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# CYCADS

Official Newsletter of IUCN SSC Cycad Specialist Group

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Feature Articles
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CSG Member List

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# CYCADS

Official newsletter of IUCN/SSC
Cycad Specialist Group
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The Cycad Specialist Group (CSG) is a component of the IUCN Species Survival Commission (IUCN/SSC). It consists of a group of volunteer experts addressing conservation issues related to cycads, a highly threatened group of land plants. The CSG exists to bring together the world's cycad conservation expertise, and to disseminate this expertise to organizations and agencies which can use this guidance to advance cycad conservation.

Official website of CSG:
http://www.cycadgroup.org/



**Cover photos**
Front: *Cycas siamensis* at Kanchanaburi, Thailand
Back: *Cycas laotica* at Khammouan, Laos
Photos by JS Khuraijam

Design & layout: JS Khuraijam
Copy Editors: M Calonje & JS Khuraijam

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All contributions published in *Cycads* are reviewed and edited by IUCN/SSC CSG Newsletter Committee and members. IUCN/SSC CSG members can send contributions to **jskhuraijam@yahoo.com**

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*Dioon merolae* at Chiapas, Mexico Photo by Chip Jones

# MESSAGE

*Cycas cairnsiana* in Queensland, Australia; I was honored to have the privilege to work with Manuel Lujan Anzola and Nathalie Nagalingum this year. Their innovative survey and genetic methods build a greater understanding of *Cycas* conservation – I anticipate you will read the results in a future issue!

Dear Friends,

I write this letter from the IUCN/SSC Leaders' Meeting in Abu Dhabi. Some of our Cycad Specialist Group are attending, and it is great to catch up and to absorb the great energy and enthusiasm here for Species Conservation. Our cycad group is moving forward solidly, and this gathering provides inspiration on how to further advance our efforts on behalf of the cycads.

I am excited to share CYCADS volume 4 with you! These pages contain a diverse selection of current science on the geography, evolution, and conservation of these living treasures. Two feature articles present an important advance in cycad ecology from Brazil, as well as a historical retrospective on the Mexican National Cycad Collection. The history provided by Dr. Vovides and his colleagues highlights the great value in collaboration among organizations and people to advance cycad science and conservation – those international links forged over the decades will create further successes

Please let me also make an important announcement: the PROCEEDINGS OF CYCAD 2015 are on the way! We will publish this work as a special upcoming volume of CYCADS. Thank you to all who have submitted their papers – I look forward to sharing these with you very soon. It will be great to add this anthology to the unbroken chain of volumes going back to the very first cycad conference – another example of how our Cycad Specialist Group keeps doing great things.

Here, among the gathered worldwide leaders of dozens of Specialist Groups, our TEAM CYCAD is held up as an example of a high-functioning, well-organized and productive network. Bravo – you earned those compliments! The diligent work of each member (see page 21) acting in concert moves cycad conservation forward. It is wonderful to be a part of such a great team – let's keep that great momentum as we enter the next decade!

Thank you,

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Cycad Specialist Group

*Zamia chigua* at Bajo Calima, Valle del Cauca, Colombia. Photo by Michael Calonje

# New report of *Eumaeus* (Lepidoptera: Lycaenidae) associated with *Zamia boliviana*, a cycad from Brazil and Bolivia

**Rosane Segalla & Patrícia Morellato**

The species of the genus *Eumaeus* Hübner, 1819 (Lepidoptera: Lycaenidae) are obligate-herbivores, in the larval stage, of many Neotropical Zamiaceae (Clark et al. 1992; González, 2004; Castillo-Guevara, 2007; Cascante-Marín & Araya, 2012; Prado et al., 2014; Ruiz-García et al., 2015). They exhibit gregarious behavior and their bright colors are thought to be aposematic, serving as a warning signal to predators (DeVries 1977; Bowers & Larin, 1989; Nash et al., 1992). Lepidoptera, generally, are commonly studied for their interactions with their plant hosts (Castillo-Guevara 2007), however, many interactions between plants and animals, especially those involving cycads, are poorly documented in South America.

*Eumaeus minyas* Hübn. is distributed from Mexico to Colombia, in South America and is exclusively involved in herbivory of *Zamia* feeding on of fronds and female reproductive strobilus of *Zamia furfuracea* L.f., *Zamia skinneri* Warsz. ex A.Dietr., *Zamia neurophyllidia* D.W.Stev., *Zamia loddigesii* Miq. (DeVries 1976, 1983; Clark & Clark,1991; Clark et al. 1992;Castillo-Guevara & Rico-Gray, 2002), *Zamia encephalartoides* D.W.Stev. (González, 2004) and also of *Dioon edule* Lindl.(Castillo-Guevara, 2007).

*Zamia boliviana* (Brongn.) A.DC. (Cycadales, Zamiaceae) occupies a distribution range between Bolivia (Beni, Cochabamba, La Paz and Santa Cruz) and Brazil, in the state of Mato Grosso (Jørgensen et al. 2014; Skelley & Segalla 2019; Segalla & Calonje 2019; Segalla et al. 2019). The species is a small plant, up to 80cm tall, with a subterranean stem, and 1 to 3 leaves per crown. It inhabits different Cerrado (the Brazilian savanna) phytosiognomies, from scrubland to woodlands, across different types of soils, and also on rocky outcrops (Skelley & Segalla 2019). Many populations have been decimated or severely fragmented due to the expansion of extensive agriculture and ranching activities in Brazil but also Bolivia (Segalla et al., 2019; Skelley & Segalla 2019, Segalla et al. 2019).

The occurrence of *E. minyas* in populations of *Z. boliviana* has been recorded in situ in the state of Mato Grosso, Brazil, over the last four years and results suggest a stable co-occurrence in cycad populations of different cerrado areas. Voucher material has been deposited in the entomological collections of Museu de Zoologia of Universidade of São Paulo (MZUSP) and at the Laboratório de Scarabaeoidologia (Setor de Entomologia da Coleção Zoológica, UFMT), Instituto de Biociências, Universidade Federal de Mato Grosso, Cuiabá, Mato Grosso, Brazil. Eggs, adults and different instars of larvae were observed in *Z. boliviana* plants (Fig. 1). Oviposition occurred on vegetative and reproductive parts of the cycad, with eggs being present on cataphylls, petioles, leaflets and rachis, pollen strobilus and ovulate strobilus (Fig. 1).

