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Plant Conservation in the Caribbean Island Biodiversity Hotspot

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Abstract While the Caribbean is a recognized "biodiversity hotspot", plant conservation has not received adequate attention; particularly, given the high levels of endemism in many plant groups. Besides establishing protected areas, there needs to be a sustained effort to study the taxonomy, systematics and ecology of the flora. Recent phylogenetic studies have shown high levels of endemism and conservation studies indicate a large propotion of the flora is threatened with extinction. Eight recommendations are given for plant conservation in the region.

Keywords Biodiversity hotspot · Caribbean islands · Ecosystem · Plant conservation

Introduction

The Caribbean Islands, comprising the Bahamas, Greater and Lesser Antilles and some islands located off the northern coast of South America, represent the most important insular system of the New World. As one of the 34 biodiversity hotspots sensu Mittermeier et al. (2004), these islands represent a global priority for conservation. In a recent study based on data sets that integrated biological and social factors, Shi et al. (2005) found the Caribbean Islands to be one of the six

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"hottest" hotspots. Similar conclusions can be drawn from other studies that identify the Caribbean Islands as a hotspot with unusually high levels of habitat loss (Brooks et al., 2002).

The conservation of plant resources on each of these islands is an imperative for ensuring sustainable development and the provision of essential ecosystem services (Kress & Horvitz, 2005). These extraordinary, and often overlooked islands, have been an arena for some of the most important studies in evolutionary biology, including the role of vicariance and dispersal as biogeographical avenues for speciation (Rosen, 1976; Hedges et al., 1992), the relationship between area and species richness (Schoener et al., 2005), and the evolution of convergent morphological traits under similar ecological conditions (Losos et al., 2006). Today they are testing grounds for the application of conservation biology.

The early colonial settlement of the Caribbean was driven in large part by the quest for commercially valuable plants e.g., sugar, cotton, tobacco, indigo, jalap, cassia, sassafras, brazil wood and guaiacum, indeed these high value crops, both wild harvested and plantation grown, defined the mercantile world view of the islands. The Caribbean was one of the first contact zones between the tropical world and western science—the focus of zealous colonial bioprospecting and collecting (Santiago-Valentín & Olsmtead, 2004; Schiebinger & Swan, 2005). Indeed the Caribbean islands have been subject to the classic pattern of island degradation where successive natural resources have been exhausted and abandoned in an unstable plantation based economy (Grove, 1995). This early colonial period in the Caribbean also influenced early environmental thinking with forest and watershed protection promoted by 18th century Utopian colonial environmentalists such as Alexander Anderson (Grove, 1995). Indeed the Main Ridge Forest Reserve on Tobago is very likely the oldest Forest Reserve in the Western Hemisphere where 2,430 ha of virgin forest was set aside in 1765 for "the protection of the rains" (Ramdial, 1980).

Today, the challenge for the botanical community in the Caribbean is very different. The Caribbean is a vibrant cultural, political and linguistic mosaic. The islands not only encompass relatively affluent economies supported by agriculture, tourism and banking, but also include nations characterized as some of the poorest in the world—where a paucity of basic plant resources (e.g. fire wood, forage and crop land) defies all attempts at economic development. Each island holds a unique portfolio of species and habitats that is increasingly threatened with degradation and extinction (Westermann, 1952, 1953; Leiva, 1989; Adams, 1997). To retain this diversity of plants and habitats and the associated ecosystem services requires a commitment to building national and regional capacity and to preserving and restoring the natural areas that sustain the life and economy of the region (Leiva, 1989; García & Roersch, 1996; Clubbe, 2005).

The Decline of Plant Diversity in the Caribbean Islands

The botanical diversity of the Caribbean Island hotspot is extraordinary. While the land areas are relatively small, totaling circa 229,550 km^2, the islands support a native flora of ca. 11,000 species and 1,520 genera of seed plants (Acevedo-

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Rodríguez, 2007). Work by Francisco-Ortega et al. (2007, In press) shows an amazingly high level of endemism at the genus level with a high proportion of monotypic genera. The Hotspot possesses 182 endemic genera recognized as accepted taxonomic entities (Francisco-Ortega et al., 2007, In press), 94 of these genera are monotypic (ca. 50%). In global terms, the Caribbean is comparable to the Madagascar (260) and Cape Floristic (160) hotspots for number of endemic genera (see Mittermeier et al., 2004; Francisco-Ortega et al., 2007). However, given the relatively small size of the land mass and the highly fragmented nature of surviving habitats, this represents an extraordinary packing of endemic lineages into a mosaic of increasingly fragmented refugia.

