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Cover Photograph: Lilisbeth Rodriguez, a young Panamanian biologist and great field companion, investigating a large Zamia pseudoparasitica plant 15 meters above ground in Omar Torrijos National Park, El Copé, Panama. Photograph © Philip Bell-Doyon

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New Notes on the Ecology of the Epiphytic Gymnosperm and Panamanian Endemic *Zamia pseudoparasitica*

Philip Bell-Doyon[1*] and Juan Carlos Villarreal A.[2]

Abstract - The Panamanian endemic cycad *Zamia pseudoparasitica* Yates was surveyed in the Omar Torrijos National Park, Provincia de Coclé, from May to July 2018. The species is the only strictly epiphytic gymnosperm and its life history is little known due to the inaccessibility of the plants. Using single-rope and prussik-knot tree climbing techniques, population density, seed dispersal strategy and ant-garden specificity were evaluated. *Zamia pseudoparasitica* is locally common in parts of the park with up to 24 individuals per hectare. No ripe ovulate cone was found, precluding the observation of seed dispersers. Almost a quarter of monitored plants presented an ant nest near or within its root system. The ants identified belonged to five genera: *Camponotus*, *Cyphomyrmex, Megalomyrmex*, *Odontomachus*, and *Rogeria*. *Zamia pseudoparasitica* has unique ecological attributes related to its peculiar life history. We believe the species should receive more attention from environmental authorities and the public to help preserve its habitat.

Resumen - La cícada endémica de Panamá *Zamia pseudoparasitica* Yates fue monitoreada en el parque nacional Omar Torrijos, Provincia de Coclé, entre mayo y julio de 2018. Es la única especie de gimnosperma estrictamente epífita y su historia natural es poco conocida debido a que la especie se encuentra a alturas poco accesibles (10-20 metros). Usando una técnica de escalado de árboles con un nudo prussik, evaluamos la densidad de la población, la estrategia de diseminación y la especificidad de jardines de hormigas. *Zamia pseudoparasitica* es bastante común en partes del parque nacional y se encuentran hasta 24 individuos por hectárea. No encontramos conos ovulados maduros así que no pudimos observar los diseminadores de las semillas. Aproximadamente, una de cuatro de las plantas monitoreadas tenía un jardín de hormigas en su sistema de raíces. Las hormigas identificadas pertenecían a cinco géneros: *Camponotus, Cyphomyrmex, Megalomyrmex, Odontomachus* y *Rogeria*. *Zamia pseudoparasitica* tiene características ecológicas únicas relacionadas a su hábit peculiar. La especie debería recibir más atención por parte de las autoridades y del publico para ayudar en la preservación de su hábitat.

Introduction

The Neotropical genus *Zamia* (Zamiaceae, Cycadales) includes 81 accepted species names (Calonje et al. 2018, 2019), many of which have a very restricted range. It is arguably the most ecologically diverse genus of cycads (Jones 2002). Panama has seventeen species of which twelve are endemic, including *Zamia pseudoparasitica* Yates—the only known strictly epiphytic gymnosperm (Stevenson 1993; Taylor et al. 2008, 2012, 2014). The naturalist of the H.M.S. Herald, Berthold Seemann (1854), first published the name *Zamia pseudoparasitica*. He referred to an epiphytic *Zamia* described by J. Yates and collected by J. Warszewicz in Chagres, Provincia de Panamá. Dressler (1975) brought the strange epiphyte back into botanists' sight after recollecting the plant near Santa Fe, Provincia de Veraguas. The morphology has been well-documented (Stevenson 1993, Taylor et al. 2012) and we recently uncovered a specialized symbiotic

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bacteriome within the coralloid roots of the species (Bell-Doyon et al. 2020). The weevil beetle *Notorhopalotria taylori* Tang and O'Brien has been identified in staminate cones and seems to be the main pollinator (O'Brien and Tang 2015). The beetle may be attracted by an odor-mediated push-pull mechanism (Terry et al. 2007). *Zamia pseudoparasitica* is classified as "near threatened" on the IUCN red list (Taylor 2010), mainly because of deforestation and poaching (Stevenson et al. 2003). For example, in the Donoso region (Provincia de Colón), 13,600 hectares of intact landscape will be deforested due to copper mining (First Quantum Minerals 2017). Donoso harbors thousands of *Z. pseudoparasitica* individuals and the mining activities threaten one of the largest known populations (Villarreal, pers. obs.). This paper aims to provide novel ecological information and to raise awareness about this peculiar and precious species of cycad.

