (monocot, dicot, gymnosperm, pteridophyte).

Additional resources became available during phase three, including Axelrod (in prep.), Pedro Acevedo-Rodríguez's (2005) Vines and Climbing Plants of Puerto Rico and the Virgin Islands and Acevedo-Rodríguez & Strong's (2005) Monocotyledons and Gymnosperms of Puerto Rico and the Virgin Islands. A new list of plants regulated by DRNA was signed into law February 11, 2004 ("Reglamento para Regir Las Especies Vulnerables y en Peligro de Extinción en el Estado Libre Asociado de Puerto Rico") and the ranks for plants contained therein replaced those from the 1999 list.; the 1999 ranks, however, are indicated in a comments field. We also began accessing the Missouri Botanical Garden's TROPICOS online database (http://mobot.mobot.org/W3T/Search/vast.html) to improve our understanding of plant distributions.

Significant work was done in phases two and three to more accurately determine nativity status, but some further work is needed.

Herbarium Labels

Electronic herbarium label data were imported into the database from several sources including A (13 specimens), AMES (7 specimens), FLAS (230 specimens), GH (183 specimens), MO (1,850 specimens), NY (2,378 specimens), SJ (386 specimens), UPRRP (5,098 specimens), and US (1,933 specimens). Specimens from US and UPRRP are entirely from collections by Pedro Acevedo and Franklin Axelrod, respectively. In total, the database has data from 12,078 herbarium labels

including 2,633 Acevedo specimens and 5,098 Axelrod specimens. Data from each specimen were entered into the References table, and are linked through the SiteRefs table to localities in the Sites table. Label data for potential names are attached to an accepted taxon name in an Occurrences table. Some data from the University of Puerto Rico, Mayagüez (357 records) has been received, but are not yet integrated into the database. More importantly, more than 30,000 herbarium labels databased by Gary Breckon and Jeanine Vélez of the University of Puerto Rico, Mayagüez (MAPR), became available online at http://herbaria.plants.ox.ac.uk/bol/home/, and we have begun an extensive review of these data.

Collection Books

Data from George Proctor's collection books were hand entered into the database beginning in phase two and ending in phase three. In total, data from 4,925 specimens have been entered – up to specimen number 45500 (April 15, 1989).

Other Occurrence Data

Several literature sources were used to obtain occurrence data within Puerto Rico. Specific locality data for plants in municipalities and conservation areas were entered from Ackerman (1995), Cedeño & Breckon (1996), Little & Wadsworth (1964), Little et al. (1974), Proctor (1989), and several other sources. All plant taxa listed in Acevedo-Rodríguez & Axelrod (1999) for the Río Abajo Forest Reserve were also entered. These data are linked to sites and names as described for herbarium specimens above. In 2006, we began to enter additional data from Acevedo-Rodríguez (2005) and Acevedo-Rodríguez & Strong (2005). Additional occurrence data from vegetation plots in Puerto Rico has been provided by T. Mitch Aide (University of Puerto Rico) and Tom Brandeis (IITF). These data are in the process of being incorporated into the database.

Site Names

Site names were imported or entered from locality data sources including herbarium specimens, collection books, and literature. Specific site names are tied to municipality and/or conservation area, where appropriate. Some work is needed to normalize site names, as some sites are referred to in multiple ways or in multiple languages.

Rarity

At the end of phase two, we reported 83 plant taxa that may be extirpated or extinct in Puerto Rico, based on an initial review of the literature. This represented about 3.5% of the native flora. From a preliminary search of the occurrence data, it appeared that more possible extirpations would be identified by reviewing occurrence data for all plants on the DRNA list of 1999. This was completed. In addition, we reviewed the entire DRNA list to look for plants that may be critically imperiled in Puerto Rico following criteria established by IRC for the Floristic Inventory of South Florida and conforming to the Natural Heritage Program criteria (see box), which was originally designed by The Nature Conservancy and is now managed by NatureServe (www.natureserve.org).

