ORCHIDS WITHOUT BORDERS: STUDYING THE HOTSPOT OF COSTA RICA AND PANAMA

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ABSTRACT. The Mesoamerican region is one of the richest in orchid diversity in the world. About 2670 species, 10% of all orchids known have been recorded there. Within this region, most of the species are concentrated in the southernmost countries. Costa Rica with 1598 species (or 0.030 spp/km^2) and Panama with 1397 species (0.018 spp/km^2) stand at the top of endemic species list of all Mesoamerica, with 35.37% and 28.52%, respectively. These figures, however, are misleading, as political boundaries do not have any relationship to orchid diversity. If we ignore the political frontier, there is a common biogeographic area. However, if we put the border back, the numbers in terms of scientific production and research change dramatically. Costa Rica has increased the knowledge of its orchid flora through the establishment of a successful research system, whereas Panama has lacked a similar process. To address this problem, the Lankester Botanical Garden at the Universidad de Costa Rica and the Universidad Autónoma de Chiriquí, Panama, established a new research center focused on the study of orchids. The aim of the cooperation is to provide the methodology, information, and expertise for a long-term project on taxonomy and systematics of the orchids of Panama

KEY WORDS: Orchidaceae, Mesoamerica, Costa Rica, Panama, floristics, taxonomy

The Mesoamerican region is one of the richest in orchid diversity in the world. About 2670 species, 10% of all orchids known, have been recorded there. The distribution of orchids in the region is not uniform. Diversity at country level depends on geological, climatic, and orographic factors as well as territorial extension. However, when examining the diversity index for Orchidaceae (calculated as number of species/km^2), a trend is evident. The southern regions of the isthmus, with Costa Rica and Panama, head the list with rates of 0.03 and 0.018, respectively (Fig. 1). These numbers are also reflected in terms of absolute diversity, with 1598 and 1397 orchid species of Orchidaceae recorded for this two countries, respectively, the highest values in the region (Ossenbach *et al.* 2007; Fig. 2). Phylogenetic studies on the evolution of the family show that both countries currently have a floristic contingent of different origins, joining the rich Andean flora with the large number of taxa from nuclear Mesoamerica, which disappear quickly in the South American flora (Fig. 3). From a phylogeographical point of view, and the peculiarity of its geological history, Costa Rica and Panama represent a laboratory for the evolution of orchids, and a critical examination of their orchid floras is of scientific priority under both the study and conservation of biodiversity (D'Arcy & Correa 1985; Dressler 2003).

Despite its geological and floristic similarities, the political boundary has affected knowledge and scientific production. A strong imbalance between the two countries is evident. In the last 10 years, about 170 scientific papers for the orchid flora of Costa Rica were published. In contrast, about 70 scientific papers were devoted to the orchids of Panama. Costa Rica has increased the knowledge of its orchid flora through the establishment of a successful research system, whereas Panama has lacked a similar process. The latest, in-depth studies on the orchids of Panama took place more

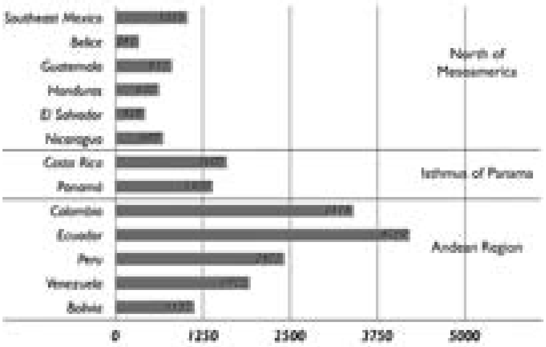

FIGURE 1. Comparison of the number of species/ km² between northern Mesoamerica, Isthmus of Panama, and the Andean countries.

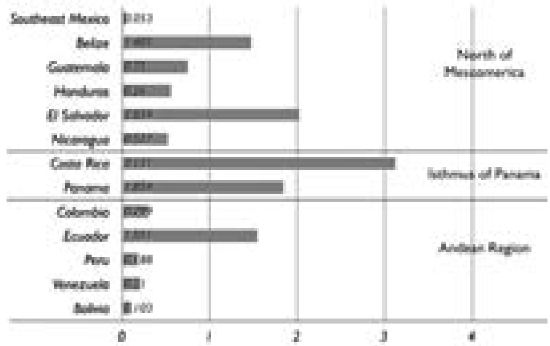

FIGURE 2. Comparison of the number of species between northern Mesoamerica, Isthmus of Panama, and the Andean countries.

than 20 years ago; recent information has been produced sporadically by researchers based in other countries (Dressler 1993; Williams & Allen 1946-1949). In this paper, we analyze the future and challenges of orchid research in the isthmus of Costa Rica and Panama. We present the main objectives of the scientific cooperation between Jardín Botánico Lankester of the Universidad de Costa Rica and the Universidad Autónoma de Chiriquí, Panamá.

Geography

Costa Rica and Panama are situated in the southeast of Central America (11°15'N-7°10'N, 85°56'N-77°09'W) and comprise a narrow land strip called the Isthmus of Panama that links North and South America, separating the Atlantic from the Pacific Ocean (Fig. 4). In the north of Costa Rica along the border with Nicaragua, floodplain lands separate the mountain ranges of Guanacaste from northern Central America. These chains are formed by active volcanoes such as the Rincón de la Vieja (1916 m) and Arenal (1670 m). The Cordillera Volcánica Central in Costa Rica has higher elevations with active volcanoes: Poás (2708 m), Irazú (3432 m), and Turrialba (3340 m). To the southeast lies the Cordillera de Talamanca, an intricate mountain range with the highest elevations of the isthmus, usually above 3000 m. This mountain range has no active volcanoes and is protected mostly by the La Amistad International Park. The highest peak is Cerro Chirripó (3820 m) followed by the peaks of Buenavista (3491 m), Durika (3281 m), Kamuk (3549 m), and Echandi (3162 m) in Costa Rica. Close to the border lie the highest peaks of Panama: Volcan Barú (3475 m), Cerro Fábrega (3335 m), and Cerro Itamut (3293 m) (Fig. 5). The Cordillera de Talamanca loses elevation towards central Panama in the provinces of Veraguas and Coclé. Central Panama is the narrowest stretch of the isthmus, and elevations are relatively low. It includes Cerro Azul (571 m), Campana (1030 m), Gaital (1185 m), and Jefe (1007 m). Towards Colombia, the ridges of San Blas and Darien extend along the Pacific with the highest peak, Cerro Tacarcuna (1875 m). Along the Atlantic side, the main ranges are Sapo, Bagre, and Jurado. Other important geological formations are the peninsulas of Azuero, Burica, Osa, and Nicoya, comprising lower-elevation mountain ranges but relatively isolated from Talamanca.

