

# Palms

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# THE INTERNATIONAL PALM SOCIETY, INC.

## The International Palm Society

**Founder:** Dent Smith

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### FRONT COVER

*Coccothrinax jimenezii* in the Dominican Republic. See article by Peguero et al., p. 145.

### BACK COVER

*Calamus erinaceus* is a mangrove associate that grows near the edge of a brackish stream. See article by Loo et al., p. 109.

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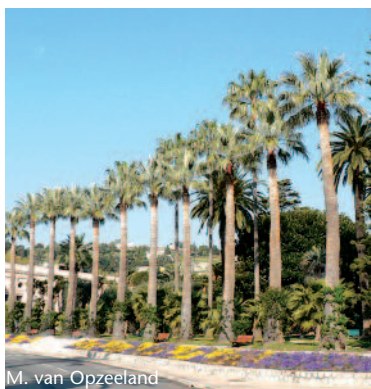


*Coccothrinax jimenezii*. See article by Peguero et al., p. 145.

# PALM NEWS

Villagers of Bossou, Guinea drill into the terminal bud of *Raphia hookeri* to extract the sap, which quickly ferments into palm wine. A recent open-access publication by K.J. Hockings et al. (Roy. Soc. Open Sci. 2: 150150. 2015) reported that **wild chimpanzees enjoy palm wine just as much as humans do**. Some chimpanzees (about half of the local population) learned to use wadded leaves like scoops or sponges to pilfer palm wine from the collecting vessels and enjoyed frequent bouts of drinking, becoming visibly inebriated... or just sleepy. The authors discussed the relevance of their study to the ongoing debate of how and when ancestral humans evolved the ability – and indeed, the desire – to consume alcohol.

*Ganoderma* has both friends and foes. Several species are used in traditional medicines and health products, but the fungus is also the scourge of palm growers in both agronomic and horticultural settings. One of the difficulties in studying *Ganoderma* is the chaotic state of its taxonomy. In a step toward sorting out the relationships among species of the *Ganoderma lucidum* complex (which includes *G. zonatum* and *G. boninense*, the major pests of palms), L.-W. Zhou and colleagues produced a **multilocus phylogenetic hypothesis and a key for the identification of thirteen species of *Ganoderma*** (Phytochemistry 114: 7–15. 2015). In the same issue of the journal (114: 160–169), C.-L. Ho and Y.-C. Tan provided a detailed molecular-level analysis of how *Ganoderma* infects oil palm (*Elaeis guineensis*) and how the palm responds to the infection. It is hoped that a better understanding of which species attack palms and how they infect will lead to better ways of controlling the fungus.



A new investigation of the phytochemistry of *Washingtonia filifera* was prompted by the observation that this species is resistant to the Red Palm Weevil (*Rhynchophorus ferrugineus*) plague that is sweeping through the palm-growing regions of southern Europe. Cangelosi and colleagues reported (Phytochemistry 115: 216–221. 2015) that **the leaf bases of *W. filifera* have high concentrations of a new chalconoid, filiferol, and that this naturally occurring chemical is toxic to RPW larvae**. The authors suggested that filiferol, specifically its concentration in the leaf bases, naturally protects the terminal bud of *W. filifera* from RPW. Perhaps this discovery can inform new preventative treatment strategies against RPW.

As we prepared this issue for press, we learned of the deaths of two much-loved members of the IPS community: **Jim Wright of San Diego, California, USA**, and **Jean-Christophe Pintaud of IRD Montpellier, France**. Jim was well-known in Southern California for his love of palms and willingness to mentor others. He served for a time on the IPS Board of Directors, which brought him into contact with IPS members from around the world. Jean-Christophe will be remembered by the IPS community for his many contributions to palm taxonomy in New Caledonia and South America. Both were champions of palms and will be sorely missed.

# An Introduction to the Native Palms of Singapore

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The native palm flora of Singapore can be described as a microcosm of the palm flora of the Malay Peninsula. With 20 genera, Singapore has close to two-thirds of the genera found in the contiguous palm flora that is formed between Peninsular Malaysia (131,598 km<sup>2</sup>) and Singapore (716.1 km<sup>2</sup>).

The Singapore flora has long been considered a natural part of the flora of Peninsular Malaysia but distinguished from the eastern islands of Borneo, the Philippines and the eastern Archipelago and aligned with the Sumatran Flora (van Steenis 1950; Takhtajan

1986). It is also notable for its near absence of insular endemic species (Corlett 1992). The native flora consists of 2145 native plant species, of which 639 (29.8%) are already considered nationally or globally extinct (Chong et al. 2009).

With 54 species, the palm flora in Singapore makes up 23.6% of the contiguous palm flora formed by Singapore and Peninsular Malaysia, which is also largely representative of Malaysian palms distributed west of Wallace's Line (Baker & Couvreur 2012). This is remarkable as Singapore's land area is a mere 0.54% of the combined land area. This could largely be attributed to the occurrence of diverse habitats in Singapore comprising saline environments of mangrove forests, freshwater habitats of inland swamps, and mixed dipterocarp forests, with palms occupying various levels of the multi-tiered vegetation.

### Habitats

The Republic of Singapore consists of a group of 59 islands located at latitude 1°N and longitude 104°E, off the southernmost tip of continental Asia, separated by the Straits of Johore from Peninsular Malaysia to the north. The mainland measures 49 km east to west and 25 km from north to south with a coastline of 197 km (Singapore Department of Statistics 2014).

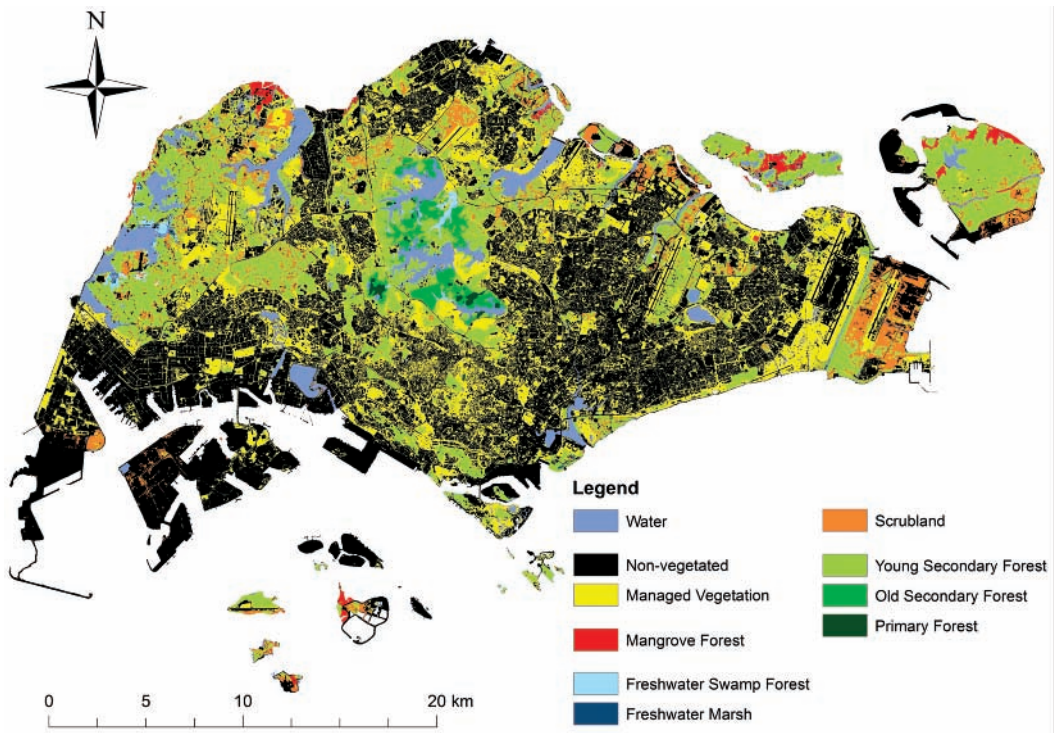
The average daily maximum and minimum temperatures are around 31°C and 24°C respectively. The relative humidity is usually between 61% and 65% on dry afternoons but

frequently exceeds 90% in the early hours of the morning before sunrise. Although rain falls throughout the year, the wettest months are usually during the first part of the Northeast Monsoon season from November to January. During the Southwest Monsoon season from May to September, early morning line squalls occasionally hit the island. The average rainfall per year for the past five years is 2285.7 mm.

While Singapore is immediately known as a highly urbanized and built up city state with lush wayside greenery, there are primeval patches of rainforest in protected reserves that total 3347 hectares (4.67% of the total land area of the island republic) and include Bukit Timah Nature Reserve, Central Catchment Nature Reserve, Sungei Buloh Wetland Reserve and the 10 Ha Labrador Nature Reserve (NParks 2012).

The principal native vegetation of Singapore is lowland dipterocarp rainforest (Corlett 1991). Most of the palm diversity and other native flora is found within the mainland's nature reserves. A small freshwater swamp forest still exists within the central catchment as the Nee Soon Swamp Forest and is a habitat where swamp associates such as *Eleiodoxa conferta*, *Korthalsia flagellaris*, *Daemonorops sabut* and *D. longipes* feature prominently.

1. Vegetation map of Singapore and its surrounding islands. Figure courtesy of Alex Yee.



**Tab. 1. Taxonomic representation of the native palms of Singapore with classifications based on Dransfield et al. (2008).**

Subfamily	Tribe	Subtribe	Genus	Extant members (Extinct)		
Arecoideae	Areceae	Arecinae	<i>Nenga</i>	1		
			<i>Pinanga</i>	2 (4)		
			Oncospermatinae	<i>Oncosperma</i>	2	
				unplaced	<i>Cyrtostachys</i>	1
				unplaced	<i>Iguanura</i>	1
				unplaced	<i>Rhopaloblaste</i>	1
			Oranieae	NA	<i>Orania</i>	1
		Calamoideae	Calameae	Calaminae	<i>Calamus</i>	8 (3)
					<i>Daemonorops</i>	11 (1)
<i>Ceratolobus</i>	0 (1)					
				Korthalsiinae	<i>Korthalsia</i>	4 (2)
				Plectocomiinae	<i>Myrialepis</i>	1
					<i>Plectocomia</i>	1
					<i>Plectocomiopsis</i>	1
				Salaccinae	<i>Eleiodoxa</i>	1
					<i>Salacca</i>	1
Coryphoideae	Caryoteae	NA	<i>Caryota</i>	1		
	Trachycarpeae	Livistoninae	<i>Licuala</i>	2 (1)		
			<i>Pholidocarpus</i>	1		
Nypoideae	NA	NA	<i>Nypa</i>	1		

Outside the nature reserves along coastal areas on the mainland and off-shore islands are back-mangrove associates *Licuala spinosa* and *Oncosperma tigillarium*. *Nypa fruticans* and *Calamus erinaceus* are mangrove associates restricted to pockets of existing mangroves on the mainland and on large offshore islands such as Pulau Ubin and Pulau Tekong (Yee et al. 2001)(Fig.1).