The surviving biodiversity of the Caribbean has weathered centuries of overharvesting and habitat loss. Indeed this hotspot has suffered the near complete loss of its indigenous cultures and the decimation of all unique endemic vertebrate guilds, for instance, the loss of the endemic macaws (Raffaele et al., 1988; Woods, 1990; Pregill & Crother, 1999; Ottenwalder, 2001). Centuries of colonial agriculture have resulted in the near complete loss of many lowland habitats, particularly the seasonally dry forests of the Caribbean. In the last 30 years there has been some significant progress in producing "red-lists" of threatened species following guidelines from the IUCN (IUCN, 1994, 2001). Assessments based on early IUCN guidelines are available for Cuba (Borhidi & Muñiz, 1983) and Jamaica (Kelly, 1988). More recently, Cuban botanists have produced an initial red list for Cuban endemics that covers over 20% of the flora of this island (Rankin-Rodríguez & Areces-Berazaín, 2003; Berazaín-Iturralde et al., 2005). Preliminary assessment for about 400 Cuban species of vascular plants has been recently published (González-Torres et al., 2007) and conservation strategies and recovery plans have been outlined for several taxa (e.g., United States Fish and Wildlife Service, 1993, 1998, 2005; Leiva et al., In press). In addition, Zona et al. (2007) have reviewed and assessed the conservation status of West Indian palms. Some additional species are already in the IUCN Red List (Clubbe et al., 2004; IUCN, 2007) and are the subject of IUCN Action Plans (Donaldson, 2004).

As is characteristic of many biodiversity hotspots, the botanical inventory is not complete and there is an urgent need for more botanical fieldwork (Zanoni, 1989, Francisco-Ortega et al., 2007). However, important initiatives have been developed, the most important ones are: the 13 volumes published in the "Flora de la República de Cuba Series" (www.bgbm.org), two recent works for the Puerto Rico flora (Acevedo-Rodríguez, 2005; Acevedo-Rodríguez & Strong, 2005), the first plant checklist (Acevedo-Rodríguez, 2007), and the "Flora of Greater Antilles Project" (www.nybg.org/bsci/fga/). It is also clear from existing fieldwork that the region's endemic flora is increasingly restricted to isolated refugia and that many of the region's endemic taxa are restricted to single localities. It is estimated that at least 23 of the flowering plants endemic from Cuba are currently extinct (Berazaín-Iturralde et al., 2005; Zona et al., 2007). No recent figures of the other islands are available. Clearly, some of the taxa mentioned in this review have not been found in the wild for long periods of time. We believe that fieldwork targeting these "lost" species is an immediate priority for the region. Recent fieldwork in the Cockpit Country of Jamaica targeted the area's "lost species" and rediscovered three species assumed extinct (Gordon et al., 2006).

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A recent review of Caribbean palms (Zona et al., 2007) records a number of highly threatened and restricted taxa—e.g. *Attalea crassispatha* (Mart.) Burret reduced to less than 30 adult trees in Haiti, *Pseudophoenix lediniana* Read with less than 50 adults in Haiti, and *Coccothrinax borhidiana* O. Muñiz restricted to an area of less than three kilometer squared in coastal Cuba. Of the 134 palm taxa in the Caribbean a total of 52 (39%) are threatened sensu IUCN, one species is Extinct and eleven are Critically Endangered (Zona et al., 2007).

DNA phylogenies are giving new perspectives for conservation strategies for the region (Francisco-Ortega et al., 2007; Jestrow et al., In press). For example, using the Asteraceae as a case study. *Salcedoa* F. Jiménez and R. L. Katinas (Asteraceae) an endemic genus from the Dominican Republic, that is Critically Endangered (sensu IUCN). Discovered a few years ago by botanists from the National Botanic Garden of Dominican Republic, this monotypic genus is known in a single locality from "Cordillera Septentrional" (Jiménez et al., 2004). Only 15 plants have been recorded and this taxon survives in an area where the original forest has been severely fragmented by urbanisation and agriculture. The news of this discovery reached the national media, and currently *Salcedoa* has been adopted as a symbol for conservation in the province of Salcedo. There are plans to create a protected area where this genus occurs. The example of *Salcedoa* illustrates an urgent need to conduct biodiversity inventories on areas where there are still pockets of the original vegetation and to initiate on-site conservation actions.

The ancient gymnosperm lineage of the cycads provides more examples of the region's conservation challenges and the value of molecular phylogenetics as a component of conservation planning. The monotypic *Microcycas* A.DC. (Zamiaceae) is the only Gymnosperm genus endemic to the Caribbean Islands. It is confined to a few localities on Western Cuba and has been the subject of several conservation programmes (Peña García & Grillo Mensa, 1982; Del Risco et al., 1984; Peña García et al., 1987a, b, 1989, 1992, 1998a, b; Vovides et al., 1997; Peña García, 2000). Morphological, molecular, and fossil data support *Microcycas* as sister to *Zamia* L., a large genus with ca. 60 species found from Bolivia to Mexico and on southeastern USA and the West Indies (Stevenson, 1990; González-Geigel, 2003; Hill et al., 2003; Bogler & Francisco-Ortega, 2004; Chaw et al., 2005; Hermsen et al., 2006). Major conservation challenges for this critically endangered genus include extremely low seed production and subsequent low recruitment in the few remaining populations (Del Risco et al., 1984; Peña García et al., 1987b).