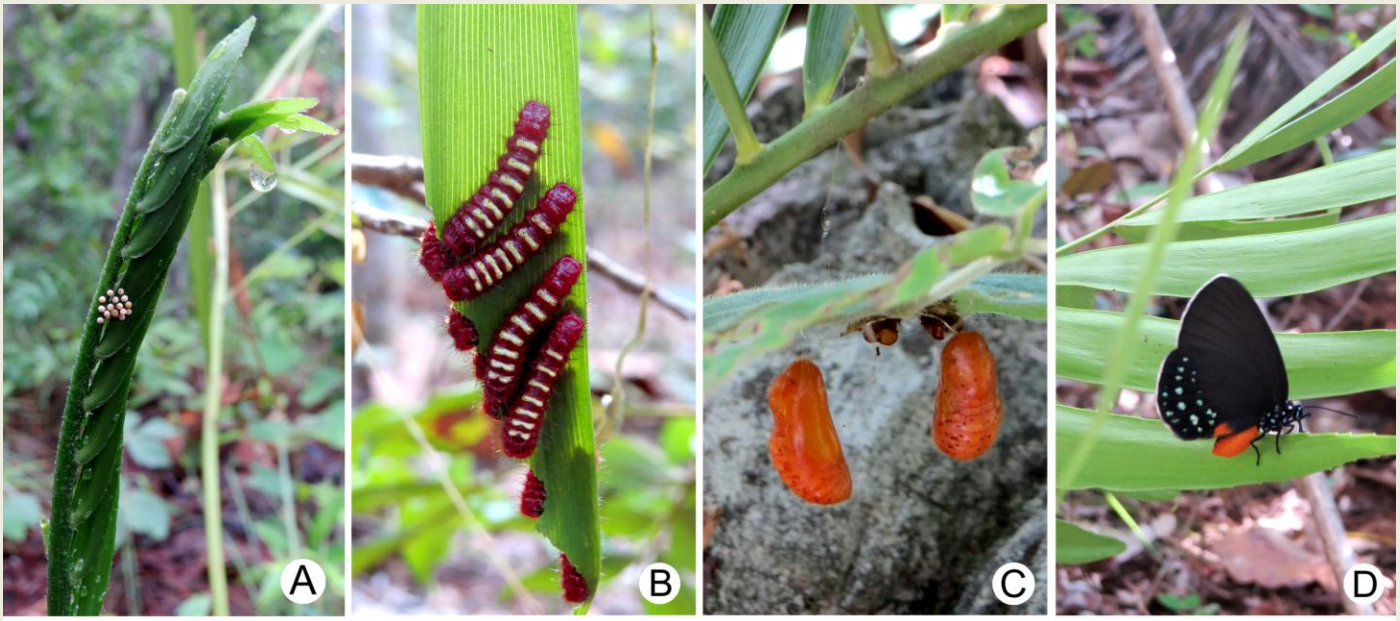


**Figure 1**. *Eumaeus minyas* in vegetative and reproductive parts of *Zamia boliviana*: A-B. eggs on cataphylls and a recent emerged leaf, C-D. larvae on petioles and leaflet, E-F. larvae on pollen strobilus and ovulate strobilus G. pupae in the abaxial side of a leaf and H. adult butterfly on*Z. boliviana* leaf. All photos from Cáceres, Mato Grosso State, Brazil. (Photos: Rosane Segalla).

Despite the few studies on the ecology of this lycaenid butterfly in South America, we can infer that its geographical distribution occurs concomitantly with the distribution of the populations of species of *Zamia*, their host plants species. The populations of *E. minyas* appeared healthy, with all life stages observed and an uninterrupted life cycle as expected for natural populations (Fig. 1). However, the destruction of cycad habitats threatens the survival of this endemic butterfly species, as it is an obligate herbivore which depends on these plants for the completion of its life cycle. Our observations suggest that the butterfly prefers to oviposit on immature expanding leaves or young reproductive parts. We have evidence that the vegetative and reproductive phenology of *Z. boliviana* is adapted to the Cerrado seasonality and that *E. minyas* life cycle is in synchronicity with the emergence and development of *Z. boliviana* leaves and strobilus.


## Acknowledgements

We thank Marcelo Duarte da Silva, curator of Lepidoptera of Museu de Zoologia of Universidade de São Paulo (MZUSP) and Alexandre dos Santos of Laboratório de Fitossanidade of Instituto Federal de Educação, Ciência e Tecnologia de Mato Grosso (IFMT), Campus Cáceres, Mato Grosso for the support with the entomological specimens and their identification. We thank the IFMT for supporting the development of the doctoral thesis of the first author. LPCM receives a research productivity fellowship from National Council for Scientific and Technological Development (CNPq). We thank Michael Calonje and Irene Terry for the comments in the text.


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The Mexican National Cycad Collection at the Jardín Botánicos Francisco Javier Clavijero, Xalapa

# The Mexican National Cycad Collection 45 years on

**Andrew P. Vovides, Carlos Iglesias & Miguel A. Pérez-Farrera**

Cycads are one of the world´s most endangered plant species largely owing to human activities leading to habitat destruction and collecting by commercial horticulturists as well as enthusiasts. They are listed in the IUCN Red List (IUCN 2019). Their distribution is within the tropical and sub tropical regions of the world in Asia, Australasia, Africa, the Americas and Oceania with 355 species among ten genera (Calonje et al., 2019). Mexico is home to 61 spp making it 2nd worldwide for species diversity after Australia with 87 spp followed by S. Africa with 39 spp.

The beginning of what was to become the Mexican National Cycad Collection at the Jardín Botánico Francisco Javier Clavijero in the City of Xalapa (JBC), Veracruz began in 1975 with *Dioon edule* with the JBC accessions number 1975-002 collected near the classical locality of Chavarillo where C.J. Chamberlain once collected at the turn of the XXth century (Chamberlain 1919). I was set the task by Arturo Gómez-Pompa the Director of the then biotic resources research institute (INIREB) to work on the Flora de Veracruz project Zamiaceae fascicle (Vovides et al., 1983) in collaboration with John D. Rees, a geographer form California State University knowledgeable on cycad distribution and localities in Mexico and Central America. We did field explorations in the mid 1970s and early 80s then later in collaboration with Bart Schutzman of the University of Florida, Gainesville, thus we collected living and dried material for the herbarium, the living material accessed into JBC to form the National Collection. Several new species were discovered and described. When the JBC passed to the administration of INECOL in 1989 explorations continued throughout the 1990´s to mid 2000s. During this transition period 1989–1990, Andrew Vovides was Post Doc at Fairchild Tropical Garden (now Fairchild Tropical Botanic Garden FTBG) researching cycad pollination syndrome with Knut Norstog and Priscilla Fawcett. A Sister Garden relationship was initiated in 1989 with FTBG with aims for plant exchange, teaching and research projects. During the early to mid 2000s

collaboration with the Montgomery Botanical Center, botanical explorations further incremented our living collections with duplicate plant material. With plant exchange we managed to have in our national collection cycad species from Africa (*Encephalartos* and *Stangeria*), Australia (*Macrozamia* and *Lepidozamia*) West Indian and Central American zamias as well as Asian *Cycas* spp. Needless to say both institutions are CITES registered. The well-documented National Cycad Collection has given support to researchers requiring plant material for molecular studies and systematics, anatomy, cytotaxonomy, palynology, taxonomy and physiology (Vergara et al., 2002; Vovides and Olivares, 1996; Gutiérrez-Ortega et al., 2014, 2017).