### Diversity of Native Palms

Twelve species are considered nationally extinct (Loo et al. 2014). The native palms in Singapore are diverse across higher taxonomic levels with four of the palm subfamilies with six tribes represented (Table 1); Calamoid palms make up the largest group with 28 extant species within four subtribes, namely, Calaminae, Korthalsiinae, Plectocomiinae and Salaccinae. The second largest subfamily is the Arecoideae represented by nine species in seven genera from two tribes. Coryphoid palms are represented by four species in three

genera in two tribes. The subfamily Nypoideae is, of course, represented by the monotypic genus *Nypa*. This also means Singapore palms are morphologically diverse. In habit, we find rattans (e.g., *Plectocomia elongata*), canopy trees (e.g., *Orania sylvicola*), understory trees (e.g., *Nenga pumila*) and understory palms of the ground layer (e.g., *Pinanga simplicifrons*).

### Rediscoveries and a new record

Much of Singapore's native palm species were extirpated along with the loss of primeval vegetation over the centuries of rapid development. Swamp forest associates, in particular, are highly endangered due to habitat loss. Freshwater swamps were wiped out early on in Singapore since 1800s due to land conversion for crops such as gambier, pepper, pineapple, rubber, market gardening, aquaculture and in more recent times, for canalization, reservoirs, housing and industrial development (O'Dempsey & Chew 2011). Recent rediscoveries of five species of palms

thought to be previously extinct locally and one new rattan genus record have offered a glimmer of hope for the native palm flora.

A single population of *Pinanga simplicifrons* (Fig. 2) was rediscovered by Ang et al. (2010) in Nee Soon Swamp Forest and subsequently in 2012 another population discovered within the Catchment reserves. This is a diminutive palm that matures at knee-height. Another swamp forest species, *Salacca affinis*, was rediscovered in another part of the same forest (Loo 2011). *Pholidocarpus kingianus*, a rare large canopy palm, was rediscovered in the Central Catchment Nature Reserve (Sunia Teo, pers. comm., 2011) and a small population of *Cyrtostachys renda*, a swamp forest species, was rediscovered in the Western catchment area (Ali Ibrahim, pers. comm.). *Plectocomiopsis geminiflora*, a genus and species previously unrecorded for Singapore was discovered within the Central Catchment Nature Reserve not far from a walking trail (Tan et al. 2011). This perhaps vindicates the observations that collectors have shunned rattans in making herbarium specimens. It could also be that this rattan is morphologically similar to *Myrialepis*

2. *Pinanga simplicifrons* rediscovered in Nee Soon Swamp Forest, a highly threatened habitat in Singapore. Beside it, Bill Baker from Royal Botanic Gardens, Kew



*paradoxa* in terms of vegetative characters, especially in juvenile stages. The fruits of both rattans, however, are distinguishable. This discovery means that all genera of the Plectomiinae are represented in the Singapore palm flora.

### Arecoid Palms

Two species of *Oncosperma* are native to Singapore and both are conspicuous canopy palms that develop into many-stemmed clumps. *Oncosperma tigillarum* (*nibung*) is found near coastal swamps and forests, and its saltwater-resistant wood is used in the building of *kelongs* (Malay for an offshore platform built for fishing). The inland species, *Oncosperma horridum* (*bayas*) (Fig. 3), is common in the lowland dipterocarp forests and can be distinguished by its splayed fronds as opposed to the former which has drooping leaflets. Both are very spiny and have long backward pointing black spines on their stems.

*Nenga pumila* var. *pachystachya* (Fig. 4a) is fairly common in the forest understory and swamp forests where they are found growing in the water, producing stilt roots at the base. *Pinanga malaiana* (Fig. 4b), which looks similar, is not as easily encountered in the forest. The two genera can be differentiated with certainty through the arrangement of the flowers on the rachis – *Pinanga* has flowers and fruits that are arranged in a distichous pattern throughout the length of the rachillae while *Nenga* has spirally arranged flowers and fruits confined to the base of the rachillae with male flowers only at the tips. Currently, there are only two known small populations of *Pinanga simplicifrons* within the Central Catchment Nature Reserve and this diminutive palm certainly makes a good candidate for *ex situ* conservation efforts. Four other *Pinanga* species (*P. disticha*, *P. limosa*, *P. singaporensis* and *P. subbruminata*) are presumed nationally extinct.

While *Cyrtostachys renda* is a rather ubiquitous wayside plant in Singapore, it was not long ago presumed nationally extinct in the wild (Chong et al. 2009). Fortunately, this charismatic palm of freshwater swamps with its red crownshaft was rediscovered in the Western Water Catchment by the National Parks Board (NParks), Singapore. While this area is not gazetted as a nature reserve, it is a military training area, which offers protection of habitats from development and public access.

*Rhopaloblaste singaporensis* (*kerinting*) (Fig. 5) is the only member of the genus that has a





3. *Oncosperma horridum* – leaves of this species are splayed out as opposed to droopy leaflets of *O. tigillarum*.



4. A. *Nenga pumila* var. *pachystachya* – note the spiral arrangement of the fruits. B. *Pinanga malaiana* – a distichous arrangement in all *Pinanga* palms.

clustering habit (Banka & Baker 2004). To the north of Singapore, it is distributed in Johor, Pahang and Perak in Peninsular Malaysia. In Singapore there are several clumps in Bukit Timah Nature Reserve, MacRitchie and in and around Nee Soon Swamp Forest. This palm is seen only in areas of good primary forest.

*Orania sylvicola* is critically endangered with a few individuals left in the wild in Singapore. It is a distinctive single-stemmed feather palm in the Catchment Nature Reserve, as it is the only native canopy arecoid palm that is not spiny.

### Calamoid Palms

Baker (2015) recently sank *Daemonorops* and *Ceratolobus* into an expanded *Calamus*. However, for the sake of consistency with the recently published Field Guide to the Palms of Singapore, which this article complements, we adhere to the traditional generic limits here. See Baker (2015) for revised nomenclature.

The Calamoideae contains many varied habits – giant climbing rattans such as *Plectocomia elongata* that punch through the forest canopy or smaller rattans such as *Calamus lobbianus*,

an understory rattan that is often stemless or with a short stem at maturity. The salaks, *Salacca affinis* and *Eleiodoxa conferta* (Fig. 6), are acaulescent, forming tall thickets with their clustering habit that is made up mainly of towering leaves to 3 m tall.

*Daemonorops* is the most well represented with 12 members of which one (*D. lewisiana*) is presumed nationally extinct. Both the sections *Daemonorops* and *Piptospatha* are represented by *D. angustifolia*, *D. grandis* (Fig. 7) and *D. lewisiana* for the former and *D. didymophylla* (Fig. 8b), *D. micracantha*, *D. leptopus*, *D. hirsuta* (Fig. 8a), *D. kunstleri*, *D. geniculata*, *D. sabot*, *D. periacantha* and *D. longipes* for the latter. The Section *Piptospatha* is further divided (*sensu* Dransfield 1979) to 1) those that have fruits that bear “dragon’s blood” (*D. didymophylla*, *D. micracantha*), 2) those with pale green fruit borne on rusty brown rachillae with enlarged spines around the leaf sheath mouth (*D. hirsuta*, *D. kunstleri*), 3) species with spines that form interlocking galleries occupied by ants (*D. sabot*) and 4) species with short to moderate erect or climbing stems with inflorescences bearing papery bracts and relatively large fruit (*D. periacantha*, *D. longipes*).



5. *Rhopaloblaste singaporensis* is a clustering species found only in certain pockets of forest fragments in the nature reserves of Singapore.

The genus *Calamus* in Singapore is almost as large with 11 species, of which, three (*C. densiflorus*, *C. luridus*, *C. ornatus*) are presumed nationally extinct. *Calamus diepenhorstii*, *C.*

*insignis*, *C. javensis*, *C. laevigatus* and *C. ridleyanus* belong to the Section *Calamus* and are typically very slender rattans with pencil-thin stems. *Calamus oxleyanus* is a distinctive



6. A cluster of *Eleiodoxa conferta* in Nee Soon Swamp Forest. Freshwater swamp forests are a highly-threatened habitat in Singapore.

7. *Daemonorops grandis* – This inflorescence with its persistent bracts that would have been enclosed within the outermost bract is typical of the section *Daemonorops* within the genus.





8. A. *Daemonorops hirsuta* is as vicious as a rattan can get and gives credence to the genus name which translates to “demon shrub”! B. *Daemonorops didymophylla* – Dragon’s blood, a deep maroon resin exudes from in-between the scales of the fruits. It was used as varnish and in chinese medicine in the past.

understory rattan with its black spines and irregularly-grouped leaflets that are waxy beneath. *Calamus javensis* and *C. laevigatus* have their lowermost pair of leaflets swept backwards to form ant-infested chambers. *Calamus oxleyanus* (Fig. 9) has beautifully grouped leaflets.

*Calamus erinaceus* (Back Cover) belongs to the Section *Podocephalus* (*sensu* Furtado 1956) and is morphologically the most robust rattan of the genus in Singapore. It is a mangrove associate, whose habitat has been reduced to a few pockets in Singapore due to extensive development of coastal areas.

The three genera *Plectocomia*, *Myrialepis* and *Plectocomiopsis* belong to the subtribe Plectocomiinae and are hapaxanthic. In the juvenile stage, the three look similar especially *Myrialepis paradoxa* and *Plectocomiopsis geminiflora* (Fig. 10). Stems of *Myrialepis paradoxa* tend to have more complete whorls of spines on their stems and lack the tattering, disintegrating ocreas that feature in young parts of *Plectocomiopsis geminiflora*. Leaflets of *Plectocomiopsis geminiflora* have conspicuous long golden bristles along the upper surface of the mid-nerve. These vegetative characters, as

described by Dransfield (1982), easily distinguish the two species in the field.

*Plectocomia elongata* (Fig. 11) is a magnificent rattan in the nature reserves. It emerges through the canopy and, after flowering and fruiting, litters the forest floor with its large combs of spent infructescences. In Singapore, the rattan is best view atop the tree-top canopy walk in the forests around MacRitchie Reservoir, where the rattan regularly peeks out of the blanket of green rainforest canopy.

There are four extant species of *Korthalsia* in Singapore. Two species, *K. echinometra* (Figs. 12a) and *K. rostrata*, are ant rattans with ocreas that have developed into chambers that allow ants to inhabit. Chan et al. (2012) carried out a study of the diversity of ant species inhabiting the ocrea of the two rattan species in Singapore. They reported two different species of ants in the genera *Dolichoderus* and *Philidris* in *K. rostrata* and a single ant species of *Iridomyrmex* in different clumps of *K. echinometra*. Additionally the study also described the presence of the aphid *Cerataphis orchidearum aptera* in the ocrea of *K. echinometra*, indicating a relationship between the ant and aphid species.