Study Site and Method

Zamia pseudoparasitica was surveyed from May to July 2018 in the Omar Torrijos National Park, Provincia de Coclé, between 500 and 1100 meters above sea level. The study site is an undisturbed rainforest located 18 kilometers away (straight line) from the Donoso border and the closest mining site. Trails were carefully scouted for the presence of *Z. pseudoparasitica* (Fig. 1) and georeferenced every time at least one individual was sighted. At each point, we noted the number of plants per tree and evaluated the presence of cones. Plant population density per hectare was estimated based on a 25 m linear buffer zone

Figure 1. *Zamia pseudoparasitica* with an ovulate cone located more than 20 m above ground in the Omar Torrijos National Park, Coclé, Panama. See how the branch is densely crowded by epiphytes. Credit photo: Maycol Madrid. Used with permission.

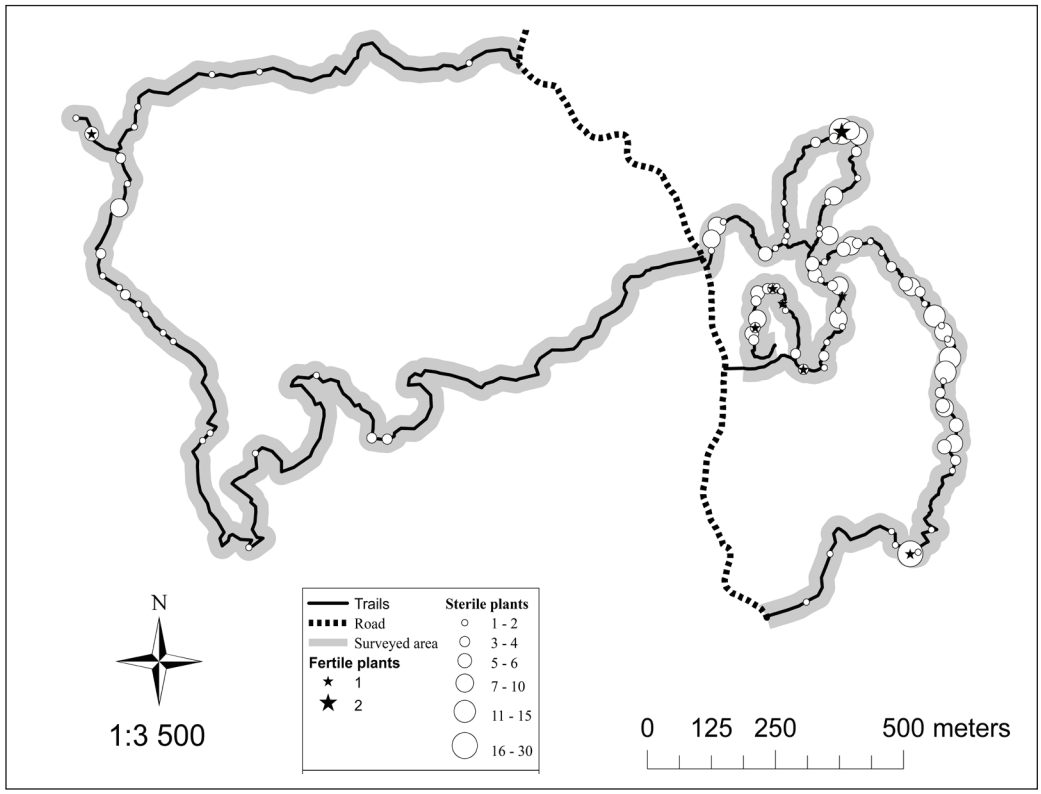

Figure 2. Trail map (with 25 m buffer zones in gray) representing the distribution of sterile and fertile *Zamia pseudoparasitica* in the surveyed area. The coordinates and exact location of the population are not shown to protect the species from poachers, but they are available to researchers upon request.