Geology

Costa Rica and Panama act as a geological unit. Both countries lie mostly on the Costa Rica-Panama microplate, a complex area of interaction of three tectonic plates: Nazca, Cocos, and Caribe (Fig. 6). According to Coates *et al.* (1992), three major events led the tectonic evolution of the southern Central American isthmus. First is the volcanic activity favored by the convergent tectonics of the eastern Pacific subduction zone, one of the primary forces that produced the volcanic arc that extends from North America to the south. Another tectonic effect is the subduction of the Cocos Ridge on the Pacific. This submarine range led to the rise of the isthmus from the Arenal Volcano in Costa Rica to nearby Cerro Campana and Gaital at El Valle, Panama. From this region, the Cordillera de Talamanca emerged and

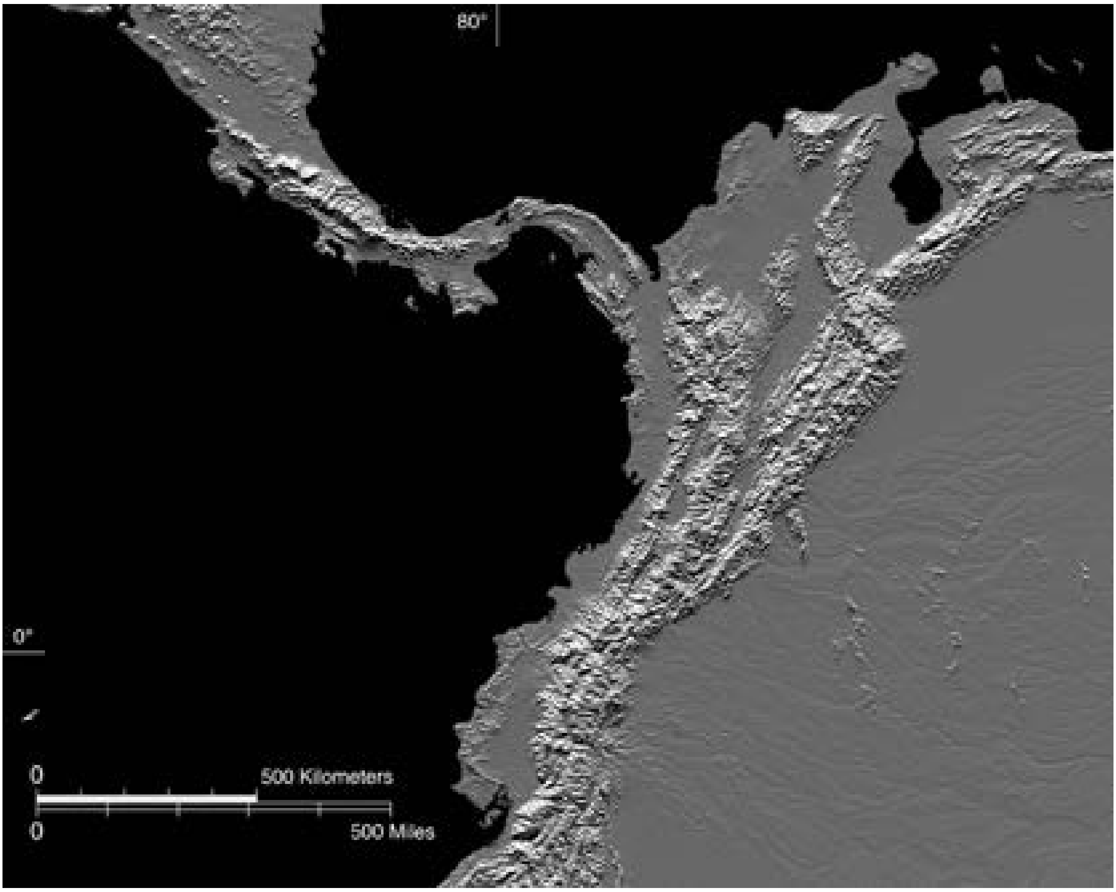

Figure 3. Costa Rica and Panama lie close to the Equator between North and South America.

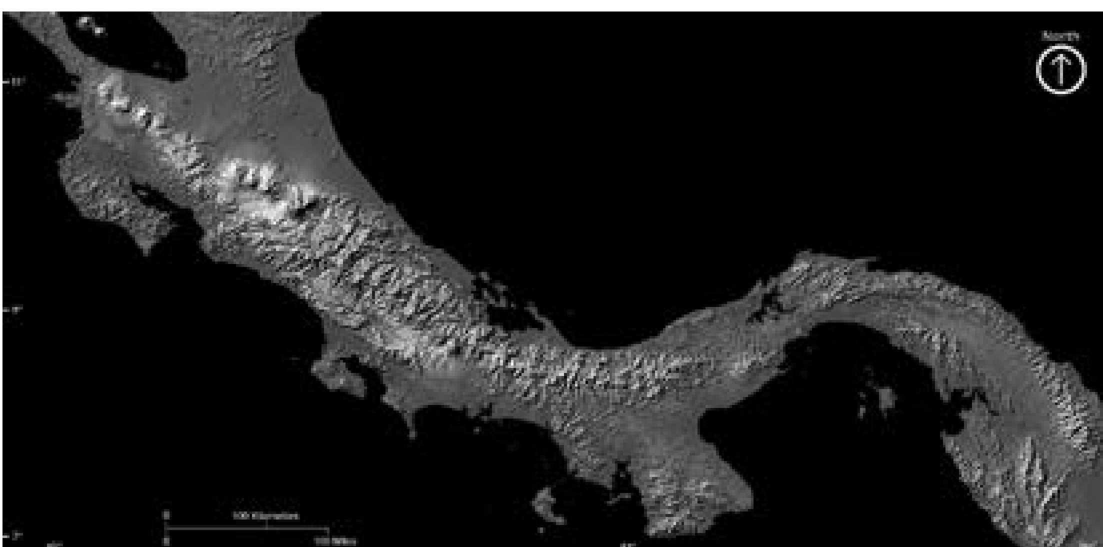

Figure 4. Satellite view of Costa Rica and Panama.

Figure 5. View of Durika-Utyum peaks at Cordillera de Talamanca in Costa Rica. Clouds are formed by the humid trade winds from the Caribbean. The Pacific side remains relatively clear. Courtesy of Daniel Jiménez.