Critically imperiled. Critically imperiled in Puerto Rico because of extreme rarity (five or fewer occurrences, or fewer than 1,000 individuals), or because of extreme vulnerability to extinction due to some natural or human factor. For taxa with two to five occurrences, IRC ranks as critically imperiled those taxa with 3,000 or fewer individuals. For taxa with a single occurrence, IRC ranks as critically imperiled those taxa with 10,000 or fewer individuals.

Finally, all remaining native taxa were reviewed to search for additional plants that may be extirpated. We are currently in the process of reviewing occurrence data for all remaining taxa to

search for plants that may critically imperiled in Puerto Rico. Comments have been added for all plants possibly extirpated or extinct in Puerto Rico, and these comments were reviewed by Carlos Trejo-Torres, then of Citizens for the Karst.

Karst Belt Data
The karst belt of northwestern Puerto Rico has been described as an important ecological resource (Lugo et al. 2001). Using the herbarium specimens and literature sources described above, a preliminary flora was developed for the karst belt. The boundaries identified for the karst belt are from a GIS layer provided by the IITF (karst_belt.shp). A taxon was assigned to the karst belt if an herbarium voucher was known to be collected within its boundaries, if it was recorded from one of the conservation areas located primarily within the karst belt (Cambalache, Guajataca, Laguna Tortuguero, Piñones, Río Abajo, San Patricio and Vega), or if it was recorded from one of the following municipalities that have significant areas of karst: Aguadilla, Isabela, Quebradillas, Camuy, Hatillo, Arecibo, Barceloneta, Florida, Manatí, Vega Baja, Vega Alta, and Dorado.

Substrate Data
During phase two, substrate data were compiled from several sources. These data were used to identify species that grow on certain substrates, such as karst, limestone, or serpentine. Sources included Liogier (1985-1997), Britton & Wilson (1923-1930), Ackerman (1995), Proctor (1989), Cedeño & Breckon (1996), and others.

Elevation Data
During phase two, data from herbarium specimens and Proctor's collection books, along with Ackerman (1995) and Proctor (1989), were used to develop a table with coarse elevation data. Elevation zones of <500 m, 500-1000 m, and >1000 m were created and populated with plant names.

Habitat Data
During phase two, data from herbarium specimens and Proctor's collection books, along with Ackerman (1995) and Proctor (1989), were used to develop a table with coarse habitat data. Habitat designations of Dry Forest, Moist Forest, and Wet Forest were created and populated with plant names.

Literature Review
During phase two, a literature search was conducted for plants on the DRNA list of 1999. This search yielded 70 unique references. These data can be viewed in the Literature_DRNA_Taxa table.

GIS Data
Site names for occurrences of endemic species collected by Proctor have been provided to Danilo Chinea at the University of Puerto Rico, Mayagüez who has agreed to attach GIS coordinates to each unique site name.

Site Visits
Since 1998, the senior author has made more than 10 trips to the island of Puerto Rico to meet collaborators and become familiar with the landscape and flora. In September 2003, both authors attended the second symposium held on karst research at the Interamerican University of Puerto Rico in Bayamón.

Results

Floristic Inventory and Assessment of Puerto Rico (FIAPR) Database Online

The FIAPR Database Online has been designed and a working model will be uploaded to the web on October 2, 2005. The working model will allow us to test the online application and will be available for collaborators to review. Data from several tables in the FIAPR are being reviewed, compiled, and transferred to new tables in order to support the online application. Based on the completion of the data transfer, a beta (test) version will be launched for public review on January 1, 2006. While earlier versions of the database treated all species from the Commonwealth of Puerto Rico, the online version will focus more narrowly on the island of Puerto Rico and the Northern Karst Belt.