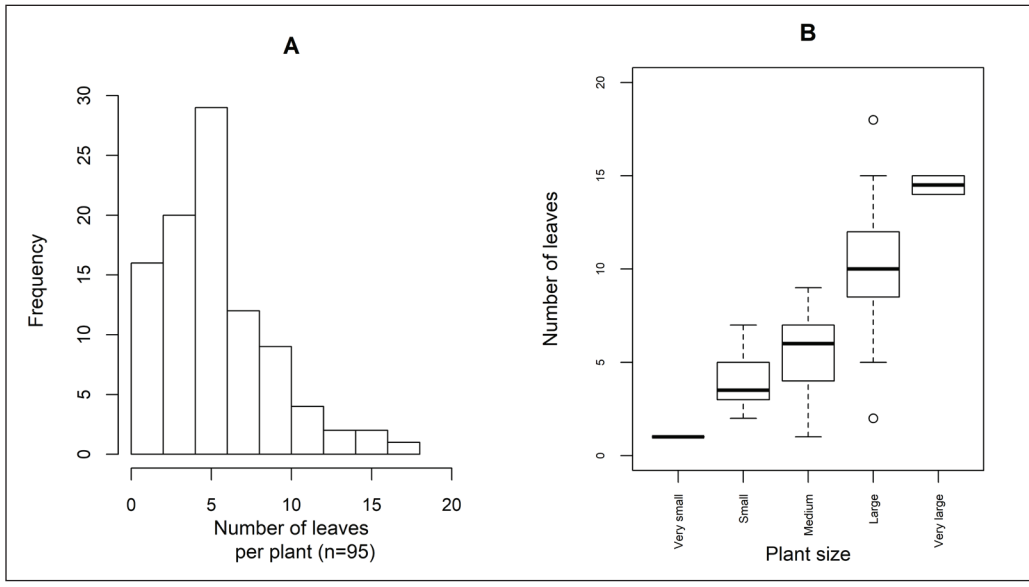

Figure 3. Plant size and number of leaves for the 95 individuals evaluated. A. Frequency distribution of plants according to their number of leaves; B. Mean number of leaves per size category (Very small n=4; Small n=30; Medium n=40; Large n=19; Very large n=2).

(approximate average visibility) on both sides of the monitored trails using ArcGIS (Fig. 2). The total area surveyed was 34.1 hectares along 7.38 km of trails. Because the number of individuals varied greatly among trails, we evaluated density independently for each of the four trails. For one of the most densely populated trails, we noted the relative size and the number of leaves of each plant. Relative size was visually assessed to five categories from ground level. We plotted descriptive data (Fig. 3) in R (https://www.r-project.org/). A camera trap was set up in front of the only accessible ovulate cone for six consecutive weeks. Regular observation periods were conducted of three of the most developed ovulate cones to observe seed-dispersers. We used a single-rope and prussik-knot tree climbing technique to reach 55 plants up to 15 m above ground. We dug out by the base of the cycad to expose its roots. When ants were observed, we collected two to three individuals with larvae from the root system of *Z. pseudoparasitica*.

Results and Discussion

Zamia pseudoparasitica did not recolonize 50-year old adjacent secondary growth. Plants seem to grow mainly on large horizontal branches and in branch forks, on many species of canopy trees and at any height apart from the uppermost and thinnest canopy branches. In the undisturbed forest, we counted from ground level a total of 422 individuals of which 19 were fertile (seven staminate and 12 ovulate plants). The smallest fertile plant was a medium-sized cycad with only four leaves. Population density varied from 2.8 to 24.7 plants per hectare, depending on the trail, for an average of 12.4 plants per hectare in the total surveyed area (34.1 ha). Density is likely to be underestimated because: 1. failure to detect all individuals and; 2. a seemingly single large plant from ground level sometimes turned out to be an agglomeration of many individuals of varying sizes, once we climbed up the trees. For the 95 plants evaluated, the mean number of leaves per plant was 5.8 and the most common plants were of medium size (n = 40) (Fig. 3). We believe the demographic pattern may indicate that the local population is not at risk, with many individuals in all size categories, and the presence of several fertile plants. The longest leaf we have seen was about 2 m and the smallest 20 cm long. None of the ovulate cones were ripe, hence no observation of sarcotesta consumption nor seed dispersal was made. We couldn't assess whether there is a seasonal pattern in cone ripening. Seeds may be dispersed by arboreal mammals as in aroids (Vieira and Izar 1999). However, we believe that, as has been suggested before (Stevenson 1993), medium to large fruit-eating bats (e. g. *Artibeus* spp.) might be particularly good candidates because they: 1) tend to be abundant in Neotropical forests (Rex et al. 2008), 2) consume the skin and pulp of some larger fruits (e.g. *Eugenia* spp., *Spondias* spp.) without damaging the seeds (Ortega and Castro-Arellano 2001), 3) transport food-items to a secondary site before eating it (Morrison 1978), and 4) use olfactory cues to locate ripe fruits (Rieger and Jakob 1988). The smell of ripe mucilaginous sarcotesta from ovulated cones of *Z. pseudoparasitica* has been described as "rank/sour" (Stevenson 1993), a typical smell of bat-consumed flowers (Helversen and Winter 2003).