9. *Calamus oxleyanus* in Bukit Timah Nature Reserve with its beautiful grouped leaflets.



10. *Plectocomiopsis geminiflora* – a recent new record for Singapore.



11. *Plectocomia elongata* – View from the Tree-Top Walk in Macritchie, a 250 m long free-standing suspension bridge that offers a bird's eye view of the forest canopy with a highest point at 25 m. Photo by Bill Baker.





12. A. *Korthalsia echinometra* – ferocious ants live within the specialized tubular ochrea. B. Ants tending to the larvae within the ochrea.

*Korthalsia rigida* is less easily encountered in the forest reserves but easily recognized by its robust form and lack of vicious-looking spines. *Korthalsia flagellaris* (Fig. 13) is a freshwater

swamp forest associate and is thus found in a highly endangered habitat in Singapore. This species has a very large entire leaf when it is a sapling and at this stage has been mistaken

13. The dimorphic leaves of *Korthalsia flagellaris* – Foreground: simple at the seedling stage and Background: splitting to form leaflets as it matures.





14. The common palm civet (*Paradoxurus hermaphroditus*) on *Caryota mitis*, the fruits of which, make up an important part of its diet. Photo by Tze Kwan Fung.

15. The pink-red fruits of *Licuala ferruginea*. The species epithet describes the rusty-brown hairs that cover the infructescence.





16. *Licuala ferruginea* – an acaulescent fan palm found in patches of primary rainforests within the nature reserves.

for *Johannesteijsmannia* species (Dransfield 1979). At maturity, this rattan is like the flagship of the swamp forest, as it emerges out of the canopy, with its versatile leaflets moving in the slightest wind.

### Coryphoid Palms

*Caryota mitis*, the fishtail palm, is the only native palm that is an early secondary forest species. It is also a very common landscape palm in parks and waysides. It is ecologically significant as this medium-sized, clustering palm with a high fecundity is an important food source for the common palm civet, *Paradoxurus hermaphroditus* (Fig. 14) (Sivasothi,

pers. comm), which is Singapore's last wild native urban carnivore.

*Licuala ferruginea* (Figs. 15 & 16) and *L. spinosa* occupy non-overlapping habitats. The acaulescent *L. ferruginea* is found in late secondary to primary rainforests, while the multi-stemmed *L. spinosa* is found in coastal forest. Wild specimens of *L. spinosa* are less common on the mainland than on islands such as Pulau Ubin, where it can be found along trails further inland from the coastal beach areas on the island. The diminutive *Licuala triphylla* was once common in the western areas of Singapore but is now considered extinct.



17. A stand of *Nypa fruticans* in a mangrove swamp on Pulau Ubin, an offshore island northeast of the mainland. Swollen leaf bases afford stability to the palm in the soft mud of mangrove swamps.

*Pholidocarpus kingianus*, a large, majestic, single-stemmed fan palm that was presumed nationally extinct was rediscovered in 2011 by the National Parks Board within the Central

Catchment Nature Reserve in a degraded swamp forest, the only location where it is known to exist in Singapore (O'Dempsey & Chew 2011).

18. The infructescence of *Nypa fruticans*.





19. The inflorescence of *Nypa fruticans*. The inflorescence has a terminal head of pistillate flowers and bears lateral branches with spikes of staminate flowers.

### *Nypa fruticans* (Figs. 17–19)

This species is known to locals mostly for its young endosperm which is candied and made into sweet meat for Malayan desserts such as *Cendol* and *Ice-Kacang*. It and some rattans are probably the only native palms with any surviving ethnobotanical use. In generations past, the leaves were used as thatch and its inflorescence stalk cut and tapped for sugar. Pulau Ubin probably has the biggest population of *Nypa* palms in Singapore. All three mangrove species can also be found at the Sungei Buloh Wetland Reserve, a protected area that serves as a good outdoor classroom for anyone keen on learning about tropical mangroves.

### Conclusions

Singapore has a wide palm diversity in terms of representation at the subfamily and tribal

level. It remains to be seen if more new records and rediscoveries of native palms once considered locally extinct will be made. Who knows what palm lies undiscovered in the precious pockets of primeval forests found in this “City in a Garden”? Both *in situ* and *ex situ* conservation efforts are underway for the biodiversity in our forest reserves and we are hopeful these will be successful in increasing the numbers of individuals that are highly threatened, such as *Orania sylvicola*, *Pholidocarpus kingianus* and *Pinanga simplicifrons*.

### Acknowledgments

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# Bringing the Coconut to Kayapó Villages of the Amazon: Evaluation of a Sustainable Development Project

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In this article, we attempt a critical evaluation of our own eight-year project in Brazil of planting coconuts in Kayapó Indian villages aiming to improve their livelihoods and support their role in tropical forest conservation. Between 2006 and 2007 we delivered a total of 1400 coconut seedlings to Aukre village. Seven years later, the coconut plants are beginning to mature, and we had the opportunity to visit Aukre and assess the fate of the plants. Mortality rate was higher than 95%, but the 54 surviving, fruiting coconuts grown from our delivery of seedlings were responsible for a 300% increase in the adult population of this species.

We advocate that the expansion of coconut (*Cocos nucifera*) cultivation in indigenous villages in the Amazon could be an important step for biodiversity conservation, mainly because it would contribute to nutrition and hydration for the indigenous people who defend the land from non-sustainable developers (Salm et al. 2007, 2010). Our main

argument is that the potential for increased production of coconut could help to mitigate the negative impact of rapid human population growth in these areas by simultaneously increasing (coconut) tree populations and improving indigenous nutrition. Here we give an evaluation of our sustainable development project to plant

coconut palms in Kayapó Indian villages of southern Pará, Brazil, as a strategy for forest conservation and food security. We examine both the success rate of the coconuts and the Kayapó opinion of the project.

Coconuts are one of the most useful plants in the tropical world. The people of the islands in the Pacific Ocean domesticated and use all parts of coconut trees for numerous daily necessities – food, drink, oil, medicine, fiber, timber, thatch, mats, fuel and domestic utensils (Harries 1979). The European travelers of the sixteenth century were amazed by the uses of coconuts in eastern India. They facilitated the expansion of this species to its current pan-tropical distribution by taking

fruits for food and drink during oceanic journeys (Harries 1979). Today, this palm is an important source for subsistence nutrition, and coconut culture bolsters the economy in nearly one hundred countries around the tropics with the production of dozens of products (Cuenca 1997).

The culture of coconuts has been substantially expanding in Brazil due to the domestic demand for coconut water. This drink is widely consumed in Brazilian cities, where people are eager to pay more for coconut water than for industrialized drinks. Coconut fruits are also used in cuisine. In the form of dried coconut, for example, it may complement tapioca, a traditional indigenous food made from manioc

1. Fruit-producing coconut palm grown from our program's seedling. Aukre Village, Kayapó Area.







2. Cluster of coconut palms grown through our program’s seedlings bordering the Aukre village’s airport.

(Okwu 2001). Coconut milk, a generic term for the highly nutritious aqueous extract of the solid coconut endosperm, plays an important role in the gastronomy of several tropical countries (Seow & Gwee 1997). Furthermore, the leaves of coconut palms can also be used for thatching (Johnson & Nair 1985).

In Brazil, the Kayapó were once semi-nomadic and their mobile lifestyle afforded them a diverse supply of food (Vidal 1977). They moved through the forest, hunting and gathering as they went and planting crops for the future when they returned. They sometimes trekked for years before they returning to a previously inhabited site (Posey 1981). However, missionaries and the Brazilian government, then represented by the SPI (Service of Indian Protection), induced them to settle into permanent villages, mostly in the 1970s (Turner 1992).

In the long run, permanent settlements cause problems for the Kayapó. Because they overhunt and gather in the forest immediately surrounding the village, the forest does not have time to recover as it did when the people were trekking. Nevertheless, seen as a whole, the Kayapó Territory is a remarkable example

of the importance of indigenous lands for conservation. This area spans more than 13 million hectares in the Xingu River Basin, and effectively protects seasonally dry Amazonian forests and natural savannahs. Within this area the Kayapó contain the spread of the chief environmental threats to the region, such as the construction of paved roads and hydroelectric dams, and the clearing of forests for pastures and soybean plantations (Zimmerman et al. 2001).

Nevertheless, the Kayapó have already earned and spent several million dollars from the illegal sale of timber, which nearly exhausted the natural stocks of mahogany (*Swietenia macrophylla*). Although this business did bring some communal benefits, leaders frequently abused the illegal deals to provide themselves with airplanes, houses, cars etc., in frontier towns adjacent to the Kayapó reserves (Zimmerman et al. 2001). They also made goldmine concessions, which contaminated important rivers (Barbosa et al. 1998) and introduced malaria and other diseases. During this time, the Kayapó also went through a population explosion. For certain groups, the annual population growth rates reached 5%. In some villages, the population doubled every

**Table 1- Abundance of young and adult coconut palms in Aukre village houses before (1997) and after (2014) the first results of our coconut seedlings distribution program.**

	Young (Kayapó)	Young (by us)	Adults (Kayapó)	Adults (by us)	Total adults
2007	18	98	23	-	23
2014	8	4	21	54	75

**Table 2. Distribution of adult coconut trees among Aukre village houses before (1997) and after (2014) the first results of our coconut seedlings distribution program.**

	No. of houses (%) without any adult coconut	No of coconuts (%) owned by the 3 (10%) richest houses	Pielou Equitability for adult coconut distribution	Dominance D for adult coconut distribution
2007	23 (69.6)	13 (56.5)	0.601	0.15
2014	13 (41.9)	28 (37.3)	0.775	0.08

14 years (Verswijver 1992). If such a situation continues, the negative impact that the Indians have upon their land will be likely to grow, and their nutritional problems will only increase.

We present a quantitative evaluation of our coconut culture project. This assessment is based on a coconut census made in Aukre village in 2014 in comparison to the data that we had in 2006/2007. Our program delivered a total of 600 coconut seedlings to Aukre village in April 2006 and 800 seedlings in November 2007. Because the region is seasonally dry, the time of year in which seedlings are planted is crucial, as coconut seedlings require lots of water during establishment. At the forest management farm Marajoara, 130 km from Aukre, annual precipitation between 1995 and 2001 ranged from 1636 to 2170 mm, with >90% falling between November and May; in some years no rain fell for three or four months during the dry season (Grogan 2001). The climate in Aukre is slightly wetter with average rainfall close to 2200 mm yearly.