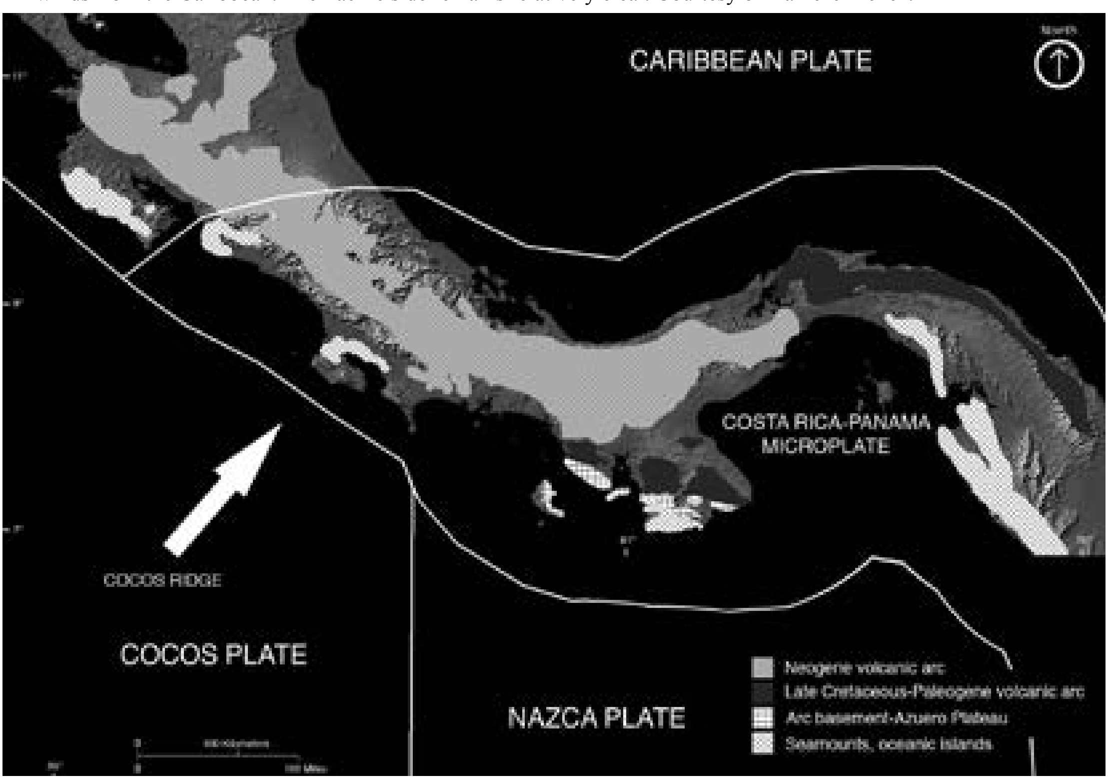

Figure 6. Plate tectonic configuration of the Isthmus of Panama. Both countries lie in a complex area of interaction of three tectonic plates: Nazca, Cocos, and Caribe.

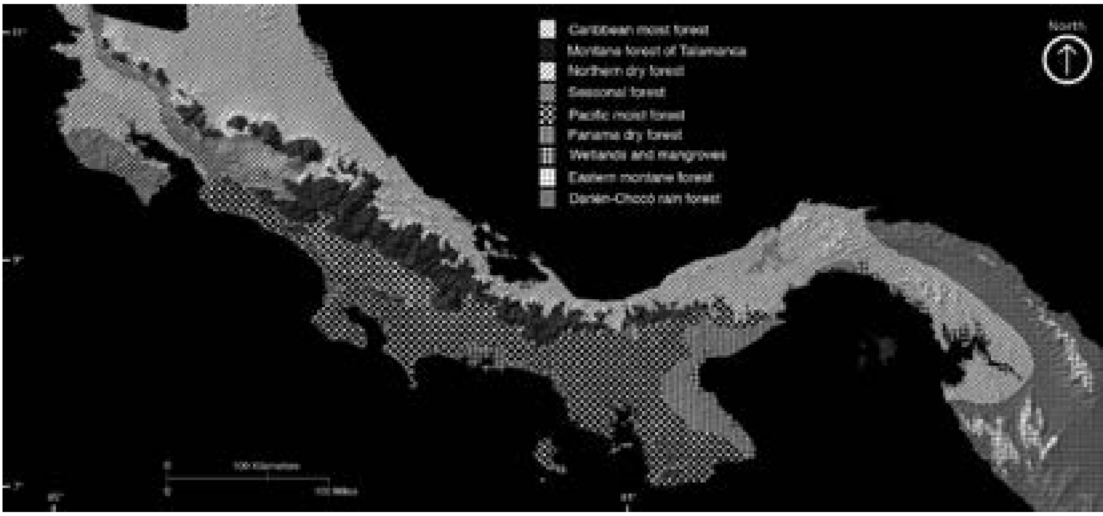

Figure 7. Vegetation units of Costa Rica and Panama.

reduced the marine connections. Finally, the southern region of the isthmus was affected by the collision of the volcanic arc with northwestern South America and led the uplift of eastern Panama (San Blas and Darién ranges) and northern Andes of Colombia and Venezuela in the late Neogene. In general terms, the closure of the Isthmus of Panama started some 15 Myr ago in the middle Miocene and was finally closed 3.5 Myr in the Pliocene (Fig. 6).

Climate and vegetation

The climate and vegetation of Costa Rica and Panama are affected by their geographical position close to the Equator and surrounded by two oceans, mountain chains with different elevational ranges, and the prevailing wet winds of the Caribbean. Usually the Caribbean lowlands are moist and warm (Fig. 7). Precipitation originates mostly from the trade winds from the Caribbean colliding with the mountain ranges, mostly on the Cordillera de Talamanca and the action of the Intertropical Convergence Zone (Kohlmann *et al.* 2002). Towards the region of central Panama, there are low hills such as Campana and Gaital with montane forests fed by interaction of the wet winds. The Cordillera de Talamanca has broad elevational ranges, and the wind system is complex. The climate varies from humid in the Caribbean watershed to dry and cold at the top of the highest mountains of Talamanca. The Pacific slope of Talamanca is wet from the collision of local winds with the moist air from the Pacific Ocean. The north Pacific region of Costa Rica and eastern Peninsula de Azuero in Panama are warm and dry with marked seasonality. To the east of Panama the climate is warm and rainy, similar to that of Chocó in Colombia, one of the wettest regions on Earth (Dressler 1993).