There is a paucity of studies on conservation genetics in the Caribbean Islands, and we anticipate that in the near future co-dominant DNA microsatellite markers will be developed more extensively for plants from the region. Preliminary results from Meerow and Nakamura (2007) and Meerow et al. (2007) within the *Zamia pumila* L. (Zamiaceae) complex show considerable amounts of variation in some of the Caribbean island populations and suggest that they will be extremely useful to address several evolutionary and systematic questions. At least three species from this complex, *Z. angustifolia* Jacq. and *Z. lucayana* Britt. from the Bahamas, and *Z. stricta* Miq. from Cuba have very restricted distributions (Eckenwalder, 1980; Stevenson, 1987; González Géigel, 2003).

Ironically the endemic Caribbean family Goetzeaceae as the result of DNA analysis is no longer regarded as valid; however, further phylogenetic research has

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discovered a fascinating biogeographic link to the flora of Madagascar (Santiago-Valentín & Olmstead, 2003). The initial phylogenetic studies have resulted in further conservation studies of this endemic genus. The endemic genus *Goetzea* Wydler (Solanaceae) characterizes many of the issues facing endemic lineages in the Caribbean. *Goetzea elegans* Wydler from Puerto Rico was known from about 150 reproductive individuals; however, fieldwork has discovered two additional localities. Studies concerning the reproductive biology and conservation status of this species have been the focus of a recent Masters Thesis (Caraballo-Ortiz, 2007). *Goetzea ekmanii* O.E. Schulz is recorded from a single locality in the Dominican Republic with about 30 individuals. *Goetzea* and three other endemic genera, *Coeloneorum* Radlk., *Espadaea* A. Rich, and *Henoonia* Griseb. form a monophyletic assemblage that is the sister group to the South American genus, *Metternichia* Mik. This lineage is sister to *Duckeodendron* Kuhlm., which is also restricted to South America. This clade includes *Tsoala* J. Bosser & W.G. D'Arcy, a monotypic genus endemic to Madagascar. This group of Caribbean–South American–Madagascan genera forms the subfamily Goetzeoideae which is one of the most early-diverging branches for the Solanaceae (Santiago-Valentín & Olmstead, 2003; Olmstead et al., submitted).

With over 28 species, *Leucocroton* Griseb. (Euphorbiaceae) is one of the most species-rich endemic genera of the Caribbean Islands. This genus is sister to *Lasiocroton* Griseb. (five species), which is also endemic to the Caribbean Islands (Francisco-Ortega et al., 2007; Jestrow et al., In press). *Leucocroton leprosus* (Willd.) Pax & Hoffm. is currently known from a single locality with only three individuals at Los Haitises (Dominican Republic). The species was also collected in two additional localities in Hispaniola by E. L. Ekman in the early 20th century, the status of these populations is unknown. No recent field explorations have been carried out to confirm the existence of the species (Jestrow, unpublished).

The Caribbean grasses while ecologically important are poorly studied. With nine endemic genera, this family ranks sixth among those with a high number of endemic genera. The Poaceae represent a clear example of the many research and conservation gaps that need to be filled in the Caribbean Hotspot. None of these genera have been included in any molecular phylogenetic studies; therefore, the evolutionary placement of these taxa is unknown. Two of the three bamboo genera endemic to Cuba (i.e., *Ekmanochloa* Hitchc., 2 spp.; *Mniochloa* Chase,1 sp.) are extremely rare and have not been found since the early 1960s. The third bamboo genus, *Piresiella* Judzie., Zulo. & Morr. (1 sp.), was described in 1993 and it is locally common on limestone mountains of western Cuba. Two of the genera of the subfamily Pooideae (*Lepturidium* Hitchc. & Ekman and *Triscenia* Griseb.) are thought to be threatened. The monotypic *Lepturidium* is the only plant genus endemic to "Isla de la Juventud" in Cuba. It is extremely rare and restricted to halophyte savannas on siliceous sands. The conservation status of the monotypic *Triscenia* is uncertain as this genus has not been found in the wild in the last 45 years, historically the species was considered common in serpentine areas of eastern Cuba (Catasús-Guerra, 1997, 2002).

Other endemic species have not been found since their original descriptions. For instance, in their recent phylogenetic study of the Nyctaginaceae, Douglas and Manos (2007) reported that despite intensive fieldwork by themselves and botanists

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from Jardin Botanico Nacional they were unable to find the monotypic Cuban genus *Caribea* Alain, one of the few Caribbean genera endemic described in the last 50 years (Alain, 1960).