Through cultivating cycads much experience had been gained regarding propagation form seeds and offsets, compost mixtures, fertilization and pest control. Ecological and demographic studies over a period of several years we learned much about growth rate and life cycle of *Dioon edule* as well as becoming aware of poaching through decapitation of leaf crowns for sale by street peddlers (Vovides, 1990; Octavio-Aguilar et al., 2008) an illegal activity since cycads are protected by national legislation regarding threatened and endangered species.

We learned basic cultivation and propagation skills a rural nursery was set up with the collaboration of local inhabitants at Monte Oscuro in the Chavarillo district. In this area poaching of *D. edule* crowns occured for almost 30 years and the farmers discouraged this. Similar nurseries were set up in Chiapas state for the propagation of *Dioon merolae*, *Ceratozamia mirandae*, *C. matudae* and *Zamia soconuscensis*. The idea of these nurseries is to encourage conservation through propagation from seed where farmers have incentive to conserve the cycad habitat through benefits from plant sales and reintroduction of plants back into habitat (Vovides et al., 2010).

The weevil pollinator *Rhopalotria mollis* on *Zamia furfuracea* male cone.

Cycad propagation nursery at El Triunfo Biosphere Reserve, Chiapas

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*Dioon merolae* in Chiapas, Mexico. Photo by Michael Calonje

# Speciation processes in Mexican cycads: our research progress on the genus *Dioon*

**José Said Gutiérrez-Ortega, María Magdalena Salinas-Rodríguez, Miguel Angel Pérez-Farrera & Andrew P. Vovides**

The idea that extant cycad genera had synchronous bursts of diversification during the Cenozoic era has been well supported by multiple recent studies that have applied phylogenetic methods (e. g. Nagalingum et al., 2011; Salas-Leiva et al., 2013). This evidence is interesting, because it implies that all modern cycad species evolved in the same niches that better favored the evolution of angiosperms: whereas angiosperms became the dominant plant group on Earth, cycads were restricted to very specific niches that allowed their persistence through evolutionary times. Yet, how did extant cycad genera persist and diversify ? We are now trying to answer this question by emphasizing on Mexican cycads.

Because branching in phylogenetic trees represent events of lineage divergence, phylogenetic methods are useful to understand the spatial and temporal patterns in cycad evolution. However, speciation is a process that occurs at the population level, and it is influenced by demographic history, ecological relationships and natural selection regimes, which are factors not easily detected by phylogenetic methods. Therefore, revealing the mechanisms that occur during the inter-species and inter-population divergence is useful to understand how and why speciation occurs. The obtained information from studies in speciation will not only contribute to reveal the origin of species and the validity of accepted taxa, but it will also provide important suggestions for effective conservation (e. g. Meerow *et al.*, 2018).

A first case that called our attention is that occurring within the species *Dioon merolae*. *Dioon merolae* occurs at both sides of the Isthmus of Tehuantepec, which is one of the most important geographic barriers promoting allopatric divergence in many plant and animal taxa in Mexico (Peterson *et al.*, 1999). This isthmus separates the *D. merolae* populations into two geographic-ecological groups: the western populations occur in tropical forests co-occurring with xeric plant communities, whereas the eastern populations occur in more mesic forests (Fig. 1).

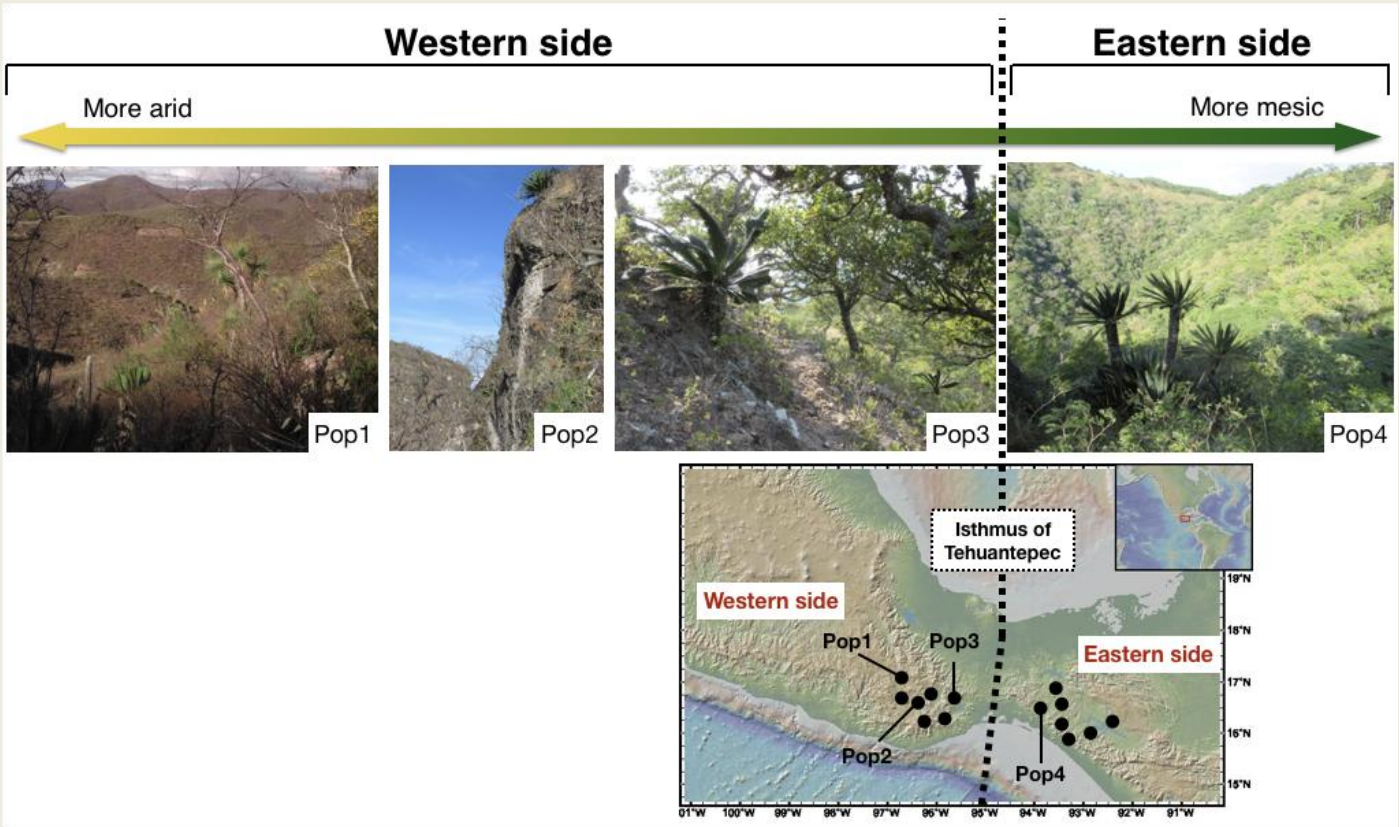


**Figure 1**. *Dioon merolae* is distributed in both sides of the Isthmus of Tehuantepec. The western populations are distributed in more arid environments than the eastern populations. The numbers of populations in each photo (Pop1—4) correspond to those indicated in the inset map. The base map was produced with GeoMapApp (http://www.geomapapp.org).