The orchid flora of Costa Rica and Panama

In general, the orchid flora of Costa Rica and Panama is a reflection of its geological history. Some factors that determine its floristic composition are the location between the great continental floras of north and south, climate, and proximity to the Andes, the most biodiverse area in the Neotropics. The lifting of the Cordillera de Talamanca with elevations up to 4000 m produced new environments for colonizing plant species from the Andean region. Recent studies on the evolution of Orchidaceae (Conran *et al.* 2009; Ramírez *et al.* 2007) support the hypothesis of an ancient origin of the family (76-84 Myr ago). Therefore, during the formation of the Isthmus that began about 15 Myr ago with the emergence of an archipelago, orchids could colonize the islands long before its closure. Some of the endemic species could also be explained by allopatric speciation produced in those ancient islands (Burger 1980). With the closure of the isthmus about 3.5 Myr and the union of the peninsulas of Nicoya, Osa, Burica, and Azuero, other species managed to colonize most of the regions of the isthmus (Fig. 6). These events may be supported by current species

FIGURE 8. Some of the endemic species of *Lepanthes* from Costa Rica and Panama.

composition. For example, most of the genera in Pleurothallidinae (the most diverse subtribe of the Neotropics) from middle and upper elevations (1500-4000 m) such as *Brachionidium* Lindl., *Lepanthes* Sw., *Pleurothallis* R.Br. s.l., and *Stelis* Sw. s.l. are more diverse in Costa Rica and Panama than in other areas of Central America. *Fernandezia* Lindl., *Telipogon* Kunth, and other terrestrial genera such as *Aa* Rchb.f. and *Petrichis* Lindl. are other examples (Dodson 2003; García Castro *et al.* 1995). However, the northern region of Costa Rica and central-southeast Panama have floras with few similarities. The northern region of Costa Rica has a northern influence, whereas the southeast of Panama is closely related to the flora of Colombia and Ecuador. An exemplary genus to study the evolutionary floristic relationships in the isthmus is *Lepanthes* Sw. Most of the species are found in montane and premontane rain forests at elevations of 1500-2500 m. Many species are endemic to certain ridges or hills, and their distribution is often narrow. In Costa Rica there are about 120 species (Bogarín *et al.* 2012), whereas in Panama 60 species were recorded (Pupulin *et al.* 2009). Both countries share 35 species, all distributed from central and southern Costa Rica to western Panama. In the region of central Panama, few species are shared (Fig. 8). As an example, *L. schizocardia* Luer, described from the region of Cerro Jefe, was reported for Costa Rica (Dressler 2003). However, a study of the populations from Costa Rica and Panama showed that *L. schizocardia* is an endemic of central Panama, sister of two endemic species from Costa Rica, *L. montis-narae* Pupulin, Bogarín & C.M. Sm. and *L. sotoana* Pupulin, Bogarín & C.M. Sm., both formerly treated as *L. schizocardia* (Pupulin *et al.* 2010). With the advancement of floristic research in both countries we expect to present a more detailed picture of their complex floristic relationships.

A review of the history of the orchidology in Costa Rica and Panama

The botanical exploration of Costa Rica and Panama, which mainly began in the nineteenth century with the visits of E. Arce, G. Barclay and R.B. Hinds, H. Cuming, A.S. Oersted, G. Skinner, J. von Warscewicz, and H. Wendland, led to the discovery of the first orchid species in the region (Ossenbach 2009; Fig. 9). As a side effect of the search for a possible route for the construction of a canal, exploration continued in the nineteenth and early twentieth centuries thanks to a large group of resident naturalists. Efforts by A. Endrés and later H. Pitter, A. Tonduz, A. Brenes, and C.Wercklé among others contributed greatly to reveal the rich flora of the isthmus. Within this group of naturalists, who through their work made Costa Rica the best-known country in Mesoamerica in terms of its orchid diversity profile, was the Charles H. Lankester (Fig. 10). His collection of Orchidaceae, gathered in a period of almost 40 years in the environs of Cartago, the old capital of Costa Rica, was an obligatory stop for botanists who visited Costa Rica and provided countless new species to science. Most of the species were described by Oakes Ames of Harvard and his colleagues over more than three decades of intensive floristic work (Fig. 11). The legacy of C. H. Lankester formed the basis for the creation of the Jardín Botánico Lankester (JBL) in 1973 as part of the Universidad de Costa Rica (UCR) (Fig. 12). With the creation of JBL, Costa Rica secured a permanent institution devoted to the study of orchids. Meanwhile, after the publication of *Orchidaceae Powellianae Panamenses* by Schlechter (1922) and Flora of Barro Colorado Island by Standley (1927), Panama received a strong impetus from L. O. Williams and P. Allen who published the Flora of Panama: Orchidaceae (Williams & Allen 1946-1949), the first formal treatment of the country's flora (Fig. 13).

Figure 9. **A.** Hugh Cuming (1791-1865). From a lithograph by Hawkins, 1850. Courtesy of Rudolf Jenny. **B.** Josef Ritter von Rawiez Warscewicz (1812-1866). Courtesy of the Hunt Institute for Botanical Documentation.

Figure 10. Charles H. Lankester in 1936. Courtesy of Ricardo Lankester.

Since 1963 and for over 20 years, R.L. Dressler has undertaken the systematic study of orchids of Panama,

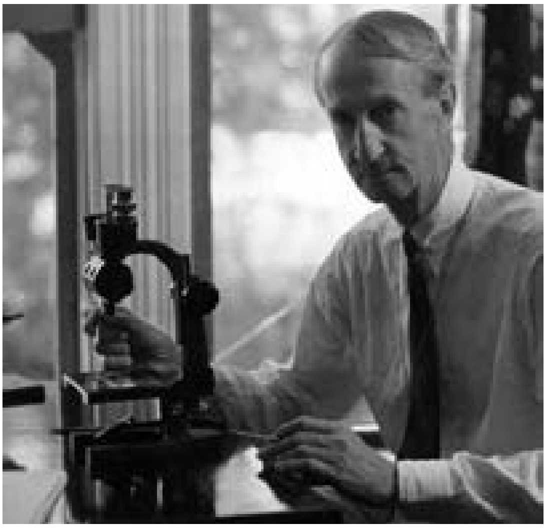

FIGURE 11. Oakes Ames (1874-1950). Courtesy of the Oakes Ames Herbarium, Harvard University.

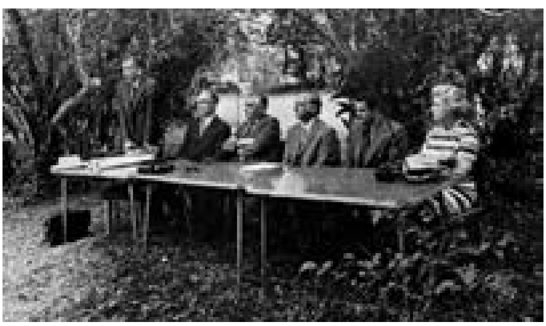

FIGURE 12. Inauguration of the Lankester Botanical Garden on March 2, 1973. Courtesy of Ricardo Lankester.

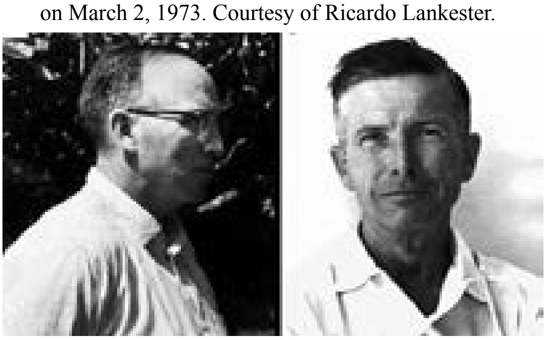

FIGURE 13. **A.** Louis O. Williams (1908-1991). **B.** Paul H. Allen (1911-1963). Courtesy of L. D. Gómez.