Caribbean Responses

Plant conservation has often been marginalized as a peripheral activity for the agencies involved in protected area or forestry management. The future challenge for plant conservation in the Caribbean is how to maintain plant populations as evolutionary lineages, as ecological components of functioning landscapes and as economic resources within a rapidly changing ecological and political context.

We recognize that plant conservation, encompassing the needs for managing increasingly fragmented habitats and populations within human dominated landscapes, will face a number of challenges:

(1) Effective conservation solutions must increasingly include strong elements of social science, resource economics, and commercial practice; an "academic" awareness of the need for plant conservation alone does not necessarily change practices. Here the botanical community needs to improve its ability to more effectively communicate the value of plants and the need for their conservation to the world beyond the herbarium.
(2) Important plant areas are rapidly becoming ecological islands, and many of their enclosed species' populations will increasingly face issues of viability. There is an urgent need to improve the protected area network in the Caribbean to encompass key areas of botanical diversity as part of a general commitment to identify and retain Key Biodiversity Areas (sensu Langhammer et al., 2007).
(3) As habitat conversion proceeds and reduces the viability of wild populations and diminishes the quality of ecosystem services there is a need to test and apply tools for the cost effective restoration of large scale Caribbean landscapes, such tools need to effectively promote natural regeneration and serve the goals of biodiversity restoration whilst providing economic service to resident communities.
(4) Plant communities will be subject to the continued impact of invasives (i.e., introduced non-native plants, animals, and pathogens). There is an urgent need for cost effective tools for predicting and preventing invasions; and in particular, fragmented reserves may need permanent management. The speed of economic development and the massive movement of horticultural materials between islands for landscaping indicates that invasive species issues will not decline in importance. The ability to identify new plant species is a key part of the regional resources needed to manage invasives.
(5) Development of effective and easy to use (particularly by non-specialists) monitoring protocols and plant identification tools to assess the effectiveness of plant conservation activities. This will be of particular value in isolated reserves subject to continuing degradation. Whilst the "taxonomic impediment" has been recognized as a problem retarding the documentation of plant diversity there is also an urgent need to break the larger and less publicized

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"management impediment" where the absence of practical management for conservation areas impedes conservation progress.

(6) The botanical infrastructure of the region is profoundly under invested. There is a real need to strengthen existing scientific institutions and to develop the next generations of Caribbean conservationist and botanist. The botanic gardens of the Caribbean have demonstrated leadership through the adoption and promotion of the Global Strategy for Plant Conservation (Leadley, 2006). A "Conservation Action Plan for Botanic Gardens of the Caribbean Islands" has been produced (Burbidge & Wyse-Jackson, 1998). The regional network "Caribbean Botanic Gardens for Conservation" had held two conferences the first at Fairchild Tropical Botanic Garden (FTBG) (2002) and the second at the Belize Botanic Garden (2005). However the majority of herbaria, university botany facilities and botanic gardens in the region are poorly supported and suffering from a lack of investment.

(7) There is an enormous gap between "academic" research and its application to the practical management of threatened habitats and species by community groups, protected area managers and motivated volunteers. There is a need to translate science publications into readily disseminated and adopted guidelines and instructions that can improve site management of habitats and species.

(8) Fundamental to all of the above is the need to raise the professional and public profile of plant conservation as it is still a poor sister to animal/wildlife conservation. This may require a move from the species as a conservation goal towards the broader promotion of habitat and ecosystem services (Maunder & Clubbe, 2002). For instance, the montane forests of the Caribbean are essential water sources for island economies and as such should be promoted as an integral part of island economies and biodiversity infrastructure.

Molecular Perspectives and Concluding Remarks

The Caribbean, as one of the planet's biodiversity hotspots, contains an irreplaceable botanical heritage that underpins the ecology and economy of every island. This heritage is eroding rapidly. Molecular phylogenetics is part of the array of tools that is needed to secure habitats—it provides a measure for taxonomic diversity and importantly provides a point of inspiration that can generate further conservation research and action. Phylogenetic research can provide an insight into the evolution and age of a flora, and will, if the story is properly told, generate a sense of wonder about the region's flora. It will be a sad day when all that remains of the Caribbean's endemic lineages will be old herbarium specimens, some DNA in a microtube, a published phylogenetic paper, and if lucky, a lonely plant in a botanic garden. The systematic community's participation in conservation is essential. Sadly, some of these species are only known to systematic botanists, the last pair of eyes to see the living plant will have been a botanists. As researchers with an ethical responsibility towards the species we study, we need to actively support the growth of Caribbean botany and generate future cadres of scientists and conservationists and, perhaps most importantly effectively communicate our sense of wonder and love for plants

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and their underlying importance to the health of the environment. Every species we study should be a focal point for communication and a flagship for habitat conservation.

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