In 2014, Aukre village celebrated its 35th anniversary with a population of 380 people. This is just 17% more than what we found seven years ago, and does not coincide with the observed 5% per year year growth typical of some Kayapó groups (Verswijver 1992). However, in the meantime Aukre spawned a new village called Ngo-meití (meaning “the village with good water”), 20 km northeast of it and downstream from the village’s main river, composed of 120 people from Aukre. If the populations of both villages are added, the total of 500 Indians fits almost perfectly with the expected 5% per year.

The Kayapó village houses are traditionally disposed around an open circle, or plaza, around the warrior-house (called “ngobe”), a sort of parliament at the center of the village. The “property” of space in a typical Kayapó village is roughly divided in slices that depart

from the center of the plaza, pass through the houses and extend towards the surrounding forest. As such “slices” go further beyond the village houses, they progressively lose meaning until a point when the territory is considered public. Areas directly behind each house are considered the private property of the corresponding house such that, if a coconut tree is planted there, the coconuts belong only to the people of that household. Agricultural plots, both on the outskirts and behind houses are considered private property, but anything that falls outside of that domain is free for anyone to harvest. Agricultural zones on the village outskirts have become important for Kayapó sustenance, and households also cultivate some edible plants and fruit trees in the vicinities behind their houses (Salm et al. 2010).

We searched the village household by household. With the assistance of a fluent Portuguese-speaking Kayapó man, we interviewed representatives from each household, taking note of who owned each coconut palm, and classifying the plants as young or adult, and if they were originally obtained by the Kayapó themselves or by our program. The palms we brought were easily distinguished, as they were all even-sized and had a general similar character; all of our saplings originated in the Brazilian Agricultural Research Corporation (Embrapa) coconut seedling farm in Aracajú, Brazil. The coconuts palms belonging to each household are necessarily planted on the territorial slice corresponding to that house. However, to make a proper assessment of palm property distributions, we questioned the Indians about the ownership of coconuts that fell between neighboring houses.

## Results

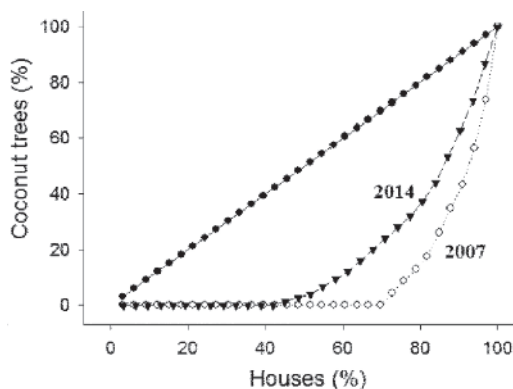
On the visit that we made to Aukre in August 2014, we found a total of 54 adult palms grown from coconut seedlings brought by our program (Figs. 1 & 2). The coconut census,

compared to the one that we had made in 2007, revealed that the adult coconut population in that village increased 326% exclusively due to the growth of the seedlings brought by our program (Tab. 1). Accordingly, each house now owns a larger number of adult coconut palms that it had before. At the same time, there are fewer houses without any coconut trees and a more even distribution of adult palm property among all the houses (Tab. 2; Fig. 3).

### Discussion

The population of adult coconuts in Aukre probably dates back to the village's creation 35 years ago. The Indians, recognizing the positive benefits of the palms, probably brought from the outside world in the earlier times and took care of them because they were so difficult to obtain.

When our small airplane landed in Aukre on 5 August 2014, we could see the coconut palms that grew from the seedlings that we brought; they were beginning to produce their first fruits. We observed children drinking coconut fruits, and the new palms created shade that many families used as a resting place to seek shelter from the heat of the sun. We were also concerned: people were drinking coconut



3. Graphical representation of the cumulative distribution (the Lorenz curve) of coconut trees at Aukre village in 2007 (open circles) and 2014 (filled triangles). The diagonal straight line (filled circles) represents perfect equality in distribution of coconut trees between all households.

water from small, unripe fruits. The water from immature coconut fruits is not as sweet as that from mature fruits, so the fact that these fruits are used indicates that this village needs more coconut palms to satisfy demand.

If our first observed impressions about the outcome of our project was of undoubted success, the quantitative analysis based on the coconut palm census was less straightforward.

4. Kayapó mother giving a child coconut water to drink.



The numbers may show success: a three-fold increase in the adult coconut population in this village. The same numbers, on the other hand, could be read as evidence of failure, as our 54 adult coconut palms were the survivors of a mortality rate higher than 95%. Coconut seedlings in urban areas or plantations elsewhere in Brazil have a much higher survival rate than this. The causes of such a high mortality rate among the coconut seedlings in Aukre village are diverse, but we suggest several reasons. First, local commitment, or lack thereof, to taking care of seedlings affected their survival particularly in watering, protecting them from being trampled and keeping them free from weeds. Although unmeasured, insufficient irrigation was certainly a chief cause of the high mortality among the coconut palms seedlings.

As we pointed out above, the climate is seasonally dry and coconuts are water-demanding palms. Due to FUNAI's bureaucratic delays, our first shipment of seedlings was not delivered to Kayapó villages until April 2006, near the end of the rainy season. The seedlings had a very short time to establish themselves before the rainy season ended (generally in May). In 2007, the coconut seedlings were planted at the appropriate time, in November, at the beginning of the rainy season. Still, from the 600 seedlings brought in 2006 to Aukre, 80 (13%) were still alive in November 2007, more than a year later. We could not tell in 2014 which of the 54 surviving adults have grown from 2006 or 2007 seedlings, as they were roughly even in size, but these data suggest that mortality from drought or other reasons continued to be significant after the seedling stage.

We surmised that children playing with the leaves of young palms was also a cause of death. We were also told by the local population that pacas (*Cuniculus paca*) like eating the sweet endocarp of recently planted coconuts. These rodents are certainly rare around a village packed with paca hunters, at least by day. A mapping of cultivated trees in the Kayapó villages of Kokraimoro and Pykararankre revealed that the Indians generally planted coconuts very close to their houses, where competition with a variety of other cultivated trees, mainly mango, may have hindered the palms' survival (Salm et al. 2010). Furthermore, the area in and surrounding the village consists mostly of red soil exposed to sun and packed fairly hard. It is mostly devoid of any vegetation and may not be conducive to palm growth and survival.

It is clear to us by now that we were quite optimistic when we projected that we could have a population of 1200 adult coconuts growing in Aukre village by 2025, providing coconut water for all the local population on a daily basis (Salm et al. 2007). In reality, the first imported palms are reaching maturity now, seven to eight years after planting, rather than the four years expected for maturity in other regions of Brazil with better water and soil conditions. Worse than that, the actual rate of seedlings survival to adulthood was approximately half of our worst-case scenario (Salm et al. 2007). The assumption that the Indians would save and replant 10% of the fruits was also clearly unrealistic. As a matter of fact, the Kayapó are not even waiting for the fruits to reach maturity before harvesting them for drinking water. Also significant is the fact that in 2006, before the beginning of our project, Aukre village had a total of 18 young coconut palms that the villagers had procured themselves, while in 2014 this number dropped to eight. The numbers are too low for a proper interpretation, but it is clear that our investment did not encourage villagers to cultivate seedlings themselves.

When we delivered the first round of coconuts in 2006, we took every opportunity to talk with villagers about various uses of coconuts, the best ways to plant and take care of the seedlings, and how to increase local seedling production. In November 2007, when we took the second coconut seedling shipment to the Kayapó lands, we conducted a coconut workshop in Kikretum village in which we attempted to disseminate non-native ways in which to use coconut products with crops indigenous to the Kayapó diet, namely, manioc. For doing so, we brought dried and shredded coconut and tapioca starch (made from the manioc root) from the city and made tapioca pancakes, fried with butter and rolled in shredded coconut. Our intention was to increase Kayapó appreciation of coconuts by exemplifying other potential ways in which to use the fruits other than merely drinking the coconut water (Salm et al. 2010). Apart from being a fun activity for both the participating Kayapó and us, we do not believe that this workshop had any effect on how the local population took care of the coconut seedlings, nor how they consumed them.

On our next trip to Aukre, there are several socio-ecological questions we would like to explore that focus on the overarching question: How does our project affect Kayapó

livelihood? Would the Kayapó accept more saplings if we were able to finance another shipment? Did our shipment make them less willing to cultivate their own coconut trees because they could count on ours? We are also curious to know if the Kayapó ever exploit the nutritional value of the meat extracted from ripe fruits, and if they had more coconuts, would they? Furthermore, would they use coconut leaves for thatching, considering that the native palm *Attalea maripa*, which are what they normally harvest for thatching, are becoming increasingly rarer close to the village (A. Jerozolimski, pers. comm.)?

Our argument is that coconut production is beneficial to Kayapó nutrition and that sustained good health of the local population contributes to protection and health of the forest and savannah in this region. Considering that each of the 23 adult coconut palms could produce around 100 coconuts per year, in the village of Aukre each of the 325 villagers in 2006/2007 could consume only seven fruits per year from their trees. Thus, the low annual production of coconut fruits indicated that coconuts did not represent a relevant source of hydration or nutritional value for the Kayapó at the time. Today, even after we tripled the coconut population, the figure is not much better than that, since villagers cannot even consume one coconut fruit per day for a single month of the year. Still, they appreciate having coconut palms around their houses, and the children especially love drinking the water of their unripen fruits (Fig. 4). They also appreciate eating dried coconut when we bring it and are always happy to receive coconut seedlings to plant around their houses. While the Kayapó leaders may not choose to invest in coconuts themselves, they are happy recipients of coconut seedlings. We hope to raise funds for the continuity of coconut seedling shipments to Aukre and other villages and that the Kayapó themselves become more prone to save a mature fruit and make a seedling for replanting. We hope these trees will be useful to help Kayapó livelihood in a future of environmental, social and economic uncertainty.

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# Changes in Seed Predation of *Attalea dubia* in a Gradient of Atlantic Forest Disturbance in Brazil

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Many tropical forest biomes are now human-modified landscapes consisting of mosaics of forests under different degrees of anthropogenic disturbances immersed in a matrix of pastures and croplands (Melo et al. 2013). The conservation of the original plant diversity in these landscapes relies on the mechanisms that allow population persistence in the remnant patches such as adult survival and seedling recruitment (Portela et al. 2010). Plant population persistence may also rely on seed dispersal and predation that allow the colonization and recolonization of the patches (Tabarelli et al. 2010, McConkey et al. 2012).

Seed predators often control the abundance and spatial distribution of plants (Janzen 1971, Wright 2002), and seed predation may vary in different microhabitats (Christianini & Galetti 2007). It is not rare to find seed predators consuming all the seed crop and restricting plant regeneration to areas harboring low activity of granivores (Janzen 1971, Francisco et al. 2002, Wright 2002, Rodríguez et al. 2014).