FIGURE 14. Robert L. Dressler looking for orchids in Ecuador, 2007.

culminating in the publication of the *Field Guide to the Orchids of Costa Rica and Panama* (Dressler 1980, 1993; Fig. 14). After his retirement from the Smithsonian Tropical Research Institute in 1986, orchid research in Panama was conducted sporadically by visiting researchers without a permanent ongoing plan of exploration and research (Correa *et al.* 2004). The absence of an active permanent center similar to JBL in Costa Rica slowed the spread of knowledge in Panama. Again, a clear example is *Lepanthes*. In *Flora of Panama*, Williams & Allen (1946-1949) recorded eight species. Later, Dressler (1993) reported 54 species in collaboration with C.A. Luer, who sporadically visited Panama (Luer & Dressler 1986). Since 1993 the number of species did not change significantly, and only six new species were added (Luer 1999). In contrast, about 53 species were recorded from Costa Rica since 1993 to the present (Bogarín *et al.* 2012). *Lepanthes* is just an example of the differences in scientific output between the two countries due to the lack of an ongoing project for the study of Orchidaceae in Panama.

Jardín Botánico Lankester and scientific production in Costa Rica

Despite their great orchid diversity, tropical regions lack important centers of orchid information. Even today, they are concentrated in Europe and North America. For historical reasons, the study of tropical plants was performed mainly by European and American botanists in the mid-nineteenth century and the late twentieth century. This produced the information, documents, and type specimens that were deposited in herbaria and libraries far from the countries of origin. To understand and protect their biodiversity, it has become imperative for tropical countries to establish centers or institutions dedicated to the study of living organisms. The AMO Herbarium in Mexico, the Rio Palenque Science Center in Ecuador, and the Jardín Botánico Lankester in Costa Rica are research centers that contributed greatly to the development of scientific projects based on their country of origin (Atwood & Mora de Retana 1999; Dodson 2004; Pupulin 2010; Hágsater *et al.* 2005). It is necessary to expand these efforts to other Neotropical countries with the aim of having an active network of institutions.

The constraints to scientific study in the tropics have been the difficulty in access to information and the lack of an appropriate system of enquiry. Scientific progress made by JBL to know and preserve the orchid diversity in Costa Rica was not constant in the beginning. In its early stages, JBL established collaboration with the Chicago Field Museum of Natural History, Harvard University Herbaria, Marie Selby Botanical Gardens, University of Florida, and Royal Botanic Gardens, Kew, among others (Atwood & Mora de Retana 1999; Pupulin & Romero 2003). These projects enriched the access to documentation for conducting orchid research in Costa Rica (Fig. 15). Early in this century, the JBL managed to consolidate its own research system, which laid the foundation for rapid development of its activities in Orchidaceae. This research system is based on some key elements: 1) botanical exploration and cultivation of specimens (Fig. 16); 2) comprehensive plant documentation including interpretation of the natural variation of populations, (Fig. 17); 3) a center with specialized equipment, trained staff, and students involved in the scientific projects; 4) a complex of well-documented collections (live plants, exsiccatae, spirit collections, tissues for DNA extraction, pollinaria, photographs and other digital documentation, botanical illustrations, etc.) (Fig. 18- 20); 5) an electronic system of interrelated databases; 6) complete access to literature and other original documentary sources concerning the taxonomy of Neotropical orchids; 7) a commitment to the policies of natural resource conservation and a strict relationship with the Ministry of Environment of Costa Rica; and 8) a network of international scientific cooperation with leading botanical research centers around the world. Through this system the JBL has assumed the role of carrying out the critical study of the orchid flora of Costa Rica. The JBL archival documents for the interpretation of Neotropical orchids are available over the Internet (see the site Epidendra, www.epidendra.org).

FIGURE 15. Type specimen of *Aspasia epidendroides* Lindl., collected in "*Panama et Columbia occidentali*" by H. Cuming in 1831. Reproduced with permission by the Board of Trustees, Royal Botanic Gardens, Kew.

FIGURE 16. Field trip at Fortuna, Chiriquí, Panamá. Photo by Eyvar Rodríguez.

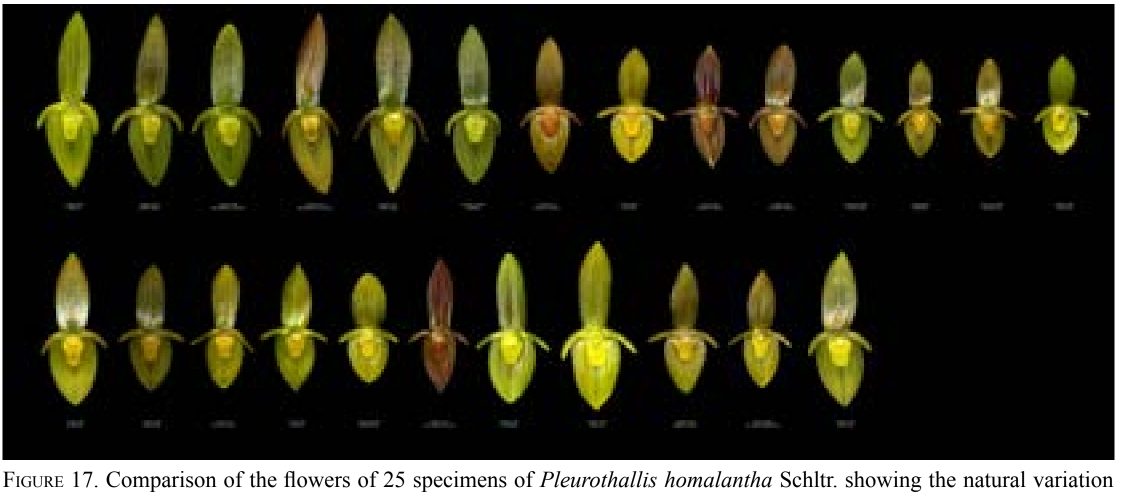

FIGURE 17. Comparison of the flowers of 25 specimens of *Pleurothallis homalantha* Schltr. showing the natural variation among individuals of different populations.