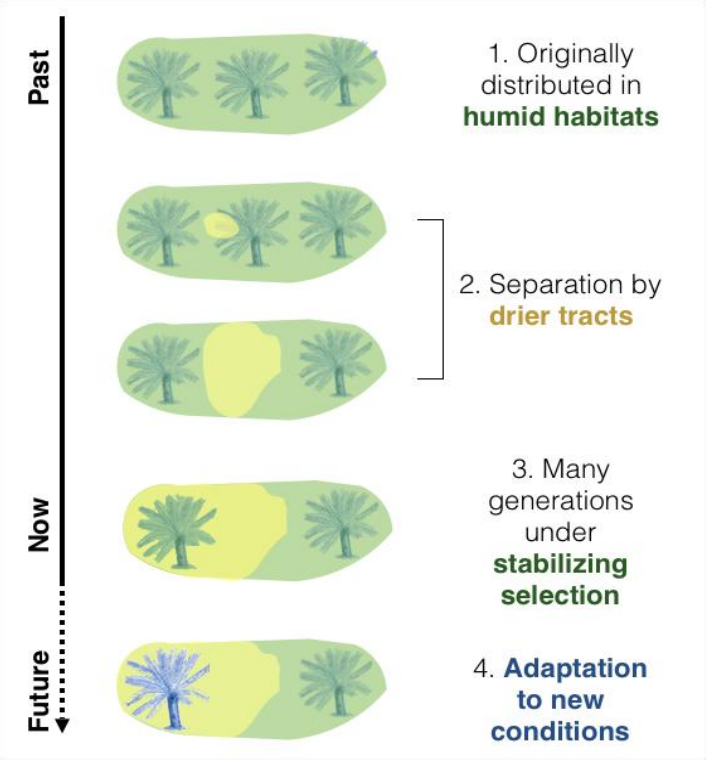


**Figure 2**. Hypothetical speciation pathway that might be followed by *Dioon merolae*. Three populations are represented: West (left), Isthmus of Tehuantepec (center) and East (right). In the Stage 1, the three populations are assumed to be connected by ancestral humid forests (green shades). In Stage 2, aridification (yellow shade) starts, and dry conditions eliminate the population in the lowlands of the isthmus; this event separates the western and the eastern populations. In Stage 3, arid conditions reach the western population, promoting constant stabilizing selection. In Stage 4, the western side would be adapted to arid conditions, allowing for the distinction of the western population as a new species (in blue).

We ask whether the presence of the isthmus and the different environmental conditions of both sides have influenced the divergence in *D. merolae*. We hypothesize that the divergence of *D. merolae* is following a speciation pathway that is described in Fig. 2:

- Stage 1: In the past, *D. merolae* occupied an ancestral niche in humid tropical forests (suggested in Gutiérrez-Ortega *et al.*, 2018).
- Stage 2: Aridification of southern Mexico made the Isthmus of Tehuantepec an unsuitable habitat for *Dioon* (Ornelas *et al.*, 2013), maintaining *D. merolae* populations in the mountainous areas and preventing gene flow between the two sides of the isthmus.
- Stage 3: Arid conditions reached the populations in the western side of the isthmus, promoting constant stabilizing selection through many generations in the western *D. merolae*.
- Stage 4. After many generations, the western side would gain adaptations to counteract aridity, allowing for the distinction of speciation.

With this hypothesis in mind, we are collecting evidence from morphological, genetic and environmental variables. When we finish this first step with the Mexican cycad *D. merolae*, we believe our study will clarify the history of a possible case of incipient speciation in a cycad species. We would like to encourage our colleagues to also deal with the clarification of the mechanisms that produce speciation in other cycads in Mexico or other countries around the world.

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# Cycad's pollen germination and conservation in Thailand

**Anders Lindstrom**

Because cycads are dioecious the collection, storage and creation of pollen banks for medium to long-term preservation and germplasm exchange is highly desirable. Indeed, artificial pollination is necessary in cycad *ex situ* collections to ensure the setting of viable seed. Several recent studies show that cycads are host specific and often pollinated by a specific pollinator and thus habitat and location of ex situ collections may mean a lack of suitable pollinators. Moreover, pollen preservation could alleviate the risks from climate-change induced asynchronous production of male and female cones of cycads. The long-term storage stability of cycad pollen is hardly known, yet recommendations on the banking of cycad pollen are of significant scientific, horticultural and conservation importance. Our project, supported by The Stanley Smith (UK) Horticultural Trust and in collaboration with Kew Millennium Seed Bank (UK) and Mahidol University (Thailand), aims to assess the pollen quality (by in vitro germination) of a range of cycad species after storage in the freezer, even as long as 17 years

From February to April 2019, Anna Nebot undertook research on the viability of cycad pollen. In the six weeks she stayed in Thailand, she developed specific germination conditions for 35 freshly harvested species (in the genera *Cycas*, *Encephalartos* and *Zamia*) and assessed viability after long-term storage in 22 species. She tested earlier researchers' media as well as added her own media for trial. Germination was tested using several media and the initial result was that different species have their specific optimum media for germination. The experiments were performed in Prof. Kanchit Thammasiri's laboratory at Mahidol University. In another project, supported by the Mohammed bin Zayed Species Conservation Fund, pollen quality is being investigated in a critically endangered cycad of Uganda.

**Figure 1.** Anna Nebot, Anders Lindstrom, and Kanchit Thammasiri at Mahidol University (left); freshly harvested and stored Cycad pollen was tested for viability from species cultivated at Nong Nooch Tropical Botanical Gardens (right). Photos by Anna Nebot.

