

NOTE

Update on the distribution of *Lepanthes caritensis*, a rare Puerto Rican endemic orchid

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ABSTRACT: *Lepanthes caritensis* is a small epiphytic orchid endemic to Puerto Rico. Although this species is very rare and demographic studies show that its numbers are declining, it is not protected under the United States Federal Endangered Species Act (ESA). Furthermore, questions remain regarding its distribution, population size and ecological interactions, including host-specificity, which could influence its likelihood of extinction. The primary objective of this study was to document the overall population size and distribution of this orchid to determine whether it warrants federal listing. To this end, extensive surveys were conducted to document the current distribution and population size of *L. caritensis*. These data were used to classify the species' rarity status according to criteria outlined by Rabinowitz, NatureServe and the IUCN. Results of these surveys indicate that the overall population of *L. caritensis* is larger and more widely distributed than previously thought. In addition, the species is not host-specific outside its originally described range, and is found on at least 4 different host species. Nevertheless, this species is indeed rare: it meets the criteria for the NatureServe category 'critically imperiled' and the IUCN category 'Critically Endangered'. Consequently, the most important conclusion of this study is that this species warrants legal protection under the ESA, particularly if its population continues to decline.

KEY WORDS: Critically imperiled species · Endangered species · Rarity status · Epiphytes · Caribbean flora · Host specificity · Rare plant distribution

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INTRODUCTION

Numerous rare and endangered species in the United States of America have yet to be assigned any legal conservation status. A recent analysis of the Natural Heritage Database (www.natureserve.org) and the US Endangered Species List revealed that merely 10% of all rare North American plant species are protected by the United States Federal Endangered Species Act (ESA) (Stein et al. 2000, Mills & Schwartz 2005). Consequently, these species are often excluded from the benefits of legal protection as well as the federal or local funding that supports research aimed at the recovery of these species.

Lepanthes caritensis Tremblay & Ackerman is a small epiphytic orchid that is endemic to the island of Puerto Rico (Tremblay & Ackerman 1993). The species was described less than 20 yr ago from specimens collected in the Carite State Forest in the Municipality of Patillas, where it was observed to be host-specific on the trunks of Caimitillo trees (*Micropholis guyanensis* A. DC. Pierre). At the time, the known population consisted of 196 individuals occurring on only 9 trees. Its closest relatives were determined to be *Lepanthes sanguinea* Hook. and *Lepanthes eltoroensis* Stimson, both of which were known from the Luquillo Mountains of the Caribbean National Forest in Puerto Rico (i.e. El Yunque) (Tremblay & Ackerman 1993).

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Years later, several taxonomic experts reviewed herbarium collections at the University of Puerto Rico. It was determined that the collections of *Lepanthes sanguinea* from Puerto Rico were indistinguishable from *Lepanthes caritensis* collections (J. Ackerman pers. comm.). Consequently, our present understanding of the species distribution is that the occurrences of *L. sanguinea* are restricted to the island of Jamaica (Luer 2009), and the known distribution of *L. caritensis* now includes 2 distinct locations in Puerto Rico: (1) the Carite State Forest and (2) El Yunque. This update is consistent with the general observation that Caribbean *Lepanthes* spp. usually occur on single islands (Tremblay & Ackerman 1993, Ackerman 1995).

Since the aforementioned updates, several changes in the populations of *Lepanthes caritensis* have been noted. In 1998, 2 of the subpopulations in Carite were destroyed by Hurricane George (Tremblay 2000). In addition, frequent verbal reports among local botanists and forest service employees indicate that several subpopulations along a popular and easily accessible trail in El Yunque have been extirpated as a result of illegal collecting and hurricane damage. Nevertheless, it has been over a decade since an intensive census of the population of *L. caritensis* was conducted to officially confirm any of these conjectures.

The main objective of this study was to determine whether the present status of *Lepanthes caritensis* justifies listing it under the ESA. Accordingly, the pri-

mary aim was to document the overall population size of *L. caritensis* and to determine its current distribution in Puerto Rico. The subsequent aim was to identify the particular tree species that host *L. caritensis* within its overall range. This updated information is essential to quantify the rarity status of this species (see Rabinowitz 1981, IUCN 2001, NatureServe 2010).