There are many advantages to developing orchid research in the tropics. The almost unlimited access to living material and wild orchid populations allow a more accurate assessment of intra- and interspecific natural variation (compared to the traditional practice of isolated expeditions and transfer of limited amounts of material to herbaria with a poor understanding of natural variation). It is possible to obtain more comprehensive documentation by studying living organisms. Adequate documentation is a system that includes the preparation of materials such as herbarium specimens, spirit collections, photographs, color botanical plates, ink drawings, and images of pollinaria among others that, compared with protologues and type documents, allow

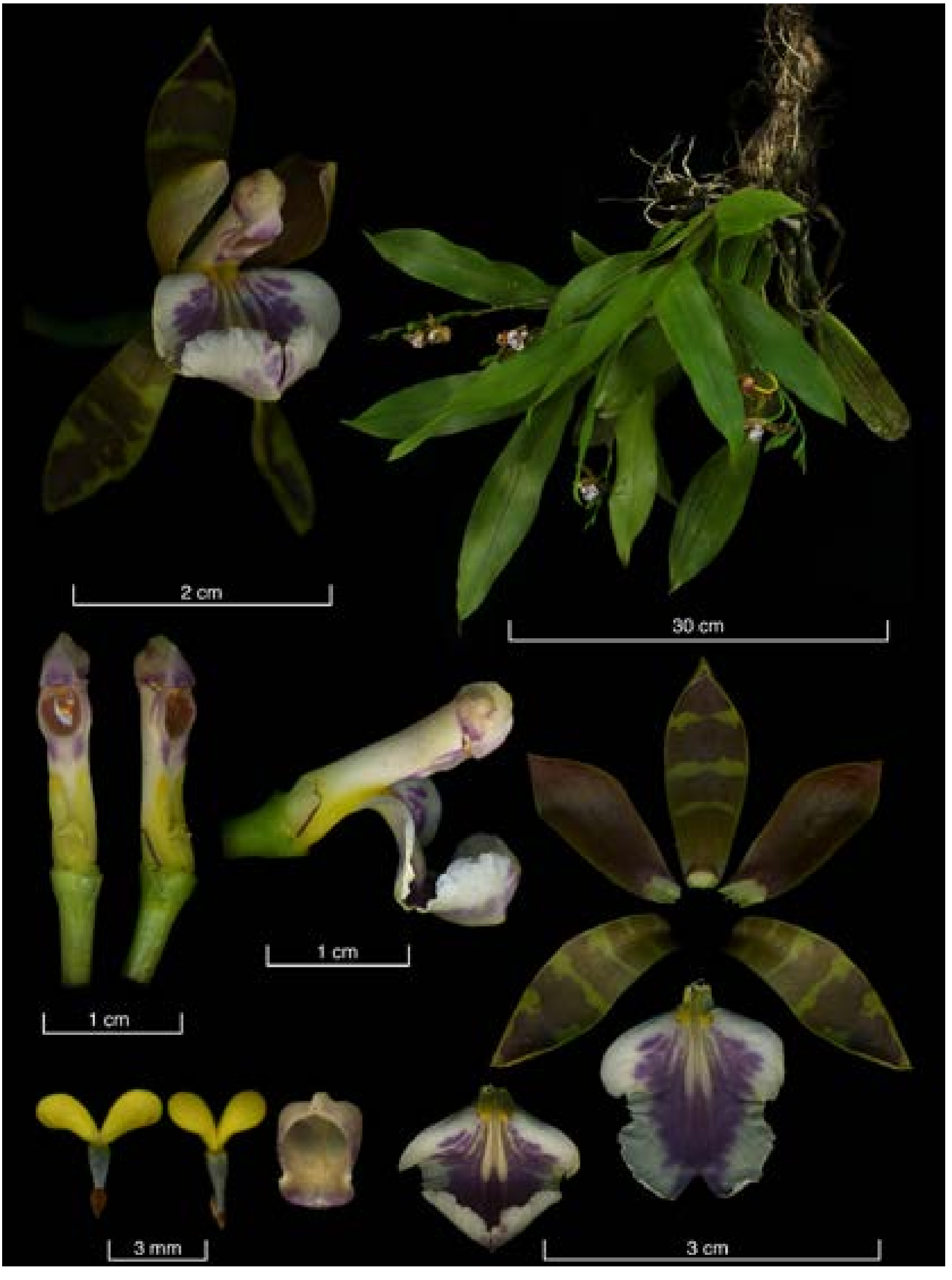

Figure 18. Botanical plate of *Aspasia epidendroides* from a plant collected in Chiriquí, Panamá. Courtesy of Herbario UCH.

FIGURE 19. Pollinarium of *Trichocentrum cebolleta* (Jacq.) Christenson, from the pollinaria collection of Herbario JBL.

the development of better taxonomic system (Fig. 15, 18). The development of electronic documentation techniques and the free flow of information through the Internet have contributed positively to increase scientific research (Pupulin 2007, 2009). Botanical exploration activities conducted in the past decade in Costa Rica, far from complete, yielded more than 100 orchid species new to science and several new records. This is a significant accomplishment for a traditionally well-studied orchid flora (Karremans *et al.* 2012).

The Orchid Project of JBL and UCH

The establishment of a permanent orchid research center in Panama is essential for the understanding of the flora of the southeastern Mesoamerican isthmus and its relationship with the Andean region. The Jardín Botánico Lankester of the Universidad de Costa Rica and the Herbarium UCH of the Universidad Autónoma de Chiriquí established a research center focused on the study of orchids. The main objectives are to perform a similar task in addition to that of JBL in Costa Rica and address the lack of an active center in Panama. With the adoption of an effective system of documentation of the diversity, JBL provided the methodology, information, and expertise for the long-term project on taxonomy and systematics (Fig. 21). Essential documents and types that were repatriated in the last 10 years through agreements with other botanical institutions such as AMES, K, W, and MA are now available for the flora of Panama (Fig. 15). The first results including scientific papers and complementary information, photographs, specimens data, and literature of the project are available at EPIDENDRA.

There are many other reasons to implement this task in both countries. Their biological potential and geographical, geological, and floristic affinities are a challenge for science. Geographical proximity allows active communication between the two institutions. The continuous development of research activities, training of students, and reciprocal staff visits are some of the advantages. Their floras are complementary, and the understanding of the species distribution on both sides of the political boundary will lead to more precise conclusions. There are still large areas botanically unexplored. One of the most diverse and least known is the Cordillera de Talamanca, where the emblematic La Amistad International Park, a World Heritage site by UNESCO, protects almost 400,000 hectares of primary forest, the largest montane forest reserve in Central America (Fig. 22). In central and southeast Panama the

Figure 20. The spirit collection of Herbario JBL. The collection has almost 10,000 samples of Orchidaceae from the Neotropics.

Figure 21. Training of students from Universidad Autónoma de Chiriquí and Universidad de Costa Rica at Fortuna. Photo by Eyvar Rodríguez.

mountain ranges of Bagre, Sapo, Jurado, San Blas, and Darien are critical areas to explore. The proximity of the isthmus to South America also benefits the interpretation of the Andean orchid flora and its relationship to the northern Neotropics.