### Team and collaborators

Prof. Hugh W. Pritchard (Kew, UK), Dr. Daniel Ballesteros (Kew, UK), Dr. Anna Nebot (Kew, UK), Prof. Kanchit Thammasiri (Mahidol University, Bangkok, Thailand), Mr. Anders Lindstrom (Nong Nooch Tropical Botanical Garden, Thailand), Dennis Kamoga (JERA, Uganda)

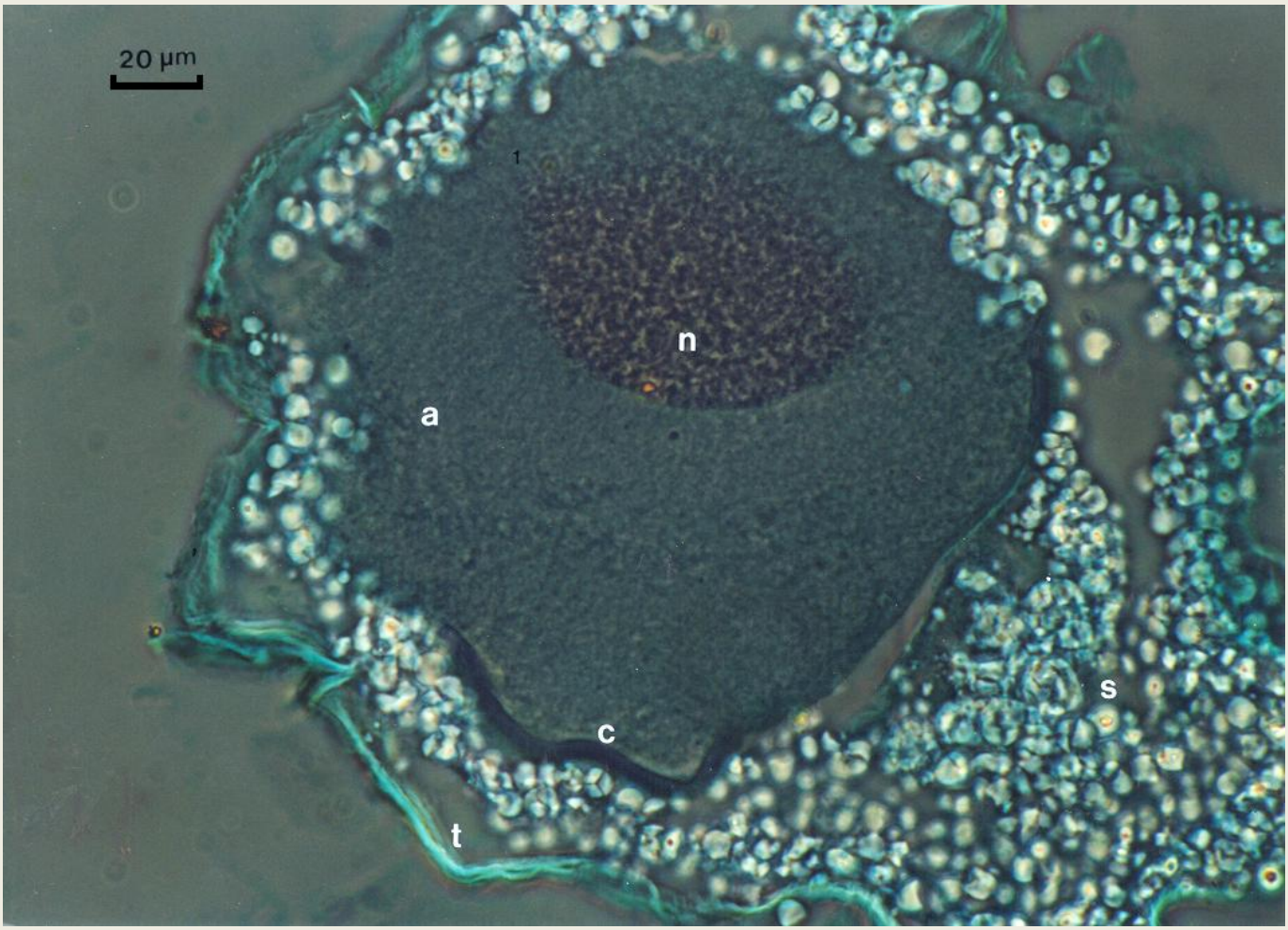


**Figure 1.** *Ceratozamia tenuis*. Cross section of the nucellus in the micropylar region. Antherozoid (a) with cilliar bands (c), nucleus (n), starch grains inside the pollen tube (s) and pollen tube (t). Stained with Safranin-fast green. (Scale bar=20 µm). (From Sánchez-Tinoco et al., 2000).

# Ancestral characteristics in modern cycads

**M. Ydelia Sánchez-Tinoco, Andrew P. Vovides & H. Araceli Zavaleta-Mancera**

Cycads conserve ancestral characters and are considered relicts from the past or "living fossils", however the living species today are of Miocene origin (Nagalium et al., 2011). Outstanding ancestral characters are the ciliated and motile antherozoids, male and female gametophytes enclosed within micro- and megaspores respectively giving rise to an independence of free water for fertilization to take place, in other words the seed habit. This harks back to the Pteridosperms or seed ferns of which the Medullosan ferns are considered their ancestors (Ikeno, 1986; Norstog and Nicholls, 1997; Sánchez-Tinoco et al., 2000) (Fig. 1). Outstanding is the female sexual organ or archegonium, this is embedded in tissue of the ovule or female gametophyte. The archegonium resembles a flask, with a neck and body. The neck is equipped with two neck-cells that assist the efficient transport of the male gametophyte toward the female gametophyte cytoplasm of the central cell thus later effecting fertilization of the egg cell (Norstog 1972; Sánchez-Tinoco et al., 2018) (Fig. 2).

The dehiscence lines in the micropylar region observed in the seed sclerotesta, support Benson's synangial hypothesis, which postulates the ovule as a transformation of grouped sporangia and subsequent abortion of the peripheral sporangia, to form a ring of free tegumentary lobes surrounding a single central fertile megasporangium (Takhtajan, 1981; Sánchez-Tinoco & Engleman, 2004).

The open female strobilus with several marginal ovules of Cycas is reminiscent of the Permian fossil *Crossozamia* (Gao & Thomas, 1989). Another ancestral trait is the stellar anatomy and pachycaulous habit with very little xylem, a throwback to the stellar anatomy of the Medullosaceae (Greguss, 1968, Nagalium et al., 2011). This contrasts with adaptations of the living cycads considered derived, such as the contractile stem in some species of Zamia, the epiphytic habit in *Zamia pseudoparasitica* of the Panamanian rain forests, the central venation in leaflets of the genera *Cycas* and *Stangeria*, and transfusion tissue in leaflets of Cycas (Brenner et al., 2003).

The pachychalaza (fusion of tegument and nucellus) present in ¾ of the length of the ovule. According to Corner (1976), the course of evolution was simplified, suggesting its primitive character.