MATERIALS AND METHODS

Extensive surveys for *Lepanthes caritensis* were conducted in the Carite State Forest and in the Luquillo Mountains of El Yunque, focusing on areas surrounding the locations where previous collections were made (Tremblay & Ackerman 1993, Ackerman 1995). In Carite, *L. caritensis* has only been discovered at locations adjacent to river drainages. Therefore, our surveys focused on each of the river drainages in the reserve (Fig. 1C). During this survey, each of the 3 main river channels in the reserve were followed for approximately 2.0 km until the origin of the drainage was reached or the terrain became impassable because of large waterfalls and/or extremely steep slopes. In total, approximately 2.5 km² of the Carite State Forest comprising the areas within 200 m of the main river channels or the smaller tributary streams were surveyed. All accessible trees were visually inspected for orchids occupy-

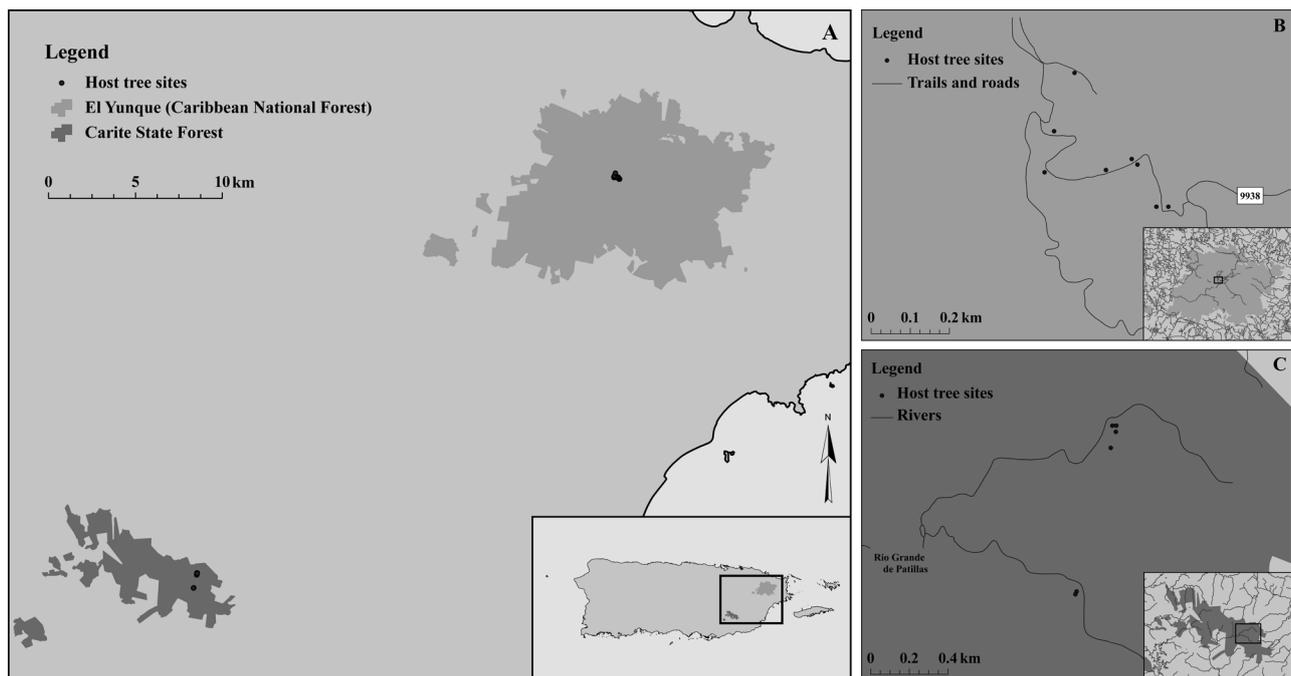


Fig. 1. *Lepanthes caritensis*. (A) Distribution in Puerto Rico (inset), with more detailed view of the (B) El Yunque and (C) Carite State Forest subpopulations

ing the bole from the base up to approximately 10 m from the base. Inaccessible trees were examined from the river with binoculars, although this proved difficult due to the dense vegetation and diminutive size of the species.

In El Yunque, surveys were focused along several trails and streams in the forest that allowed access to various sections of the reserve. Specifically, surveys were conducted in approximately 1 km² of the El Yunque forest comprising areas along the Juan Diego Stream (~0.2 km), the Big Tree Trail (~1.2 km), the La Mina Trail (~1.1 km), the Mount Britton Trail (~1.2 km), Service Road 10 (~1.2 km), the Trade Winds Trail (~7.4 km) and the Waterline Trail (~4.0 km). At these locations, the surveys were restricted to areas approximately 5 to 50 m from the trails and limited by the extremely steep slopes of the surrounding terrain. Again, the basal portion of each accessible tree was visually examined and inaccessible trees were viewed with binoculars.

Geographic coordinates were collected with a handheld global positioning system unit at each host tree. Coordinates were entered into ArcGIS 9.3 to map the overall distribution of the species. Each host tree was identified to species level. Lastly, the number of mature *Lepanthes caritensis* with reproductive potential (i.e. plants with fully developed leaves and/or some evidence of reproduction) present on each host tree was recorded. Non-reproductive individuals were identifiable by the unique morphology of their mature leaves as compared with other more common species. Additionally, *L. caritensis* have leaves that are appressed to the boles of their host trees whereas all other species have erect leaves. Since several other species of *Lepanthes* occur sympatrically with *L. caritensis* at both sites, immature individuals were excluded from the results of this survey because of difficulties of distinguishing between the seedlings of different species. Additionally, IUCN Red List protocol is to quantify only mature individuals capable of reproduction. Voucher specimens were not collected to avoid disrupting the already small population size and due to the demographic significance of adult individuals in the population (see Tremblay 1997); however, photographs of actively flowering individuals were taken when present. The data collected during these surveys facilitated further analysis to determine the rarity status of the species.