For example, because granivorous rodents are more susceptible to predation by aerial and visually oriented predators in areas with less vegetation cover, they avoid foraging in these areas (Manson & Stiles 1998, Christianini & Galetti 2007). As a consequence, seed survival is less likely in closed canopy spots than in vegetation gaps (Manson & Stiles 1998). Resource abundance can also affect the

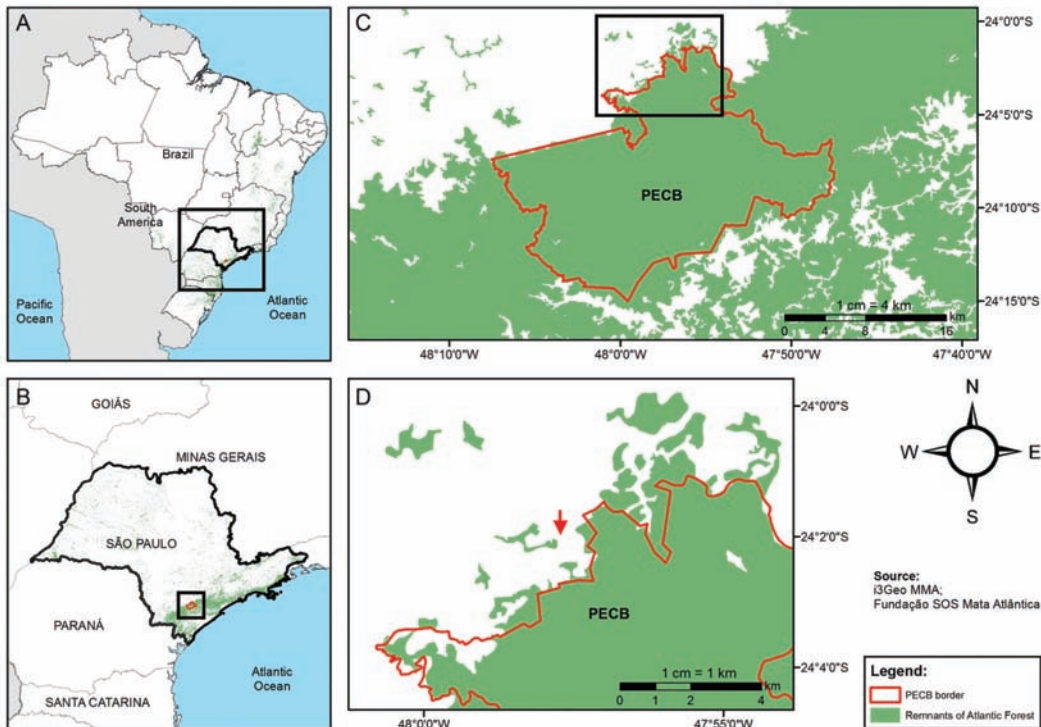
likelihood of seed predation since high seed production may satiate granivores, allowing more seeds to escape (Janzen 1971, Jansen et al. 2004, Wright 1990). Low food availability may force starved animals to forage in less favorable habitats and with a higher risk of predation (Lima & Dill 1990).

Forest disturbances such as habitat loss and fragmentation, edge effects, fire and hunting often change the abundance of pollinators, seed dispersers and granivores thus changing the likelihood of seed production, dispersal and mortality (Wright & Duber 2001, Aguilar et al. 2006, Galetti et al. 2006, Markl et al. 2012). Reductions in the abundance of vertebrate frugivores that perform seed dispersal and/or predation, such as lowland tapir (*Tapirus terrestris*), agoutis (*Dasyprocta* spp.) and peccaries (*Tayassu pecari* and *Pecari tajacu*), are common in tropical human-modified landscapes (Chiarello 1999, Peres & Palacios 2007, Galetti et al. 2009, Jorge et al. 2013). As a consequence many seeds are not dispersed and accumulate beneath parent plants, constraining plant regeneration to the vicinity (Dirzo & Miranda 1991, Cordeiro & Howe 2003, Galetti et al. 2006, Terborgh et al.

2008, Terborgh 2013). Specialized invertebrate granivores, such as weevils, may increase in response to an increase in food availability represented by undispersed seeds beneath parent plants (Wright 2003). In disturbed patches beetles may prey on a larger fraction of undispersed seeds, compensating for the decrease in seed predation by large vertebrate granivores. Such compensatory effects may constrain plant regeneration in disturbed patches but are seldom investigated (e.g. Wright & Duber 2001, Wright 2003, Galetti et al. 2006, Andreazzi et al. 2012).

The Brazilian Atlantic Forest (BAF) is a global hotspot of biodiversity consisting mostly of a mosaic of small forest fragments immersed in a matrix of agriculture, pasturelands and human settlements (Ribeiro et al. 2009). Current estimates of BAF cover varies between 11–16% of the original forest that once reached more than 1 million km<sup>2</sup> (Ribeiro et al. 2009). More than 80% of the remnants of the BAF consist of small, disturbed and isolated forest fragments smaller than 50 ha (Ribeiro et al. 2009). However, BAF still houses a rich diversity of palms including 10 genera and about 35–45 species, many of them endemics

1. Location of the study sites in São Paulo state, southeast Brazil (A, B). Atlantic forest remnants are in green. The study sites were near the northern border of an old-growth forest, the Carlos Botelho State Park (PECB) which is depicted in red (C). The red arrow in D indicates the location of the pastureland and nearby disturbed forest fragment studied.







2. View of the disturbed forest fragment from the adjacent pastureland, where some palms were sampled. The crown of several *Attalea dubia* is visible in the background (Photo: Ana Y.Y. Meiga).

(Henderson et al. 1995, Lorenzi et al. 1996). Palms often provide keystone food resources (fruit pulp and seeds) to frugivorous animals thanks to the abundance of nutritious crops and extended fruiting during periods of scarcity (Terborgh 1986, Genini et al. 2009). Palms may also out-compete other plants or create opportunities for plant recruitment thus affecting plant diversity at small scales (Aguiar & Tabarelli 2010, Correa et al. 2012). Meanwhile, palms influence the successional trajectories of disturbed sites. Disturbances often have negative effects on BAF palms, but the information available is restricted to few species (Lorenzi et al. 1996, Montúfar et al. 2011) with most studies concentrated on *Astrocaryum aculeatissimum* (Galetti et al. 2006, Donatti et al. 2009, Portela et al. 2010), *Attalea humilis* (e.g. Souza & Martins 2004, Andreazzi et al. 2012), *Euterpe edulis* (e.g. Fadini et al. 2009, Portela et al. 2010) and *Syagrus romanzoffiana* (Fleury & Galetti 2004, 2006). Surprisingly certain species of *Attalea* such as *A. oleifera* (Aguiar & Tabarelli 2010), *A. humilis* (Souza & Martins 2004, Andreazzi et al. 2012) and *A. dubia* (Ana Y.Y. Meiga pers. obs.) may increase in abundance after BAF disturbance. Mechanisms behind this apparent unusual response may include good competition performance (Aguiar & Tabarelli 2010), resistance to fire (Souza & Martins 2004),

increased seed production and reduced granivory by rodents (Andreazzi et al. 2012). The possible compensatory role of beetle seed predation in response to a potential decrease in seed eating by vertebrates mediated by environmental disturbance is poorly investigated in BAF palms (Galetti et al. 2006, Donatti et al. 2009, Andreazzi et al. 2012). We compared the fate of *Attalea dubia* seeds across a gradient of BAF disturbance including an old growth and protected forest, a forest fragment and a pastureland. We tested if rodents and weevils switched roles in seed predation across the gradient (i.e., compensation), if the number of seeds found beneath palms influences the chance of seed survival (i.e., predator satiation) and discussed the possible consequences for plant regeneration.

### Methods

**Study sites:** Palm seed predation was sampled in three sites following a gradient of disturbance: A low disturbed forest (Carlos Botelho State Park, hereafter PECB), an intermediate disturbed forest fragment ca. 1 km from the park border and a heavily disturbed site represented by a pastureland adjacent to the fragment (Fig. 1). PECB is a 37,644 ha protected area covered by old-growth humid Atlantic forest in São Miguel Arcanjo, Southeast Brazil (24°00'–24°15'S,

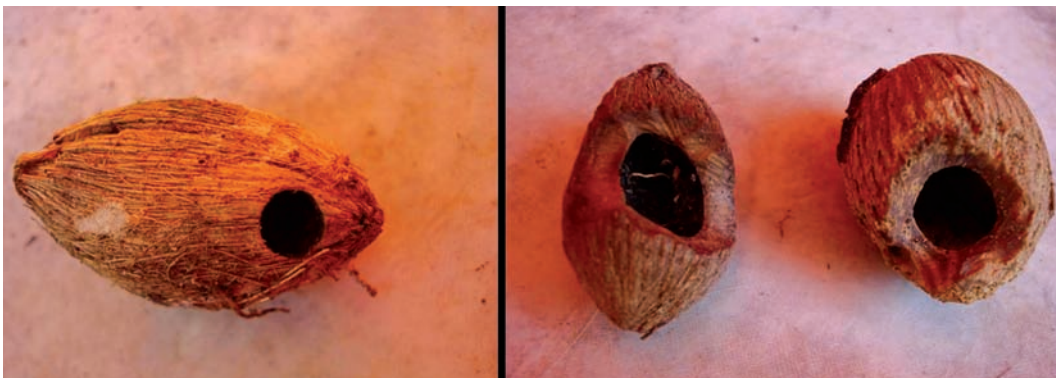
47°45'–48°10' W) (Fig. 1). PECB is a neighbor of other pristine areas that together encompass the largest continuous remnant of Atlantic forests (> 1200 km<sup>2</sup>, Ribeiro et al. 2009). The park holds at least 1000 vascular plant species (Lima et al. 2011) and several threatened large frugivores such as Lowland tapirs (*Tapirus terrestris*) and Woolly spider monkeys (*Brachyteles arachnoides*) (Brocardo et al. 2012). Mean annual temperatures vary between 17° and 22°C and mean annual rainfall between 1700 and 2400 mm, with no clear dry season (São Paulo 2008). The disturbed fragment (24°01'S, 47°57'W) is a ca. 20 ha forest patch with evidence of past logging, an impoverished flora and lower trees compared to PECB (Fig. 2). The abundance of *Attalea dubia* is higher in the fragment compared to PECB (Ana Y.Y. Meiga pers. obs.). The fragment is surrounded by pastureland planted with the African grass *Urochloa* sp. (locally known as *braquiária*) used for cattle ranching. The pastureland is sprinkled with a few isolated *A. dubia* (Fig. 2).