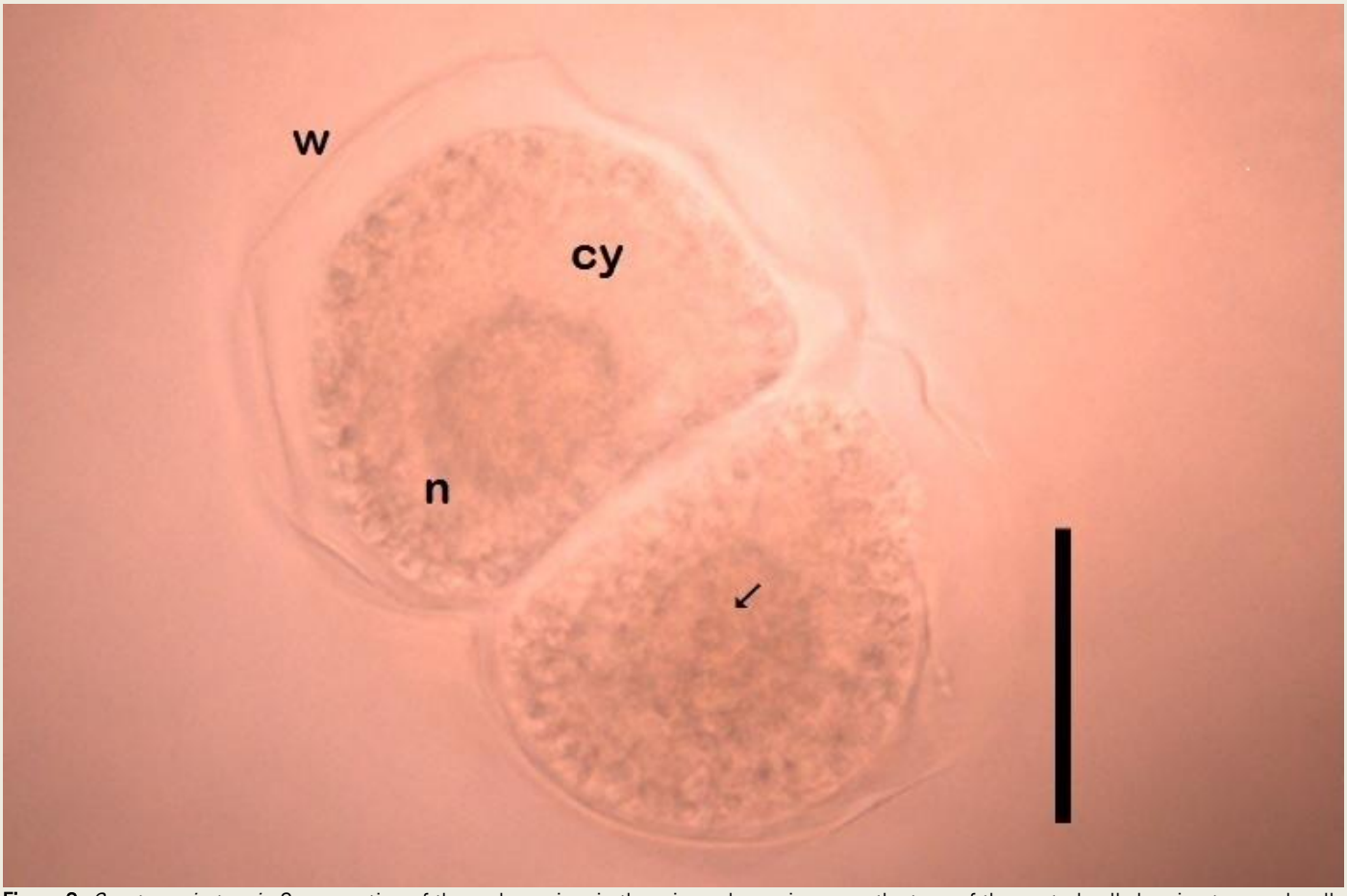


**Figure 2.** *Ceratozamia tenuis*. Cross section of the archegonium in the micropylar region, growth stage of the central cell showing two neck cells with cell wall (w), cytoplasm (cy), nucleus (n), and nucleolus (arrow). Unstained. Free hand section. (Scale bar=40 µm).

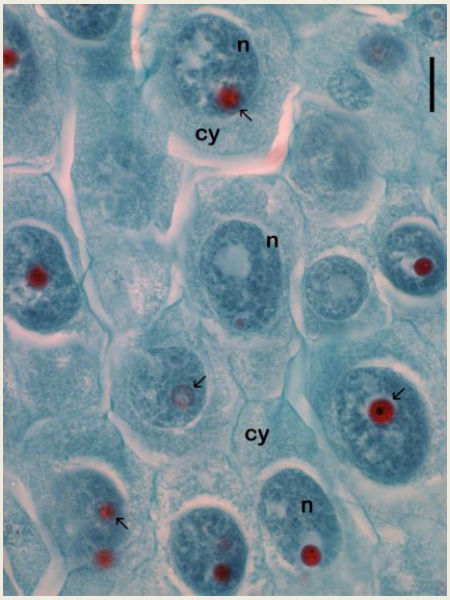


**Figure 3.** *Ceratozamia tenuis*. Tangential section of the archegonial jacket showing transfer cells with cytoplasm (cy), nucleus (n), and nucleoli (arrows). Stained with Safranin-fast green. (Scale bar=20 µm).

The double vascular supply in cycad seeds is shared with *Ginkgo* and Gnetophyta (Loconte & Stevenson, 1990; Sánchez-Tinoco, et al., 2007). The stomata in the sarcotesta refer to the origin of the tegument and supports, among others, the synangial and neosynangial hypotheses on the origin of the ovule (Benson, 1904; Kenrick & Crane, 1997).

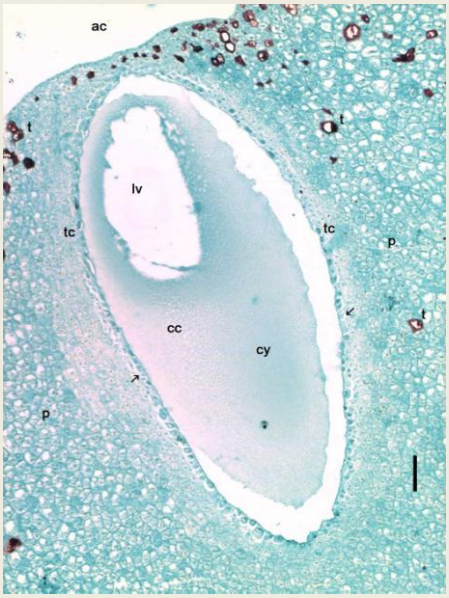


**Figure 4.** *Ceratozamia tenuis*. a. Longitudinal section of the gametophyte during the growth stage of the central cell showing an archegonium with central cell (cc), archegonial chamber (ac), transfer cells (tc) forming the archegonial jacket (arrows), vacuolated cytoplasm of the central cell (cy), large vacuole (lv), solid and amorphous tannin bodies (t) and parenchyma cells with starch grains (p). Stained with Safranin-fast green. (Scale bar=200 µm).

The fleshiness of the sarcotesta is a common character for the majority of seed-coats in the gymnosperms. In terms of phylogeny, seeds with this characteristic are considered primitive (Corner, 1976)). Large-sized cells with large nuclei and several nucleoli, observed in the transfer cells (archegonial jacket), the central cell and egg cell, considered the largest in the plant kingdom, are primitive (Figs. 3-4) (Maheswari & Singh, 1967; Sánchez-Tinoco et al, 2018).