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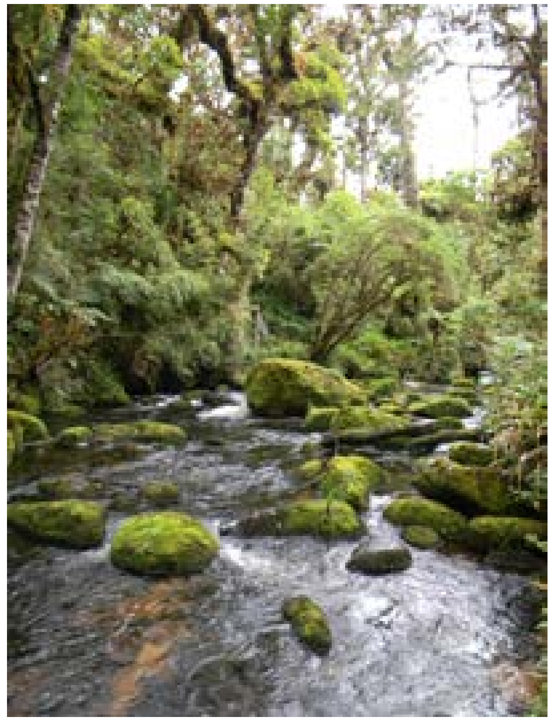

Figure 22. Río Terbi at La Amistad International Park. The river begins in Costa Rica and flows into Panama.

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CONSERVATION STATUS AND STRATEGIES FOR THE PRESERVATION OF ORCHIDS IN THE SOCONUSCO REGION OF SOUTHEAST MEXICO

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ABSTRACT. A total of 320 orchid species are registered for the biodiverse region of Soconusco in the southeastern tip of Mexico. Given certain social, political, and legal limitations, the most productive strategy for preserving and restoring populations of the various species in danger of extinction, endemic, and over-exploited has been to work directly, intensively, and long-term with communities situated within or near to the few remaining hot spots of orchid diversity and abundance. With the appropriate permits, sustainable orchid cultivation has been established in various communities. We continue with long-term research into key aspects of the biology and ecology of orchids, identification of refuge sites, and modeling of geographical distribution of species.

RESUMEN. Un total de 320 de orquídeas se han registrado para la región del Soconusco en el extreme sureste de México. Dado los inherentes limitantes sociales, políticos y legales, parece ser que la estratégica más productiva para preservar y restaurar poblaciones de las varias especies en peligro de extinción, endémicas y sobreexplotadas es el trabajo directo, intensivo y a largo plazo con las comunidades ubicadas dentro o cerca de los pocos puntos calientes restantes de diversidad y abundancia de orquídeas. Con los debidos permisos, se han establecido cultivos sustentables de orquídeas en varias comunidades y se continúa con investigaciones a largo plazo sobre aspectos claves de la biología y ecología de las orquídeas, la identificación de sitios de refugio y la modelación de la distribución geográfica de especies.

KEY WORDS: modeling of geographic distribution, orchid mycorrhizae (OM), retrospective spatial analysis of pollination, Unit of Environmental Management (UMA)

Soconusco region is situated in the southeastern extreme of Mexico in the state of Chiapas, with the greatest orchid species richness per area in Mexico (Damon 2010). The region possesses highly fertile soils on the coastal plain and a diversity of ecosystems from mangrove swamps, through a variety types of tropical and temperate forest, to alpine dwarf forest on the slopes of the 4092 m-high Tacaná volcano. Of particular importance are the Tacaná – Boquerón biological corridor designated as a priority Terrestrial Region by CONABIO* (RTP*-135) and the three Biosphere Reserves -- Tacaná Volcano, La Encrucijada and El Triunfo (CONANP*).

Constant changes in agricultural priorities and the relatively recent paternalistic strategies, have promoted an increasingly demoralized, passive, and dependent population that now subsists on government aid channeled through a variety of social, economic, and environmental programs, while production, effective land management, and conservation of natural resources continue to deteriorate. Mexico is a wealthy country that could do much to satisfy the basic demands of the population and at the same time promote and support conservation, sustainable exploitation, and legal protection of its rich natural resources. Major problems are corruption and the lack

* GLOSSARY

CONABIO – National Commission for the Knowledge and Use of Biodiversity; CONANP – National Commission of Protected Areas; NOM-ECOL-059 – Legislation for the Protection of Mexican Native Species of Flora and Fauna; OSSSU – Orchid Seed Stores for Sustainable Use; RTP – Priority Terrestrial Region. CONABIO; SEMARNAT – Secretariat for the Environment and Natural Resources. Mexico; UMA – Environmental Management Unit.

of personnel, funding, training, and commitment to environmental issues.

Within that scenario, the trade in wild species is extensive, largely unregulated and an important and well-defended source of income for many rural peasants, which then feeds into the national and international networks. Unfortunately, although regulation and the identification of vulnerable species exists (NOM-ECOL-059-2010*), with mechanisms for the issuing of permits for conservation management and sustainable exploitation of endangered species of flora and fauna, in reality most of the permits (UMAs*. SEMARNAT*) are authorized for hunting mammals and birds and there are few UMAs currently set up to commercially exploit plant and animal species that are not edible or huntable. Little has been achieved trying to work within the framework of the law to stop illegal extraction and trade in wild plants and animals or to halt habitat destruction.

The list of orchid species registered for Soconusco includes 320 species (Damon 2010), with several more awaiting identification and the resolution of taxonomic problems. At least 37 species are categorized as vulnerable or in danger of extinction within the NOM-ECOL-051-2010. Various species are endemic, and historic registers indicate that many species have now disappeared from the region. *Guarianthe skinneri* (Bateman) Dressler & W.E.Higgins, a once abundant but highly prized species, is now found only in private gardens and a few sites within protected areas and traditional coffee plantations (i.e. those with a diversity of original forest trees as shade).

Strategies for the preservation of orchids in Soconusco or anywhere else must, therefore, take into account social, political, and legal limitations. It appears that the best strategy is to work directly, intensively, and long-term with communities situated within or near the few remaining hot spots of orchid diversity and abundance. This labor-intensive, often frustrating approach depends on volunteers and a constant input of small amounts of money and materials, but it is to be preferred over short-term, government-financed projects that definitely do not work. It is also important to identify the few genuinely interested personnel within the relevant government departments and seek their collaboration for obtaining contacts and permits, in this case for the UMAs and the collection of orchids within protected areas.

The project "Ecology and Sustainable Cultivation of Soconuscan Orchids" (ECOSUR-Tapachula) has set out to make a positive contribution to the preservation of native orchid species. We have identified pollination and mycorrhizal associations as two key areas of research, with training and long-term collaboration with rural communities (Damon 2006) for the sustainable exploitation of local orchids as the only practical activities that might make a difference. The project includes a botanical garden at 80 m and an orchidarium at 1200 m for the rescue, conservation, and study of local orchids (and other plants).