**Study species:** *Attalea dubia* (Mart.) Burret (Arecaceae) is a ca. 20 m tall palm endemic to the humid Brazilian coastal forests (Henderson et al. 1995). In PECB, flowering occurs between February and April, while unripe fruits are presented throughout the year with ripe fruits peaking between September and October (Ana Y.Y. Meiga unpubl. data). The endocarp is covered with a fleshy, orange and fibrous pulp (mesocarp) surrounding one “seed.” For easy interpretation we will refer to the seed plus endocarp as “seed.” Seeds are 4.2 ± 0.4 cm in length and 2.4 ± 0.2 cm in diameter (mean ± SD, n=484), with 16 ± 4 g of fresh mass (n=12). In PECB, Capuchin monkeys (*Sapajus nigritus*) feed on the fruit pulp and thereafter drop the seeds beneath the palm. Squirrels (*Sciurus igrami*) and unidentified Sigmodontinae

rodents prey on or scatterhoard the seeds and supposedly disperse and behave as seed predators (Ana Y.Y. Meiga unpubl. data), similar to what has been reported for *Attalea* species elsewhere (Carvajal & Adler 2008, Almeida & Galetti 2007). Larvae of boring beetles (*Pachymerus* sp.) prey on the seed of *A. dubia*, leaving a characteristically circular hole in the seed coat that enables us to discriminate predation between beetles and rodents (Steffler et al. 2008) (Fig. 3).

**Measurements of seed predation:** To evaluate seed predation, we collected all seeds found in quadrats under adult palms in November 2011. Only palms that finished fruiting were sampled. In PECB, we sampled seeds in a 2×2 m quadrat adjacent to each of ten adult palms. Sampled palms were at least 100 m away from one another and with a minimum distance of 10 m from the nearest conspecific fruiting palm. In the forest fragment, where adult palms and seed density were higher, we randomly selected four adult palms with a minimum distance of 40 m from one another and at least 5 m from the nearest fruiting palm. In the pastureland we sampled four palms with a minimum distance of 40 m from the nearest conspecific. In the fragment and pastureland we collected all the seeds found on a 1×1m quadrat adjacent to each palm. All seeds were carefully inspected and assigned to a category of fate: intact, preyed on by rodents, preyed on by beetles or rotten. We compared seed density among sites with one-way ANOVA. We evaluated if the proportion of seeds in fate categories differed among sites with sequential G-tests (Rice 1989). We tested if there was a relationship between seed predation by rodents and beetles with linear correlation (both variables Log transformed). To investigate the possibility of granivore satiation

3. Seeds of *Attalea dubia* preyed on by beetles (left) or by rodents (right) (Photos: Ana Y.Y. Meiga). Each seed has a mean length of 4.2 cm.



we regressed the number (Log) or proportion of intact seeds/m<sup>2</sup> against the total number of seeds/m<sup>2</sup> (Log). For correlations and regressions we pooled all palms and sites for the analysis to increase power. All tests followed Zar (1999).

## Results

The density of seeds/m<sup>2</sup> under adult palms differed among sites (ANOVA:  $F=7.3$ ,  $df=2$ ,  $p=0.006$ ). The PECB, fragment and pastureland had  $6.3 \pm 1.2$ ,  $25.8 \pm 13.3$  and  $43.8 \pm 12.9$  seeds/m<sup>2</sup>, respectively (mean  $\pm$  SE of untransformed values). There were marked differences among seed fate categories and sites (G-test:  $G=196.6$ ,  $df=6$ ,  $p<0.001$ , Fig. 4). Intact seeds dominated samples at all sites (up to 87% in pastureland). Seed losses to rodents (up to 35%) were more common than those to beetles in PECB and in the fragment but not in the pastureland (Fig. 4). Beetles destroyed up to 16% of seeds at any given site. Rotten seeds were common in PECB (30%), rare in pastureland (<1%) and absent in the fragment (Fig. 4). Observations of the residual frequencies and sequential G-tests indicated that palms in the pastureland contributed significantly larger positive deviance than expected for intact seeds and negative deviances for seeds rotten, preyed on by rodents or beetles. Palms in PECB had a positive deviance for rotten seeds and a negative deviance for intact seeds. Finally, palms in the fragment had an excess of seeds preyed upon by rodents and a negative

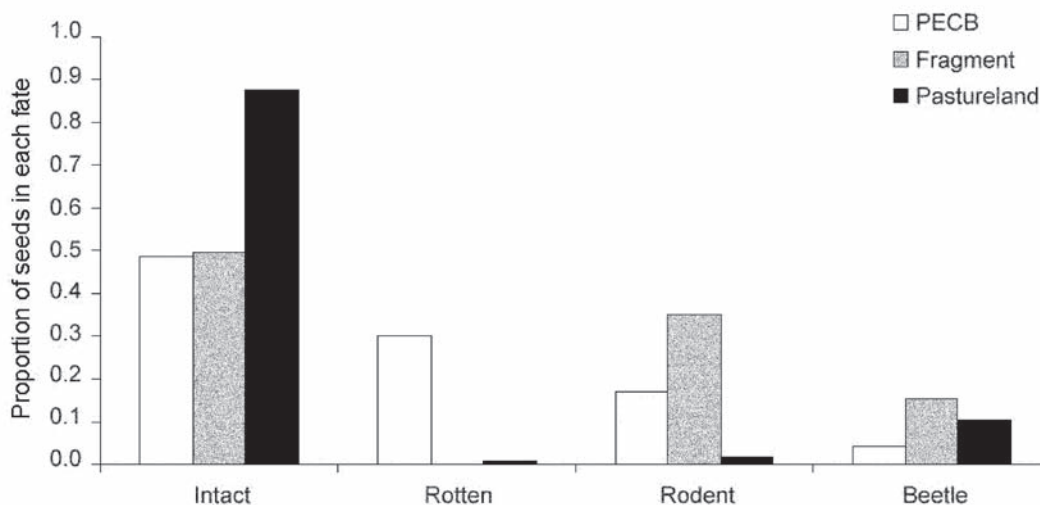
deviance of intact and rotten seeds. Seed predation by rodents and beetles did not vary between PECB and fragment ( $G=1.51$ ,  $df=1$ ,  $p=0.22$ ).

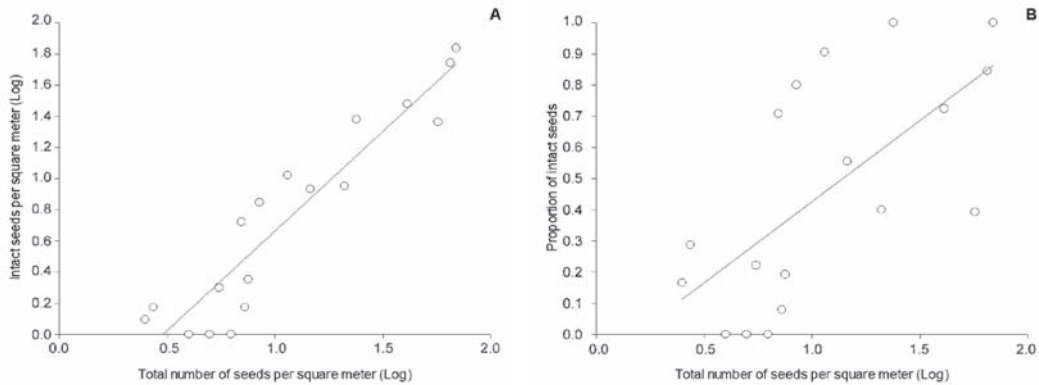
Contrary to expectations, seed predation by beetles and rodents did not show compensation and were positively related (Linear correlation on log-transformed data:  $r=0.56$ ,  $n=16$ ,  $F=7.28$ ,  $p=0.016$ ). Both the number of intact seeds/m<sup>2</sup> (slope= $1.28 \pm 0.12$ ,  $r^2=0.87$ ,  $n=16$ ,  $F=111.1$ ,  $p<0.001$ ) and the proportion of intact seeds/m<sup>2</sup> (slope= $0.52 \pm 0.15$ ,  $r^2=0.44$ ,  $n=16$ ,  $F=12.6$ ,  $p=0.002$ ) were positively affected by increments in the total number of seeds/m<sup>2</sup> under palms (Fig. 5).

## Discussion

We found great variation in the main sources of mortality of the seeds of *Attalea dubia* across the gradient of forest disturbance. However, we detected no clear effect of compensation among the sources of mortality among and within sites. The more disturbed the site, the larger was seed density and survival under parent plants. Although we did not measure seed production, we expected a significant increase in crop size with increasing disturbance because there is evidence that forest palms, such as *Attalea speciosa* from the Amazon, invest more resources to reproduction whenever exposed to high light conditions such as in pasturelands (Barot et al. 2005). The congeneric *A. humilis* also shows increased reproductive output in disturbed BAF

4. Variability in the fate of seeds found under adult palms of *Attalea dubia* in a gradient of forest disturbance in southeast Brazil. The old growth forest found at Carlos Botelho State Park (PECB) had 253 seeds sampled, followed by 104 and 175 seeds in a nearby disturbed forest fragment and a pastureland, respectively. See text for details of sampling and results of comparisons.





5. Influence of the total amount of seeds on the number (A) or proportion (B) of seeds that escape predation beneath the palm *Attalea dubia* in a gradient of Atlantic forest disturbance in southeast Brazil. Each dot depicts data for one palm and all sites are pooled. Both relationships were significant suggesting that plants producing large seed crops attain higher seed survival.

compared to controls (Andreazzi et al. 2012). Thus, more seeds would be available for seed dispersers and predators in disturbed sites. We found indirect evidence for the same effect in *A. dubia*, with four- and seven-fold higher density of seeds/m<sup>2</sup> beneath palms in the fragment and pastureland, respectively, than in the old-growth forest (PECB). A lower removal of fallen fruits/seeds by vertebrates in disturbed sites could also contribute to these values (Cordeiro & Howe 2003, Galetti et al. 2006, Terborgh et al. 2008, Donatti et al. 2009).

High seed density beneath palms increases the number and proportion of intact seeds, suggesting predator satiation (Janzen 1971, Wright 1990). This surplus of intact seeds in disturbed sites may decrease seed limitation and increases the likelihood of plant regeneration, since plants producing large seeds like *A. dubia* are often more seed limited (Moles & Westoby 2002). We often found *A. dubia* seedlings around adult palms in all sites (A.Y.Y. Meiga and A.V. Christianini pers. obs.). Indeed, spatially aggregated patterns of palm recruitment are common in disturbed BAF sites suggesting the possibility of enhanced plant recruitment near parental palms following disturbances, as has been shown for *A. humilis* (Souza & Martins 2004) and *Syagrus romanzoffiana* (Sica et al. 2014). High seed output and low seed predation may thus explain the increases in the abundance of *Attalea* in disturbed forest fragments compared to old-growth forests (Wright & Duber 2001, Souza & Martins 2004, Andreazzi et al. 2012, this study).