We sustain that cycads are not living fossils, although they maintain traits considered primitive, they are an integral part of modern tropical and subtropical ecosystems and provide benefits such as nitrogen fixation beneficial to their habitats (Grove et al. 1980). The only threat to their existence is humanity, whose daily activities of habitat destruction are driving cycads to extinction.

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# Payments for ecosystem services (PES). A new alternative for conservation of mexican cycads. Ceratozamia norstogii a case study

**Miguel A. Pérez-Farrera, Héctor Gómez-Dominguez, Ana V. Mandri-Rohen & Andrómeda Rivera-Castañeda**

Mexico has the second highest diversity of cycad species (Vovides, 2000). Around 355 species have been recorded worldwide and in Mexico there are 62 of which more than 94% are endemic (Calonje et al., 2019) and more than 50% grow in southern Mexico.

One of the endemic and rarest species of cycads in southern Mexico is *Ceratozamia norstogii*. It has aerial trunks, leaflets that are inserted into the rachis in spiral form,and extremely narrow (0.3-0.5 mm) chanelled leaflets. It grows in the oak or pine-oak forests of Chiapas and Oaxaca, Mexico between 800 and 1600 msl (Pérez-Farrera et al., 2001) (Fig. 1). This species, given its rarity, has a conservation status of Endangered (EN) by the IUCN (Vovides et al., 2010a) and Protected (P) by the Mexican conservation authorities through NOM-059-2010 (SEMARNAT, 2010). It has been extensively studied from the systematic (Pérez-Farrera et al., 2004), ecological (Martínez-Meléndez 2012), genetic (Pérez-Farrera et al., 2017), anatomical and morphological perspectives (Pérez-Farrera et al 2014).

Figure 1. *Ceratozamia norstogii* in habitat

Although this species has been relatively well studied, problems with the conservation of its populations continue. One year after its description by Stevenson, (1982) the species was widely collected; Tang (1983) mentions that a shipment of 25,000 individuals of *C. norstogii* was confiscated in the United States, with the result that one of the two previously known populations was decimated. Currently about seven populations of this species are known with few individuals. It grows in the Cintalapa and Ocozocoautla municipalities of Chiapas, and along the border of the Chimalapas, region of Oaxaca (Fig. 2)

In Mexico, for the case of cycads, two main alternatives have been put forward for their conservation and especially for the most threatened species: 1) *ex situ* (the propagation and conservation of species in botanical gardens) (BGCI, 2015) and 2) *in situ* (establishment of nurseries *in situ*) (Pérez-Farrera, 1999; Vovides et al., 1999; Vovides et al., 2002; Vovides et al., 2010c).

With respect to conservation *ex situ*, in Mexico, it is known that *C. norstogii* is protected in a few botanical gardens (Vovides et al 2010a; Vovides et al., 2013) (National collection of cycad in the Botanical Garden Francisco Javier Clavijero of the Instituto de Ecology AC, Xalapa, Veracruz; Botanical Garden Faustino Miranda, Tuxtla Gutiérrez, Chiapas and the Ethnobotanical Garden, in the city of Oaxaca). However, apparently this species is cultivated in some private gardens in the eastern United States. One of the problems with this conservation mechanism is the poor representation of the phenotypic and genetic variation of the natural populations.

Regarding the conservation *in-situ* mechanism, a network of *in-situ* nurseries has been established in Mexico. These nurseries have been established as UMAs = Management Units for the conservation of wildlife. This mechanism has been promoted by the Secretary of Environment and Natural Resources (SEMARNAT) for several species, among which we can highlight *Dioon merolae*, *Ceratozamia mirandae, Zamia soconuscensis* in Chiapas, *Dioon edule, Zamia furfuracea, Ceratozamia tenuis* in Veracruz, *Dioon spinulosum* in Oaxaca, *Dioon caputoi* in Puebla, *Dioon sonorense* in Sonora (Tang et al, 2018). Although this scheme has the potential to greatly impact

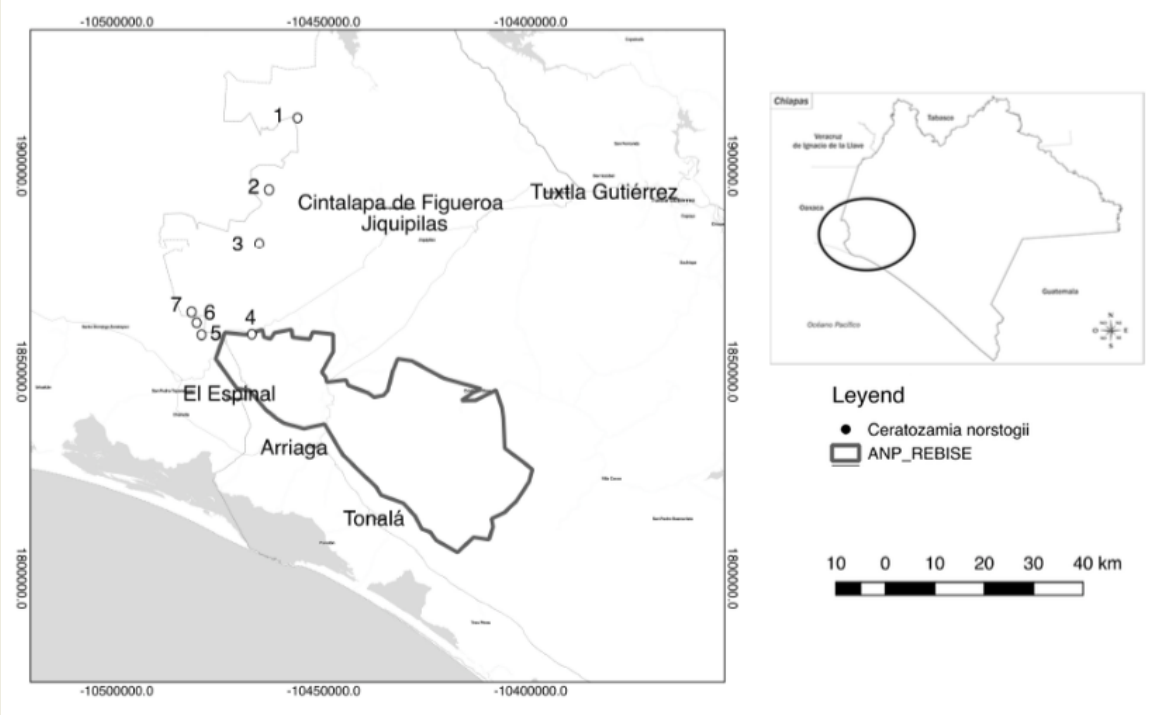


**Figure 2**. Geographic distribution of *Ceratozamia norstogii* in southern Mexico

the pressure problems of the conservation of natural populations, it has not had the economic impact and viability expected because of the bureaucratic problems that Semarnat itself has implemented for the UMA mechanisms.