Like most cycads, *Z. pseudoparasitca* possesses primary, secondary, and apogeotropic coralloid roots (Taylor et al. 2008). Some ant species are known to create garden-like structures within the root system of a wide range of epiphytic angiosperm families (Davidson 1988). Those ant-gardens are known to contribute to nutrient uptake in epiphytic tropical plants, including Bromeliaceae and Asclepiadaceae (Gonçaives et al. 2016, Treseder et al. 1995). Ants were found with larvae in the root system of 13 out of 55 plants reached by climbing. Neither specificity nor correlation with plant size was evident,

ants with larvae were found in large and small plants growing from 2 to 15 meters above ground. *Odontomachus hastatus* Fabricius (n = 2) and *O. erythrocephalus* Emery (n = 2) were the only two ant species observed managing an extensive garden-like structure crowned by diverse epiphytes including *Z. pseudoparasitica*. Other ants identified to genus (*Camponotus* (n = 3), *Cyphomyrmex* (n = 1), *Megalomyrmex* (n = 3), and *Rogeria* (n = 2)) only had small and localized breeding colonies within the tertiary root system of the cycad. *Odontomachus* and *Camponotus* species are known to manage ant-gardens in bromeliads (Camargo and Oliveira 2012, Leroy et al. 2017). *Cyphomyrmex* and *Megalomyrmex* are fungi-growing ant genera (Mueller et al. 2001, Murakami and Higashi 1997) and *Rogeria* are tiny ants of very little-known habits (Lapolla and Sosa-Calvo 2006). Many species of epiphytic plants were crowded around the cycads where garden-forming ants were found; we therefore believe that these may not associate specifically with *Z. pseudoparasitica*.

Conclusion

The absence of *Z. pseudoparasitica* from adjacent 50-year old secondary growth highlights the value of undisturbed forests for long-term in-situ conservation of viable populations. Its endemism to Panama and unique epiphytic habit make *Zamia pseudoparasitica* a promising candidate to promote as a flagship species (Caro 2010). Currently, the plant is only classified as "near-threatened" in the IUCN red list (Taylor 2010). We stress the need for revaluating its conservation status in this decade considering the growing threat from mining activities. Such intensive mining poses a real threat to large populations (e.g. Donoso) located outside of protected areas. We suggest the creation of a network of small protected areas (10-50 ha) in the Donoso region to protect pockets of particularly high cycad density without significantly curbing mining interests in the region. Future research should focus on population size and turnover, genetic diversity, and seed dispersal.

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Literature Cited

Bell-Doyon, P., J. Laroche, K. Saltonstall, and J.C. Villarreal Aguilar. 2020. Specialized bacteriome uncovered in the coralloid roots of the epiphytic gymnosperm, *Zamia pseudoparasitica*. Environmental DNA 2020;00:1–11. Doi: 10.1002/edn3.66

Camargo, R.X., and P.S. Oliveira. 2012. Natural history of the Neotropical arboreal ant, *Odontomachus hastatus*: Nest sites, foraging schedule, and diet. Journal of Insect Science 12:48.

Calonje, M.A., C. López-Gallego, and J. Castro. 2018. *Zamia paucifoliolata*, a new species of *Zamia* (Zamiaceae, Cycadales) from Valle del Cauca, Colombia. Phytotaxa 385:85–93.

Calonje, M.A., D.W. Stevenson, and L. Stanberg. 2019. The World List of Cycads, online edition. Available online at http://www.cycadlist.org. Accessed 26 January 2019.

Caro, T. 2010. Flagship species. Pp. 245–262, *In* T. Caro (Ed.). Conservation by Proxy. Island Press, Washington D.C., USA. 400 pp.

Davidson, D.W. 1988. Ecological studies of Neotropical ant gardens. Ecology 69:1138–1152.

Dressler, R.L. 1975. It grows up in the trees; really, it does. The Marie Selby Botanical Gardens 2:22–23.

First Quantum Minerals Ltd. 2017. Cobre Panama. Available online at https://www.first-quantum.com/Our-Business/operating-mines/Cobre-Panama/default.aspx. Accessed 22 January 2020.

Gonçaives, A.Z., R.S. Oliveira, P.S Oliveira, and G.Q. Romero. 2016. Species-specific effects of ant inhabitants on bromeliad nutrition. PLoS ONE 11:e0152113.

