Palms

Journal of the International Palm Society Vol. 58(1) Mar. 2014

THE INTERNATIONAL PALM SOCIETY, INC.

The International Palm Society

Founder: Dent Smith

The International Palm Society is a nonprofit corporation engaged in the study of palms. The society is international in scope with worldwide membership, and the formation of regional or local chapters affiliated with the international society is encouraged. Please address all inquiries regarding membership or information about the society to The International Palm Society Inc., 9300 Sandstone St., Austin, TX 78737-1135 USA, or by e-mail to info@palms.org, fax 512-607-6468.

Bookstore: www.palms.org

Chapters: See listing in the Supplement.

Website: www.palms.org

Palms (formerly PRINCIPES)

Journal of The International Palm Society

An illustrated, peer-reviewed quarterly devoted to information about palms and published in March, June, September and December by The International Palm Society Inc., 9300 Sandstone St., Austin, TX 78737-1135 USA.

Guidelines for authors are available on request from the Editors or on-line at: www.palms.org/palms_author_guidelines.cfm

Annual membership dues are US$45.00 for Individuals (or US$120 for three years) and include a subscription to the Journal. Donor memberships are US$500 per year. Individual Lifetime memberships are available for a one-time fee of US$1000. Benefactor memberships require a one-time payment of US$2500. Subscription price is US$45.00 per year for libraries and institutions. Dues include mailing of the Journal by airlift service to addresses outside the USA. Dues may be paid on-line at www.palms.org.

Change of Address: Send change of address, phone number or e-mail to The International Palm Society Inc., 9300 Sandstone St., Austin, TX 78737-1135 USA, or by e-mail to info@palms.org.

Claims for Missing Issues: Claims for issues not received in the USA should be made within three months of the mailing date; claims for issues outside the USA should be made within six months of the mailing date.

Periodical postage paid at Austin, TX, USA.
Postmaster: Send address changes to The International Palm Society Inc., 9300 Sandstone St., Austin, TX 78737-1135 USA.

PALMS (ISSN 1523-4495)

Mailed at Lawrence, Kansas 15 Mar. 2014

The full text of PALMS is available on EBSCO Publishing's database.

This publication is printed on acid-free paper.

CONTENTS

Features

Infructescences of *Bactris manriquei*, a new species from Bahía Málaga, Valle del Cauca, Colombia. See article by R. Bernal et al., p. 45.

FRONT COVER

The spectacular, new *Sabinaria magnifica* has leaves that are silvery-white on the underside. See article by R. Bernal, p. 5. Photo by R. Bernal.

BACK COVER

The rare, Madagascar endemic, *Lemurophoenix halleuxii*. See article by Shapcott et al., p. 27. Photo by A. Shapcott.

PALM NEWS

Disturbing news from Hawaii: **the coconut rhinoceros beetle (*Oryctes rhinoceros*), a pest of coconuts and other palms, has been found in Hawaii**. The beetle was caught on Oahu in December of 2013 during routine surveys. Since the discovery, the state Department of Agriculture and the U.S. Department of Agriculture have been working jointly to conduct trapping activities and determine the extent of the infestation. Nine beetles have been caught. The coconut rhinoceros beetle is a major pest of palms in India, the Philippines, Fiji, Samoa, Guam and other Pacific island, but until now, Hawaii was not infested. It is not known exactly how the beetles arrived in Hawaii.

The fourth **World Palm Symposium 2015** is being organized and will take place in Salento, Quindío, Colombia. Palm researchers from all over the world will meet on 24–28 June 2015 for an academic conference organized by the University of Aarhus, the National University of Colombia, the Quindío Botanical Garden, and the IRD and CIRAD institutes in France. Topics will include palm systematics, evolution, genetics, floristics, ecology, biogeography, conservation, ethnobotany and others. Details of the conference can be found at the website www.palms2015.au.dk.

The EUNOPS meeting for 2014 will be held this year at the University of Valencia Botanic Garden in Spain 10–12 May. EUNOPS (European Network of Palm Scientists) holds annual informal gatherings of biologists interested in palms for discussions and presentations. Further details can be found on the EUNOPS website (www.eunops.org).