Pathogens, rodents and beetles respond to the largest source of seed loss in the PECB,

fragment and pastureland, respectively. Low light and high humidity, typical of old-growth humid forests, often favor pathogen infestation of seeds (Augsburger 1984). Fragment edges and pasturelands are subject to high light conditions that are correlated with increased predation hazard to rodents that, consequently, avoid these areas (Stevens & Husband 1998). Rodent abundance and diversity are often reduced in BAF fragments (Pardini 2004), which may be followed by a decrease in interactions between rodents and palm seeds in small fragments (Fleury & Galetti 2004, 2006). However, contrary to this expectation we found relatively high seed predation by rodents in the disturbed fragment. It is possible that small and generalist species of granivorous rodents increase in abundance in disturbed and small fragments of BAF (Pardini 2004) in response to a decrease in top predators that control their abundance (e.g., Dirzo et al. 2014). The higher density of rodents in these areas would translate in increased seed predation by rodents (Dirzo et al. 2007). Low resource availability in fragments may also increase the likelihood of seed predation by rodents that otherwise would behave as scatterhoarders and seed dispersers (Jorge & Howe 2009). The effect of BAF disturbance on palm seed predation is rather complex and hard to predict, as it seems to be not a linear function of fragment size, distance to fragment edge, type of surrounding matrix and degree of defaunation, with palm identity also playing a role (Fleury & Galetti 2004, 2006, Galetti et al. 2006, Donatti et al. 2009, Fadini et al. 2009, Andreazzi et al. 2012). Beetles are the only relevant source of seed mortality in all sites along the gradient of forest

disturbance. This result indicates that *Pachymerus* sp. is able to disperse, find and colonize available seed hosts in pasturelands away from forests, but they are unable to cause drastic reductions in the amount of intact seeds. Although a shift between rodent and beetle seed predation was observed in PECB and the pastureland, beetles did not compensate when seed predation by rodents fell to low values within a site, as demonstrated by the positive correlation between rodent and beetle seed predation. Fruit pulp may work as a barrier against seed boorers, and pulp removal by rodents may increase opportunities of oviposition by weevil beetles (Silvius & Fragoso 2002, Ríos & Pacheco 2006, Rodríguez et al. 2014). This may be the reason why seed predation of *A. dubia* by beetles is much higher in Cardoso State Park (48.9% of seeds preyed on by beetles, Steffler et al. 2008), a large and protected site where the abundance of large rodents such as agoutis (*Dasyprocta* spp.) is higher than many other BAF sites (Donatti et al. 2009). Therefore, in the face of a decrease in rodent activity in pasturelands, reproductive success of beetles may be limited, and they may be unable to take advantage of the high number of undispersed seeds available beneath parent plants.

Release from seed predation and increasing crop size in response to disturbances may underlie the unexpected increase in *Attalea* abundance in human modified landscapes (see also Barot et al. 2005, Andreazzi et al. 2012). From a community perspective, low palm seed predation rates following disturbances may create opportunities for exotic plant invasions that often impoverish the biodiversity value of human modified landscapes. For instance, low seed predation and high plant fecundity are among the possible causes of the successful invasion of disturbed BAF by the Australian palm *Archontophoenix cunninghamiana* (Christianini 2006). Low seed predation of competitive superior species, such as *Attalea* (Aguiar & Tabarelli 2010, Andreazzi et al. 2012), may also increase community dominance of these species and decrease plant diversity in the long run (Wright & Duber 2001, Wright 2003).

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# ***Coccothrinax jimenezii* – A Critically Endangered Palm from Hispaniola**

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*Coccothrinax jimenezii* M.M. Mejía & R.G. García (Fig. 1) is assigned the IUCN's Critically Endangered conservation category. Extensive field work performed in 2015 confirmed the existence of a population of 43 individuals, mostly juvenile, in Haiti (previously reported in 1995). These field studies also corroborated that the species (18 individuals, mostly adults) is restricted to only a single site in the Dominican Republic. None of the trees was in reproductive stage during our visits. Two major conservation challenges include: (1) a current trend for water levels to increase in the hypersaline Lago Enriquillo and (2) harvest of palm leaves for making brooms in Haiti. Recommendations are made to collect seed for ex situ conservation and future species reintroductions in its original habitat.



1. Individuals of *Coccothrinax jimenezii* growing in a cluster on the fringing fossil coral reef near the shoreline of Lago Enriquillo, Dominican Republic.

Palms represent one of the most important elements of the Caribbean Island landscapes. They are also characteristic species of several of the vegetation types of the region. In addition, there are major concerns regarding palm conservation in these islands (Henderson et al. 1990; Zona et al. 2007; Roncal et al. 2008).

*Coccothrinax* (ca. 50 species) (Arecaceae) is restricted to the Caribbean Basin [Mexico, Belize, South Florida, Paria Peninsula (Venezuela), Trinidad, Tobago, Margarita Island, the Bahama Archipelago, the Greater Antilles, and the Lesser Antilles] (Dransfield et al. 2008). Most species of *Coccothrinax* are island endemics confined to the Caribbean Island Biodiversity Hotspot. Ten of these insular species occur in Hispaniola, with six of them endemic to the island (Mejía & García 2013); the remaining four are shared with other Caribbean islands. *Coccothrinax* is regarded as taxonomically difficult, in need of taxonomically reviewed, to establish clear species boundaries (Dransfield et al. 2008).

The latest described species within this genus, *Coccothrinax jimenezii*, was discovered and

described by taxonomists from the National Botanic Garden of the Dominican Republic (NBGDR) (Mejía & García 2013, Fig. 1). The specific epithet honors Francisco Jiménez Rodríguez, Head of the Botany Department of the NBGDR. In this paper we focus on the distribution range and conservation issues of *C. jimenezii* as a distinct species without discussing potential taxonomic relationships with other taxa of the genus. However, in the original description, Mejía and García (2013) suggested morphological similarities with the Hispaniolan endemic *C. gracilis*.

The original publication described a slender palm that can reach up to 5 m in height, with stem diameter of 4–6 cm (Fig. 2). It has leaf sheaths, 11–13 cm in length, that are smooth on the base and edges, made of two layers of flexible fine fibers and with no spines (Fig. 3). Petioles are (20–)33–34(–42) cm in length, and total leaf length is 51–77 cm. The hastula is 6–10 mm long, 11–13 mm wide, rigid, slightly acuminate to truncate in shape (Fig. 4), hardly noticeable on the leaf underside (Fig. 5). The leaf lamina is covered on both sides by a white-silver indumentum (more noticeable in young



2 The crown of the slender palm *Coccothrinax jimenezii*, at the Lago Enriquillo site, Dominican Republic.

leaves), and comprises 21–28 segments, 24–33 cm in length, 1–2 cm in width. Segments are bifid at the apex. The inflorescences (Fig. 6) are (20–)25–30 cm long, recurved, with 3 or 4 partial inflorescences and each one of them with (4–)10–17(–19) secondary branches, 10–15 cm long, and 13–16 rachillae, 3–6 cm long. Flowers have 4 or 5 stamens; filaments are 1–1.5 mm; anthers are 2 mm long, with two thecae; and the ovary is 1 mm long. Fruits are globose, 4.5–5.5 mm x 5.3–6.3 mm, which are slightly depressed from the apex to the base, verrucose (finely bumpy) in texture, green-yellowish in color turning whitish when fully mature. It has ruminant seeds with 5 or 6 lobes, rounded or slightly flattened, and dark brown in color.

The original description of *Coccothrinax jimenezii* was based on material from the Dominican Republic (type locality) and Haiti (Fig. 7); however, Mejía and García (2013) indicated that the only known record from Haiti came from a single herbarium collection made by T. Zanoni, M. Mejía and R. García in 1985 (specimen 82525, JBSD). With the support of the Mohamed Bin Zayed Species

Conservation Fund, we (BP, AX, WC, BJ) undertook plant exploration expeditions in Haiti in January 2015 (Fig. 2) and in the Dominican Republic (BP, FJ) in March–April 2015 to confirm if this threatened palm still existed in Haiti and to examine the known distribution of the species in the Dominican Republic. Demographic inventories were conducted to determine the number of seedlings, juveniles and adult individuals. DNA samples for conservation genetic studies were collected from all the individuals of the two populations (Fig. 8). Preliminary molecular data indicated that at least seven microsatellite (SSRs) loci can be used to address population and conservation genetics issues from this species. In addition, during our field work we recorded data pertinent to conservation threats. The project also had an outreach component with printed material (one poster and one postcard) produced to be distributed to conservation shareholders.

#### **Distribution, ecology, and conservation concerns**

**Dominican Republic.** The only population of *Coccothrinax jimenezii* from Dominican



3 Fibers of the sheaths of *Coccothrinax jimenezii*, at the Lago Enriquillo site, Dominican Republic.



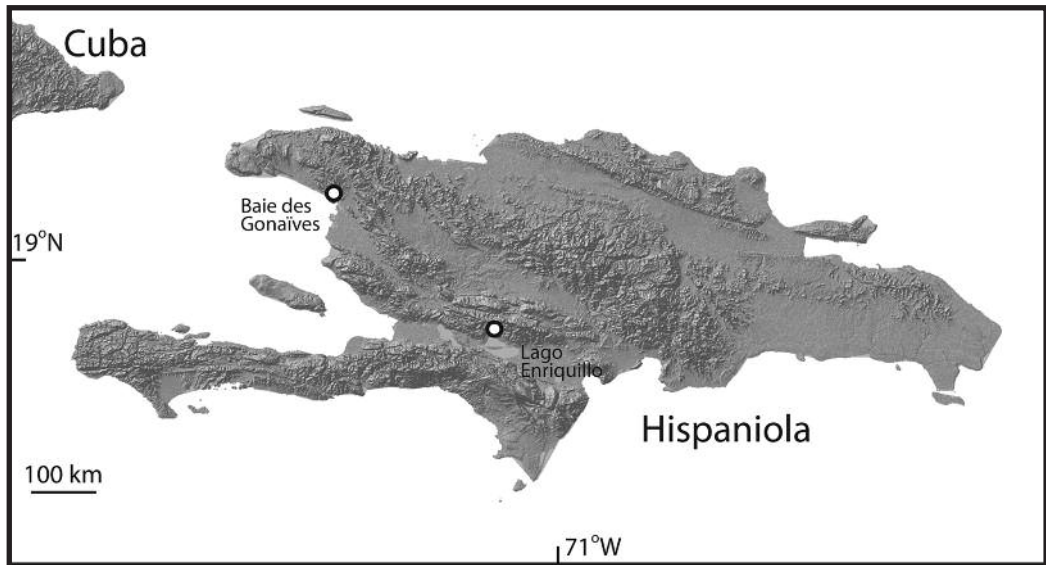
4 (top). Petiole base and hastula (leaf upperside) of *Coccothrinax jimenezii*, at the Lago Enriquillo site, Dominican Republic. 5 (bottom). Petiole base and hastula (leaf underside) of *Coccothrinax jimenezii*, at the Lago Enriquillo site, Dominican Republic.