Helversen, O., and Y. Winter. 2003. Glossophagine bats and their flowers: costs and benefits for plants and pollinators. Pp. 346–397, *In* T.H. Kunz and M.B. Fenton (Eds.). Bat Ecology. The University of Chicago Press, City, State, USA. 779 pp. Chicago, Illinois.

Jones, D.L. 2002. Genus *Zamia*. Pp. 379–433, *In* D.L. Jones (Ed.). Cycads of the World, Ancient Plants in Today's Landscape, 2nd edition. Smithsonian Institution Press, Washington, D.C., USA. 456 pp.

Lapolla, J.S., and J. Sosa-Calvo. 2006. Review of the ant genus *Rogeria* (Hymenoptera: Formicidae) in Guyana. Zootaxa 1330:59–68.

Leroy, C., F. Petitclerc, J. Orivel, B. Corbara, J.F. Carrias, A. Dejean, and R. Céréghino. 2017. The influence of light, substrate and seed origin on the germination and establishment of an ant-garden bromeliad. Plant Biology 19:70–78.

Morrison, D.W. 1978. Foraging ecology and energetic of the frugivorous bat *Artibeus jamaicensis*. Ecology 59:716–723.

Mueller, U.G., T.R. Schultz, C.R. Currie, R.M.M. Adams, and D. Malloch. 2001. The origin of the attine ant-fungus mutualism. The Quarterly Review of Biology 76:169–197.

Murakami, T., and S. Higashi. 1997. Social organization in two primitive attine ants, *Cyphomyrmex rimosus* and *Myrmicocrypta ednaella*, with reference to their fungus substrates and food sources. Journal of Ethology 15:17–25.

O'Brien, C.W., and W. Tang. 2015. Revision of the New World cycad weevils of the subtribe Allocorynina, with description of two new genera and three new subgenera (Coleoptera: Belidae: Oxycoryninae). Zootaxa 3970:1–87.

Ortega, J., and I. Castro-Arellano. 2001. *Artibeus jamaicensis*. Mammalian Species 662:1–9.

Rex, K., D.H. Kelm, K. Wiesner, T.H. Kunz, and C.C. Voigt. 2008. Species richness and structure of three Neotropical bat assemblages. Biological Journal of the Linnean Society 94:617–629.

Rieger, J.F., and E.M. Jakob. 1988. The use of olfaction in food location by frugivorous bats. Biotropica 20:161–164.

Seemann, B. 1854. The Botany of the Voyage of H.M.S. Herald, under the command of Captain Henry Kellett, during the years 1845-51. 6:201–203, 253.

Stevenson, D.W. 1993. The Zamiaceae in Panama with comments on phytogeography and species relationships. Brittonia 45:1–16.

Stevenson, D.W., A. Vovides, and J. Chemnick. 2003. Regional overview: New World. Pp. 31–38, *In* J. Donaldson (Ed.). Cycads, Status Survey and Conservation Action Plan. IUCN/SSC Cycad Specialist Group. 86 pp. Gland, Switzerland and Cambridge, UK.

Taylor, A.S. 2010. *Zamia pseudoparasitica*. The IUCN Red List of Threatened Species. e.T42175A10648571.

Taylor, A.S., J. Mendieta, R. Bernal, and G. Silvera. 2008. Strange but true. The Cycad Newsletter 31:8–9.

Taylor, A.S., J.L. Haynes, D.W. Stevenson, G. Holzman, and J. Mendieta. 2012. Biogeographic insights in Central American cycad biology. Pp. 73–98, *In* L. Stevens (Ed.). Global Advances in Biogeography. InTech. 374 pp. London, UK.

Taylor, A.S., J. Mendieta, and G. Varela. 2014. *Zamia pseudoparasitica* Yates in Seemann, a far-ranging epiphytic endemic cycad mostly of the Atlantic watershed of the isthmus of Panama. Cycad Newsletter 37:4.

Terry, I., G.H. Walter, C. Moore, R. Roemer, and C. Hull. 2007. Odor-mediated push-pull pollination in cycads. Science 318:70.

Treseder, K.K., D.W. Davidson, and J.R. Ehleringer. 1995. Absorption of ant-provided carbon dioxide and nitrogen by a tropical epiphyte. Nature 375:137–139.

Vieira, E.M., and P. Izar. 1999. Interactions between aroids and arboreal mammals in the Brazilian Atlantic rainforest. Plant Ecology 145:57–82.