To quantify the rarity status of *Lepanthes caritensis*, the data were analyzed according to 3 renowned rare plant classification systems: Rabinowitz's 7 forms of rarity, the Natural Heritage Program's

(NatureServe) Element Ranking System and the IUCN Red List (Rabinowitz 1981, IUCN 2001, NatureServe 2010). Each of these systems makes use of multiple types of data, including population size, range size and habitat specificity, to systematically quantify rarity status. Data were specifically collected for each of these criteria during the surveys in this study. Demographic data were used in conjunction with the results of previous surveys of *L. caritensis* (Rosa-Fuentes & Tremblay 2007) to calculate the growth rate of the population. Collectively, these data allow for the systematic assessment of the species' rarity status according to aforementioned systems.

RESULTS

We documented 7 trees hosting *Lepanthes caritensis* in Carite State Forest across a total area of approximately 0.5 km², and another 8 trees in El Yunque across an area of approximately 0.5 km² (Fig. 1A). In Carite, all trees were located in 2 clusters at approximately 18.09° N, 66.03° W (Fig. 1A,C) at elevations between 640 and 650 m. In El Yunque, host trees were located at approximately 18.29° N, 65.79° W (Fig. 1A,B), and were distributed along a wider elevational range, occurring between 520 and 920 m.

In total, 220 adult individuals were documented in this survey: 113 from the Carite State Forest and 107 from El Yunque. The number of individuals on each host varied considerably across the 2 sites, ranging from 2 to 33 adult individuals per tree. On average, each host contained 15 adult individuals (SD = 9.7). A number of immature individuals (i.e. individuals without visible leaf sheaths, fully developed leaves or signs of reproduction) were located on each host tree as well, but plants in this age class are very difficult to distinguish from other species of *Lepanthes*, and therefore they are not quantified here. Three of the trees from our survey were also surveyed in 2006 (Rosa-Fuentes & Tremblay 2007), when a total of 94 adult individuals were documented; these 3 trees hosted a total of 57 adult individuals in 2011. With these data, we calculated an annual growth rate (λ) of the adult population over the 5 yr period from 2006 to 2011 with the following equation:

$$\lambda = (N_{t+x}/N_t)^{(1/x)} \quad (1)$$

where N is the number of adult individuals documented in the initial survey in year t and x is the number of years passing before the subsequent sur-

vey was conducted (see Morris & Doak 2002). By applying this equation to our data, we obtain:

$$\lambda = (57/94)^{(1/5)} = 0.90 \quad (2)$$

which is a strong indication that the population of *L. caritensis* is rapidly declining in Carite, as a minimum λ value of 1 is required to maintain the current size of a population.

Additionally, at least 2 of the 9 previously identified subpopulations in Carite were extirpated via natural processes; the host trees were downed, presumably by a hurricane or large storm, and no orchids remained on the trunks or stumps. In addition, there were no remaining individuals in at least 4 locations in El Yunque where the species was previously collected. Each of these sites in El Yunque was at the lowest elevational range in which the species is distributed and was within 10 m of a popular trail that receives extensive foot traffic. These observations are consistent with speculation that illegal collection was occurring, and thus it seems possible that *Lepanthes caritensis* at these El Yunque sites was extirpated via anthropogenic means.

In Carite, the survey confirmed the reports of Tremblay et al. (1998) suggesting that *Lepanthes caritensis* is found solely on trunks of *Micropholis guyanensis* at that site. Each of the 7 documented subpopulations in Carite was located on this tree species. Interestingly, this survey also shows that outside of Carite, *L. caritensis* is hosted by a variety of tree species (Table 1). In total, *L. caritensis* was distributed on 3 other host tree species: 6 subpopulations occupied Sierra palms *Prestoea acuminata* (Willd.) H. E. Moore, 1 subpopulation occupied a Grundlach's attorney *Clusia gundlachii* Stahl and 1 subpopulation occupied an unidentifiable species possibly of the Rubiaceae family (no branches or leaves on the tree were available for inspection as the crown was concealed by a much larger neighboring tree; however, a few leaves from a member of the Rubiaceae family were discovered at the base of the tree). No *L. caritensis* orchids were documented on *M. guyanen-*

sis in El Yunque, and no individuals were documented on *P. acuminata* in Carite, although each of these potential host tree species is abundant in both forests. These findings bring the total number of tree species that can host *L. caritensis* to 4, and disprove the hypothesis that this orchid occurs exclusively on a single host species throughout its range.