In recent years a new conservation scheme has been promoted for the conservation of forests in Mexico. Since 2002, this program has been promoted by the Mexican government through the National Forestry Commission (CONAFOR). The concept consists of stimulating the conservation of lands or important forest areas by the generation of some benefit derived from the operation of the ecosystem (such as carbon capture, conservation of biodiversity or watersheds) through a payment or economic compensation to the owners of the forests. This type of approach has yielded good results on several continents, including several Latin American countries such as Costa Rica and Brazil (Börner et al., 2011; Ezzine et al., 2017). The basis of the PES mechanism is the model of the "polluter pays" principle: or "the one who conserves receives compensation".

The El Triunfo Conservation Fund (FONCET) is a civil association created in 2002 with the objective of contributing to the conservation and sustainable development of the ecosystems represented in the El Triunfo Biosphere Reserve and the Protected Natural Areas of its area of influence. FONCET supports financing strategic, long-term project that seek to ensure the conservation of the site and the development of its inhabitants, contributions it's goal is to achieve a harmonious and comprehensive development of the country and to preserve biodiversity for future generations as a heritage.

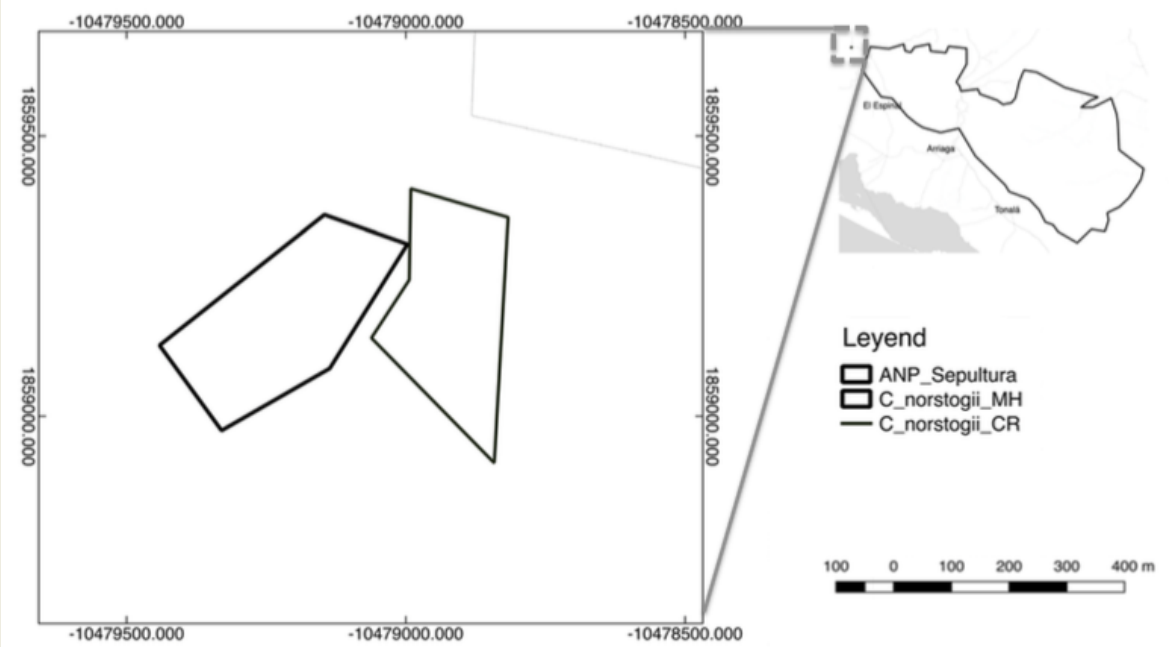


**Figure 3**. Geographical location of the properties under the PES project, approximately 14 hectares oak forest.

**Figure 4**. Activities carried out by the farmers as part of the PES project (fire breaks inside and outside the fences).

FONCET was created by the National Commission of Protected Natural Areas (CONANP), the Directorate of the El Triunfo Biosphere Reserve (REBITRI), the Institute of Natural History and Ecology (IHNE but currently known as the Secretary of Environment and History (SEMANH), the Mexican Fund for the Conservation of Nature (FMCN), Institute for Sustainable Development in Mesoamerica A.C. (IDESMAC), Pronatura Sur, and four private individuals interested in the Fund (Alfredo Cuarón, Claudia Virgen Montesinos, Fulvio Eccardi and Alejandro Hernández Yañez).

In 2008, FONCET and CONAFOR created a Matching Fund for ecosystem payments, where the federal program was improve, as the payment was part of an holistic program that not only compensated the owner for conserving their land, but also generated a model that would allow to identify the causes of deforestation and address them. The program included education, technical assistance in productive areas and development opportunities that would go beyond the years of payments. The results of this program surpassed the expectations, and the learning led to create a similar scheme for the conservation of areas where cycad populations were found

In 2017 FONCET and the Herbarium Eizi Matuda of the University of Sciences and Arts of Chiapas (UNICACH) joined efforts for the conservation of *Ceratozamia norstogii*. Funds were received for a PES for 10 years for the conservation of 14 hectares of oak forest where *C. norstogii* grows (Fig. 3). During that time the farmers will receive economic incentives to preserve and protect the reserve and they will have to actively conserve the cycad populations, technical assistant to address causes of deforestation, and finally education in order to create conscious about the importance of the species, the forest and the ecosystem services the area provides. Related to the conservation of this species are associated activities related to the conservation of their habitat, such as: a) restoration of the oak forests where the cycad grows (assisted restoration), b) creation and maintenance of fire lines (Fig. 4), c ) creation of *C. norstogii* nurseries for propagation, and reintroduction of seedlings to the habitat (Fig. 5). Likewise, parallel to these activities are research activities on the species with students and herbarium researchers, among which are: a) assessment of the conservation status of the populations and the impact of the project on its population dynamics, b) evaluation of growth and survival of seedlings under different habitat conditions (rock, trunk, shrub, bare soil), c) study on the structure, composition, and floristic diversity of the oak forests, habitat of *C. norstogii* (Fig. 6) and d) evaluation and determination of other conservation elements (plants or animals) that are under some category of protection by national or international laws within the conserved habitat.

We consider that this is a good opportunity to carry out a solid program of management and conservation for this species and that the continued monitoring of its populations is of vital importance for the success and viability of it's long-term conservation.


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**Figure 5**. Nursery *in situ* of *Ceratozamia norstogii* for reintroduction to their habitat.

**Figure 6**. Study of the structure, composition and floristic diversity of the oak forests where *Ceratozamia norstogii* grows. Research activities carried out by students of the Eizi Matuda Herbarium of UNICACH.


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*Cycas siamensis* at Kanchanaburi, Thailand. Photo by JS Khuraijam

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*Dioon merolae* at Chiapas, Mexico. Photo by Michael Calonje

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