Accepted Names and Occurrences in Puerto Rico

The FIAPR Database provides names and substantial ancillary data for all native and naturalized vascular plants in the Commonwealth of Puerto Rico, as well as many common cultivated plants that may be found persisting many years after active cultivation has ceased. The database at the end of phase one contained 3,906 names, including 617 synonyms and 3,289 accepted names; the database at the end of phase two contained 4,001 names, including 713 synonyms and 3,288 accepted names; the database at the end of phase three contains 4,002 names, including 715 synonyms and 3,287 accepted names. Of these, 73 names have been either falsely attributed to the flora of Puerto Rico, or represent uncorroborated reports or doubtful records; we reported 50 such names at the end of phase 2. Thus, 3,214 accepted occurrences of plant taxa are reported for Puerto Rico at the end of phase three.

The Flora of Puerto Rico

Of the 3,214 plants in the database that are either present in Puerto Rico or were historically documented there, 182 are cultivated plants that are not native to Puerto Rico but which may be encountered persisting from cultivation in forests or conservation areas. The actual flora of native and naturalized plants in Puerto Rico comprises approximately 3,032 kinds of plants; we reported approximately 3,050 taxa at the end of phase two.

The Native Flora (Extant and Historical)

Of the 3,032 taxa in the flora, 672 plants are either naturalized exotics, exotic waifs, doubtfully native, or of uncertain origin, comprising 22% of the flora; we reported 21% at the end of phase two, and 19% at the end of phase one. At end of phase two, 227 taxa were classified as assumed to be native and in need of additional review; this number has been reduced to 32. The native flora, extant and historical, is now 2,360.

Occurrence Data

To present, 37,015 occurrence records have been downloaded or entered into the FIAPR; we reported 33,005 at the end of phase 2. Of these, accepted names have been applied to 35,850 records.

Rarity

In 1999, DRNA was tracking 610 plant names; however some of these names are synonyms, are unpublished names, or represent non-native, false, doubtful, or unsubstantiated reports of species. We have been able to tie these names to 593 accepted names, including 556 natives with accepted occurrences in Puerto Rico. This represents 24% of the native flora; we reported 23% at the end of phase two. Of these, 11 were ranked as historical and 170 were ranked as critically imperiled by

DRNA; the vast majority of the remainder (341) were ranked as of an unknown status (N?). The tracking system used was based on the Natural Heritage Program criteria.

In 2004, an official list of species regulated by DRNA was published, replacing the previous tracking system. This list, containing only 48 species, mostly conforms to the species listed by the US Fish & Wildlife Service (USFWS) under the Endangered Species Act. Two species listed by USFWS, *Catesbaea melanocarpa* and *Sesbania tomentosa*, are omitted from the DRNA list. The ranks used in the new DRNA list conform to criteria established by the IUCN – World Conservation Union for its Red List of threatened species.

Based on a careful review of the data, we now report that 10% of the Puerto Rican flora may be extirpated or extinct; we reported 3.5% at the end of phase two. Two hundred and thirty-eight (238) species have been identified that may be extirpated or extinct in Puerto Rico, and a list of these species will be available for peer review when the beta version of FIAPR Database Online is launched.

We also report here for the first time that we have developed a working list of plants that may be critically imperiled in Puerto Rico. Seven hundred and ninety-eight (798) taxa have been so identified during a preliminary review of data for all species, representing 34% of the native Puerto Rican flora. These species will also be identified in the FIAPR Database Online.

Of the 238 taxa identified as possibly extirpated or extinct in Puerto Rico, 114 were included in the 1999 DRNA list and of the 798 taxa identified as possibly critically imperiled, 383 were included on that list.

Karst Belt Data

A total of 1,221 native plant taxa have been documented to be historically present in the karst belt; previously we reported 1,039 taxa. This represents 52% of all native plant species in Puerto Rico. Of these, 998 have been documented to be present in one or more of the existing conservation areas in the karst region; we reported 893 at the end of phase two. Other pertinent results include:

- 22 native plant species in the karst belt are listed as endangered or threatened by the U.S. Fish & Wildlife Service, or 44% of the federally-listed plants in Puerto Rico and 46% of the species now regulated by DRNA; we reported 19 species at the end of phase two. Fourteen of these species are documented to be present in one of the existing conservation areas in the karst belt. We have no data from conservation areas in the karst belt for the following federally-listed species that have been recorded there: *Adiantum vivesii*, *Auerodendron pauciflorum*, *Banara vanderbiltii*, *Buxus vahlii*, *Goetzea elegans*, *Peperomia wheeleri*, *Thelypteris verecunda*, *Zanthoxylum thomasianum.*
- We have now documented 183 plants from the 1999 DRNA list within the karst belt, or about one-third of all the native species on that list; we reported 143 plants at the end of phase two. One hundred and twenty-nine (129) of the tracked species are documented for one of the region's conservation areas.
- Of the 238 species of plants that may be extinct in Puerto Rico, only eleven have been documented to be historically present within the karst belt.

Discussion

The development of the FIAPR conforms well to our experience in developing the Floristic Inventory of South Florida and its assessment as published in Rare Plants of South Florida: Their

History, Conservation, and Restoration (Gann, Bradley & Woodmansee 2002). While the flora of Puerto Rico is about 40% larger than that of South Florida, it is not so large as to be unmanageable.

Based on our experience with the South Florida, we predict that the estimate of a 10% loss of the known native flora of Puerto Rico will not change more than 1 percentage point within the next five years. Individual species may be rediscovered, while plants thought to be extant will be discovered to no longer be present where they were last observed. The list of critically imperiled plants is expected to rise further, then fall as more data is gathered and field surveys conducted. In South Florida, our working list of critically imperiled plants fell by 40% from our initial list and the final publication of our preliminary results. Nevertheless, if Puerto Rico follows the same trend, then we could expect that 20% of Puerto Rico's native flora is critically imperiled using Natural Heritage Program criteria. If that is true, then the floras of Puerto Rico and South Florida are fairly similar: 8% possible extirpations in South Florida vs. 10% in Puerto Rico and 17% critically imperiled in South Florida vs. 20% in Puerto Rico, despite completely different land-use histories.

The 1999 DRNA list was found to be a good working list to start from, but not comprehensive, which is similar to what we found comparing our work to the tracking process conducted by the Florida Natural Areas Inventory and the listing process used by the State of Florida. Our testimony to the Florida Endangered Plant Advisory Council led to the addition of nearly 80 species to the state lists of endangered and threatened plants – a 20% increase in the number of species. The move by DRNA to focus more narrowly on species listed by the US Fish & Wildlife Service is regrettable, but understandable given the enormity of the situation regarding rare plants in Puerto Rico.

The paucity of data on species included in the 1999 DRNA list in the Northern Karst Belt and the lack of comprehensive plant lists for most conservation areas clearly demonstrate the need for significant work in the area. Furthermore, we can expect that some species attributed to the area have been done so in error. Comprehensive plant inventories and rare plant surveys are both needed to determine the importance of the Northern Karst Belt to the conservation of Puerto Rico's rare plants as well as the contribution conservation areas, current and proposed, make toward that effort.

Recommendations for Future Work

1. Launch FIAPR Database Online and continue with its development and expansion.
2. Conduct thorough herbarium searches for all species preliminarily identified as possibly extirpated or extinct in Puerto Rico.
3. Solicit peer review of list of species preliminarily identified as possibly extirpated or extinct in Puerto Rico.
4. Conduct field surveys where appropriate for all species preliminarily identified as possibly extirpated or extinct in Puerto Rico, beginning in the Northern Karst Belt.
5. Continue review of data for all species identified as possibly critically imperiled in Puerto Rico.
6. Begin field surveys for all species preliminarily identified as possibly critically imperiled beginning in the Northern Karst Belt.
7. Prepare floristic inventories for Cambalache, Guajataca, Laguna Tortuguero, Piñones, San Patricio and Vega, similar to that done for Río Abajo.
8. Normalize site names.
9. Collaborate with Danilo Chinea to attach GIS coordinates to each unique locality.

10. Begin preparation of a peer-reviewed paper on the conservation status of the flora of the island of Puerto Rico.
11. Begin preparation of a peer-reviewed paper compiling a comprehensive flora of the Northern Karst Belt of Puerto Rico.

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