Considering the forms of rarity outlined by Rabinowitz (1981), *Lepanthes caritensis* can be described as constantly sparse and geographically restricted in a specific habitat, despite occurring on more host species than previously described. When analyzed within the frameworks developed by 2 internationally recognized conservation organizations, NatureServe and the IUCN, the results of this survey show that *L. caritensis* meets criteria for listing the species as Critically Imperiled (G1) (NatureServe 2010) and/or Critically Endangered (CR) (IUCN 2001). According to NatureServe, a taxon can be classified as Critically Imperiled at a global scale if the species is 'at very high risk of extinction due to extreme rarity (often 5 or fewer populations or less than 1000 individuals), very steep declines, or other factors' (NatureServe 2010 [www.natureserve.org/explorer/ranking.htm], CNHP 2011). According to results obtained from the NatureServe Rank Calculator Version 2.0 (see Faber-Langendoen et al. 2009), this species is at very high risk of extinction because of its extreme rarity; it occupies less than four 1 km² grid cells, there are fewer than 5 populations (i.e. occurrences separated by at least 10 km) and there are fewer than 250 remaining individuals. Consequently, *L. caritensis* should be ranked as Critically Imperiled according to NatureServe criteria.

Similarly, according to the IUCN Red List Categories and Criteria Version 3.1 (IUCN 2001), 'a taxon is Critically Endangered when the best available evidence indicates that it meets any of the criteria A to E for Critically Endangered, and it is therefore considered to be facing an extremely high risk of extinction in the wild.' Specifically, IUCN Red List criteria B.2.a. and B.2.b.(ii, iv, v) state that a taxon is Critically Endangered if the geographic range in the form of area of occupancy is estimated to be less than 10 km², and estimates indicate that the range is severely fragmented or known to exist at only a single location, and there is continuing decline (observed, inferred or projected) in the area of occupancy, the number of locations or subpopulations and the number of individuals (IUCN 2001). Based on our surveys, we determined that the geographic range of this species in terms of area of occupancy is less than 10 km², it is severely fragmented, and the area of occupancy,

Table 1. Tree species hosting *Lepanthes caritensis* in Carite State Forest and El Yunque, Puerto Rico

Species	Site	No. of host trees
<i>Micropholis guyanensis</i>	Carite State Forest	7
<i>Prestoea acuminata</i>	El Yunque	6
<i>Clusia gundlachii</i>	El Yunque	1
Unknown species (Rubiaceae)	El Yunque	1

the number of locations or subpopulations and the number of mature individuals are projected to decline (Tremblay 1997, 2000). Consequently, it is apparent that this species merits legal protection under the ESA (ESA 1973).

DISCUSSION

The disjunct distribution of the 2 populations of *Lepanthes caritensis* suggests that the former distribution could have potentially been much more extensive. Historically, the island of Puerto Rico has experienced intense levels of deforestation, and the sites where the orchid is located are primary forest fragments (Chinaea & Helmer 2003); therefore, could the species have been more widespread prior to major deforestation trends? Regardless, the current distributional isolation of *L. caritensis* populations may have severe consequences, including inbreeding depression and Allee effects, which may continue to preclude species growth and recovery (Schemske et al. 1994).

The results of our survey are also an indication that although the entire known population of *Lepanthes caritensis* is located on protected land, the species may still go extinct (see Tremblay et al. 1998, Tremblay 2000). The natural extirpation of subpopulations in Carite and El Yunque seems likely to continue, as hurricanes are frequent in Puerto Rico (Lugo 2000, Tremblay 2008) and orchids on fallen trees generally do not survive (Tremblay 2008, B. J. Crain pers. obs.). At the same time, illegal collection of this species could directly contribute to local extirpation in the immediate future, and perhaps generate anthropogenic Allee effects (Courchamp et al. 2006). These factors warrant the assignment of legal conservation status to *L. caritensis* by local and federal agencies.

As a final note, the distinctiveness of all rare species merits their protection. However, this distinctiveness also indicates that they are biologically unique, and therefore we need detailed species-specific information in order to effectively manage them. Consequently, continued studies of the ecological and geographical affinities of rare species needs to be a priority. A necessary study would be to identify differences in the populations of both the orchids and their host trees in Carite and El Yunque to determine why this rare species appears to be host specific in one site but not the other. Are the local biological interactions unique at each site? Is it possible that the 2 populations are composed of 2 cryptic species? Long-term demographic studies of *Lepanthes cari-*

tensis, its hosts and its symbionts could give a clearer picture of the natural processes that may contribute to its rarity. Understanding the ecological distinctions at each site could enhance our ability to develop an effective conservation plan for this unique species, and prevent the loss of another fascinating organism.

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