In collaboration with personnel from CONANP, two UMAs for the sustainable production of orchids in rural communities in Soconusco have been established with another in process and various other communities interested in participating. The participants start out with a week of introductory training before work begins, which also serves to filter out those who are only there in the hope of financial benefits or are not willing to participate actively. The methods applied in these UMAs involve the rescue of orchid plants found on the ground, on dead and felled trees or pruned branches (e.g. of shade trees in coffee plantations) and their establishment in specially designed galleries. With time and a regime of basic care, these plants are vegetatively reproduced and the divisions planted in suitable sites in traditional coffee plantations, forest fragments, and protected areas. A proportion of the flowers produced will be naturally or hand-pollinated to produce seed for local research and *in vitro* production in our project laboratory and to contribute to the OSSSU* initiative (Seaton 2011); other flowers will be harvested and processed to make original craft items for sale for the benefit of the producers.

To be able to restore and preserve natural resources we need high-quality information about all aspects of biology, ecology, and refuge sites such as mountain peaks and ravines. In the case of orchids, especially epiphytic species, pollination and mycorrhizal associations are particularly important as they represent the two major bottlenecks in the orchid life cycle (Ackerman & Zimmerman 1994). We know little about pollination under natural conditions of a majority of the world's epiphytic orchid species, which are often inaccessible in the crowns of tall, tropical forest trees. Many species are rare, with small, widely dispersed populations. Direct observation of the flowers of most species yields little information, as pollinator visits are unpredictable, infrequent, and ephemeral. The study of orchid pollination has been dominated by few studies of charismatic, widespread, accessible, and often terrestrial species that may not be representative of the majority. Furthermore, the orchid family is notorious for a diversity of pollination mechanisms, particularly various types of deceit strategies with particularly low pollination rates.

Low-percentage pollination of flowers may be normal, or even strategic, for many epiphytic orchids, and we may advance our understanding further if we rationalize these observations at a metapopulation level. I have devised a technique for studying the pollination of epiphytic orchids without direct observation of pollinators (Damon & Valle Mora 2008; Pérez-Hernández *et al.* 2011). This technique is adaptable to any orchid population where all flowering individuals may be observed. First, the precise conditions and spatial distribution of every flower are noted and mapped, followed by mapping fruits as they appear within that arrangement. The conditions noted may include visibility, orientation, height above ground, and the density of flowers at that point to analyze the importance of these parameters for the attraction of pollinators and the successful pollination of individual flowers or aggregations of flowers. The results may indicate pollinator preference for certain conditions, or in the case of deceit mechanisms, the likelihood of achieving pollinator deception within the range of flower presentations offered. However, results obtained with two miniature orchid epiphytes indicate that none of the parameters so far studied has a significant effect (density or aggregation of flowers occasionally has a weak effect) upon the likelihood of a flower being pollinated. I have suggested that, at least for the two species we studied, the pollination of any particular flower may depend on luck or chance, but that every successful pollination event is heavily compensated by the production of thousands or millions of seeds. We hope to continue with basic pollination studies (e.g. Damon *et al.* 2012) and in particular to develop this retrospective spatial technique, using improved geopositioning, mapping, and modeling techniques to extend it to a metapopulation level. However, recent directives that coffee producers must eliminate all mosses and other epiphytes from the stems and branches of their coffee bushes have resulted in the almost total elimination of the small and miniature orchids that have so successfully adapted to coffee plantations since the end of the nineteenth century when coffee was first introduced into Mexico. As a result, it may now be impossible to continue with this interesting and revealing line of research, which would be impossible to carry out effectively within a forest environment.

The evolution and geographical distribution of Orchidaceae depend not only upon pollinators but also upon their endophytic, mycotrophic symbionts (Waterman & Bidartondo 2008), apparently involving a specific group of fungi, termed orchid mycorrhizae (OM) which belong to the *Rhizoctonia* group (Otero *et al.* 2007). Although it was originally thought that colonization was sporadic and seasonal (Hadley & Williamson 1972; Lesica & Antibus 1990), recent studies indicate that a dense and continuous colonization is the norm in tropical orchid species (Rivas *et al.* 1998; Pereira *et al.* 2005a). We now have evidence of patterns of evolutionary co-diversification and specificity (Otero *et al.* 2011), which could indicate that OM have a role to play in the rarity of many orchid species. However, to the contrary, a study of two European terrestrial species showed that questions of specificity did not determine rarity in those species (Cachapa Bailarote *et al.* 2012).

We know little about these endophytic mycorrhizal fungi that are implicated in various functions of the orchid plant throughout its life cycle, including seed germination, defense, and nutrition. Orchids can be classified within a continuous spectrum from partial (mixotrophy) to obligate mycotrophy, in which plants depend completely on the fungi for their supply of carbon and nitrogen (Julou *et al.* 2005). Orchid mycorrhizae have a positive effect on germination (Suárez *et al.* 2006; Rains *et al.* 2003), although Arditti (1992), Smith and Read (1997), and Zettler *et al.* (2003) have suggested reasons to doubt the importance of OM in this process. Studies on the symbiotic, *in vitro* germination of orchid seeds indicate that, although the seeds may imbibe water and swell in a pre-germinative phase, OM intervene in the process of differentiation and development (Zettler *et al.* 1998); without them the seeds remain trapped in the pre-germinative phase and eventually die (Pereira *et al.* 2005b). Future work will focus upon the development of *in situ* symbiotic seed germination techniques, study of the ecological niches of these endophytic fungi, and research into the biochemical pathways that determine the process of recognition between fungus and orchid, invasion of orchid cells by the fungus, and control of the process of the digestion of fungal tissues by the orchid, which effectively functions as a parasite.

We are currently involved in a project to map the geographic distribution of all the species that have been registered within the Soconusco region, which in the initial stages involved collaboration with various institutions in Central America and Colombia (list of participating institutions provided on request; Damon 2012-13). This process has been useful to emphasize which orchid species are rare not only in Soconusco but also throughout their distribution, and also where investment and collaboration are needed to enable completion of vital taxonomic and ecological studies (Costello *et al.* 2013). The actual and predictive maps of geographical distribution generated will allow the identification of sites suitable for the restoration and conservation of populations, coincidence with pollinators and fungal symbionts, vulnerability to climate change, and much more.

Over the next few years we hope to be able to begin to answer some of the fundamental questions mentioned here, using remaining, common orchid populations, traditional coffee plantations, forest fragments, and protected areas as models (Light & MacConaill 2011). We hope it is not too late to save the majority of the Orchidaceae and the ecosystems that we and they depend on for future generations (Hirtz 2011).

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