Republic occurs in Provincia Independencia, near the shoreline of Lago Enriquillo (Fig. 3), a hypersaline lake located 45 m below sea level at approximately 9 km from the border with Haiti. This is the largest lake in the Caribbean Islands, and it has three islands. These islands

and the coastal areas form a national park known as Parque Nacional Lago Enriquillo e Isla Cabritos. Therefore, this population of *C. jimenezii* is officially conserved inside a protected area. Within the park, we found a total of 16 adults and two juveniles. In



6 Inflorescences and upper stem part of *Coccothrinax jimenezii*, at the Lago Enriquillo site, Dominican Republic.



7. Location of the two known populations of the Hispaniolan endemic *Coccothrinax jimenezii* in the Dominican Republic and Haiti.

addition, we recorded one dead plant. None of the adult individuals were in reproductive stage. All plants were growing in a cluster and were relatively close to one another (total distribution area ca. 400 m<sup>2</sup>), except one adult individual that was located at approximately 1.5 km from this core population.

Lago Enriquillo is located along a valley that separates two distinct geological units of Hispaniola that represent two ancient paleo-islands that collided in the Middle Miocene (ca. 16 MYA) (Graham 2003). The environmental history of this valley has been influenced by sea-level changes linked to global climatic change. During interglacial periods it was below sea level (Mann et al. 1984). The exposed geology of Lago Enriquillo provides additional evidence for past marine environments, as outcrops of an extensive fossil coral reef fringe many sections of this lake (Reuter et al. 2013). *Coccothrinax jimenezii* grows on one of these fossil coral reef outcrops. The vegetation type can be defined as a Lowland Drought-Deciduous Shrubland with elements from the Mixed Evergreen-Deciduous Thorn Woodland, following the vegetation classification of Areces-Mallea et al. (1999). The most common plants growing in the area where this palm occurs are: *Plumeria subsessilis* (Apocynaceae), *Tabebuia microphylla* (Bignoniaceae), *Guaiacum officinale* (Zygophyllaceae), *G. sanctum*, *Isidorea leonardii* (Rubiaceae), *Cameraria linearifolia* (Apocynaceae), *Echites umbellatus* (Apocynaceae), *Acacia scleroxyla*

(Fabaceae), *Turnera diffusa* (Passifloraceae), *Calliandra haematomma* (Fabaceae), *Melocactus lemairei* (Cactaceae), *Guapira brevipedunculata* (Nyctaginaceae), *Ziziphus rignoni* (Rhamnaceae) and *Croton poitaei* (Euphorbiaceae) (Mejía & García 2013).

In the last ten years Lago Enriquillo has experienced an unexpected rise in water level. This has resulted in flooding that has had negative effects in farmland and roads (Romero Luna 2011). It is unclear what environmental variables are behind the water dynamics of this lake, although Romero Luna (2011) suggested that atypical rain fluctuations could account for changes in the lake water levels. Because the only known Dominican Republic site of *C. jimenezii* is located near the shore of this lake, we believe that changes in the hydrology represent a potential threat for the conservation of this species. Because of this major conservation concern and the fact that the population of Lago Enriquillo has fewer individuals than that of Haiti (see below), we recommend collecting seeds for *ex situ* conservation and a future reintroduction program as a main management priority for the national park authorities. It is worth mentioning that during our field trips we did not notice any use of this palm by the people who reside in this area.

**Haiti.** The only site of *Coccothrinax jimenezii* in Haiti is in the vicinity of the city of Gonaïves, Département de l'Artibonite, growing on limestone substrate; however, this substrate



8. Pierre Angelo Joseph collecting leaf samples of *Coccothrinax jimenezii* for DNA studies, at the Gonaïves site, Haiti.

did not seem to be associated with a fossil coral reef. The site is located approximately 250 m from the coastline of the Baie des Gonaïves (Fig. 3). This locality has 43 individuals, 42 of them formed a cluster that covered ca. 10,000 m<sup>2</sup>. One isolated individual was found at approximately 1 km from this cluster. The vegetation type can be defined as a Lowland Drought-Deciduous Shrubland with strong marine littoral influence. Common plants found in this area include: *Prosopis juliflora* (Fabaceae), *Parkinsonia praecox* (Fabaceae), *Consolea moniliformis* (Cactaceae), *Pilosocereus polygonus* (Cactaceae), *Tabebuia* sp., *Agave antillarum* (Asparagaceae), *Stylosanthes hamate* (Fabaceae), *Convolvulus nodiflorus* (Convolvulaceae), *Jacquemontia havanensis* (Convolvulaceae), *Stigmaphyllon emarginatum* (Malpighiaceae), *Echites umbellatus* (Apocynaceae), *Mesechites repens* (Apocynaceae), *Melocactus lemairei* (Cactaceae), *Tournefortia stenophylla* (Boraginaceae), *Cissus trifoliata* (Vitaceae), *Melochia tomentosa* (Malvaceae), *Tridax procumbens* (Asteraceae), *Capparis flexuosa* (Capparaceae), *Turnera diffusa*, *Mammillaria* sp. (Cactaceae), *Plumeria subsessilis* and *Picrodendron baccatum* (Picrodendraceae).

Despite this population having more individuals than the one in the Dominican Republic, none of the plants was more than two meters tall. Most individuals were below 1.0 m in height, and they were identified as juveniles. We did not find any seedlings, and none of the plants had fruits or flowers. We also noticed that the leaves of this species seem to be heavily harvested (Fig. 9) to make brooms, an ethnobotanical practice that we believe has detrimental consequences for the plants and might explain why all of the individuals were so short and without mature leaves. Indeed, we located only one isolated individual that was not harvested and still had a full crown of leaves.

#### Conservation assessment

Assessment for the conservation status of the target species was achieved using the red listing categories and criteria established by the IUCN (2014a). The IUCN (2014b) data base of threatened species does not include this species. In addition, Mejía and García (2013) did not provide an IUCN-based conservation assessment for this species because information for this species in Haiti was lacking. Based on



our field studies the species should receive the Critically Endangered (CR) conservation status (criteria B2C2i). The species has this status because it meets the following two criteria: [1] an Area of Occupancy below 10 km<sup>2</sup> (criteria B2) and [2] fewer than 250 mature individuals, an observed continuing decline and fewer than 50 mature individuals in each population (criteria C2i).

#### Acknowledgements

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# Photo Feature



A beautifully grown and displayed clump of *Pinanga philippinensis* at the Jeff and Suchin Marcus palm collection, Floribunda Palms, Hawai'i.

JOHN DRANSFIELD,  
*Royal Botanic Gardens, Kew*

## News of the Society

### Call for Nominations for IPS Board of Directors for 2016–2020 Term of Office

If you know anyone who can contribute to the goals of the International Palm Society and is willing to dedicate the time necessary to serve as a Director, please submit his/her name for nomination to Administrative Secretary Larry Noblick by the deadline of October 31, 2015.

**Nominating requirements:** A candidate must have been a Member of the Society for two years before being nominated as a Director. Any IPS Member may propose a candidate for nomination by writing an email or letter to the Administrative Secretary. A second nomination in writing from another Member is also required. The proposed candidate must submit to the Secretary a written consent of willingness to serve if elected.

**Duties and expectations of the IPS Directors:** The IPS Board of Directors has general charge of the affairs and business of the Society including the management of the Society's funds. Directors are expected to take an active role in Board activities by serving on appropriate committees. The Board meets once a year, at the Biennial meeting or at an Interim Meeting. An ability and willingness to travel to all (or most) of the annual Board Meetings at the Director's own expense is a strong consideration used by the Nominating Committee when selecting candidates.

The Nominating Committee for the upcoming election comprises Faith Bishock, Horace Hobbs, Julie Cleaver Malzoni, Kathryn Morgan and Lee Tracy. Questions concerning the nominating and election processes may be sent to Kathryn Morgan, IPS Nominating Committee Chair, at KathrynMorganIPS@yahoo.com, or Larry Noblick, IPS Administrative Secretary, at larryn@montgomerybotanical.org.

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### The 2016 IPS Biennial: Malaysia & Singapore

The itinerary for the 2016 IPS Biennial is now set, and the last arrangements are being made. We expect to have all of the details finalized and registration open by the end of 2015, so keep an eye on the IPS website! The Biennial will begin on Sunday, June 12 in Kuching, Malaysia, on the island of Borneo. We shall be based in Kuching for the first four nights of the Biennial, making day trips to visit habitat locations in Bako National Park and Kubah National Park, where approximately 40 different species of palms can be seen (including large numbers of *Johannesteijsmannia altifrons* and *Licuala orbicularis*). In addition, we shall visit the Semenggoh Nature Reserve, tour its spectacular collection of Bornean palms and see semi-wild orangutans. A free day will also be available with a range of tour options, including locations with an emphasis on palms, wildlife and/or cultural experiences. After four nights in Kuching, we shall make the short flight to Singapore, where we shall spend the next three nights at the world-class Marina Bay Sands hotel. While in Singapore, our focus will be two amazing gardens, the Singapore Botanic Gardens and Gardens by the Bay. In addition, we shall also have a chance to see roughly a dozen species of palms in habitat during a visit to the MacRitchie Reservoir. The tour will conclude on Sunday, June 19. This promises to be a once-in-a-lifetime palm event, with a dizzying array of natural habitats and world-famous botanical gardens.

In addition to the main Biennial, a pre-tour to Malaysian Borneo will also be offered starting on Sunday, May 29, in Miri. Over the course of 13 days, this tour will visit the best palm habitats on the island, all of which have been selected based on multiple reconnaissance trips conducted by IPS board members. There will be an opportunity to see a staggering 70 different species of palms in habitat. Specific destinations will include the National Parks of Mulu, Lambir Hills, and Similajau, along with several other areas of pristine tropical jungle. There will also be a six-day post-tour to view the palms of the Northern Territory in Australia. Darwin is a relatively short flight from Singapore and will serve as the jumping-off point for this tour. Highlights will include visits to the National Parks of Litchfield, Gregory, Eusey, Nitmiluk and Kakadu, along with other local parks and the well-established George Brown Botanical Garden in Darwin. This tour will provide access to a range of spectacular palms that are rarely found in cultivation, such as *Livistona inermis*, *L. victoriana* and *Hydriastele ramsayi*. The tour will conclude in Darwin on Saturday, June 25.