The Bulletin of the Palm Society (January–July 1956) is now available in the Members-only section of the IPS website; in the Members Only pull-down menu it is listed as Palms Bulletin (1956). The six bulletins represent a direct precursor to Principes that began publication in October 1956. Issued as mimeographed pages, the Bulletin is a rare commodity and provides a fascinating insight into the origins and early growth of the Society. The **Supplements to PALMS**, which were regularly mailed with the journal, are no longer published quarterly. Supplements will be published as needed for elections of officers, Biennial registrations and other IPS business. Announcements from the IPS are made on the website (www.palms.org) and in the monthly Newsletter that is sent to members via email. If you are not receiving the Newsletter, please send your email address to info@palms.org and asked to be added to the Newsletter list.

The Discovery of the Amazing *Sabinaria magnifica*

RODRIGO BERNAL
Instituto de Ciencias Naturales,
Universidad Nacional de Colombia,
Apartado 7495,
Bogotá, Colombia.
rgbernalg@gmail.com

1. The locality where *Sabinaria magnifica* grows.

The new genus of fan palm, *Sabinaria,* was recently discovered in the area bordering Colombia and Panama. Here is a narrative of its discovery.

The discovery of a new palm genus in the western hemisphere is a rare event. So rare, indeed, that out of the 184 genera accepted in the family up to 2012, only eleven were discovered in the Americas during the past 100 years. No wonder, then, I was shocked on 15 April 2013 when Saúl Hoyos, a former student of mine, sent me some photos of an unusual palm that looked unlike any genus known to date. Saúl had taken the photos at the base of the Serranía del Darién, the remote, forested mountain range that forms the border between Colombia and Panama, and had grabbed a specimen in a rush, while returning from a trip to the Serranía in search of the elusive *Magnolia sambuensis*. With daylight fading and five hours of forest walk ahead to their base in Capurganá, an idyllic village by the Caribbean Sea, there was no time to botanize anymore, and Saúl and his colleagues collected the specimens and took the photos while the guides urged them to move on.

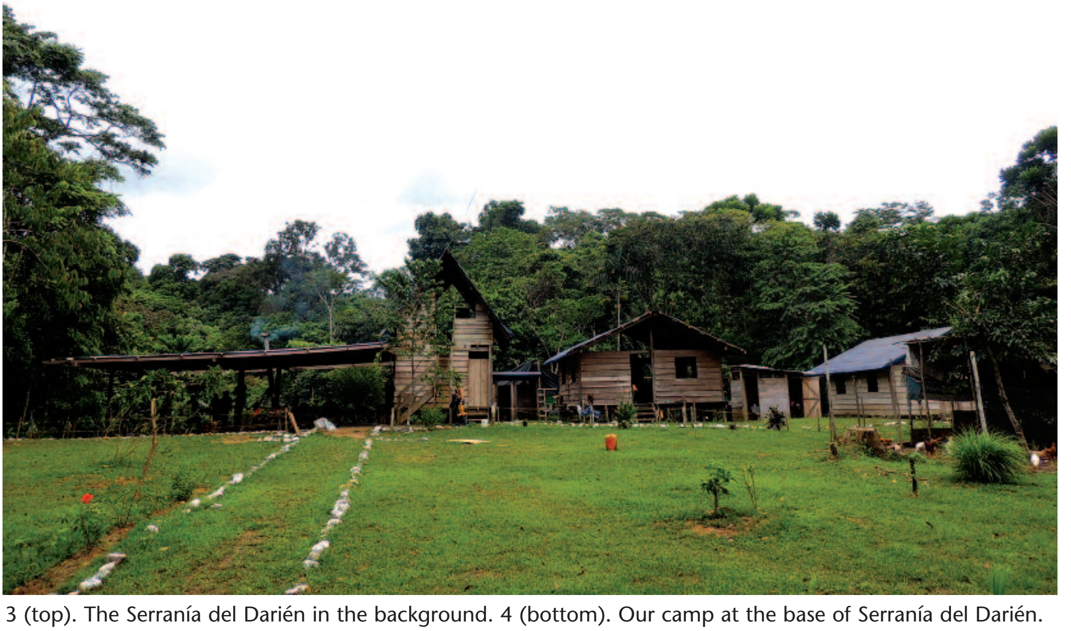
The images Saúl sent me after returning from the jungle showed a magnificent palm with numerous large, circular leaves split almost to the base into two large, perfect fans, the whole blade resembling a huge butterfly. The unripe fruits were tightly packed into a short, compact mass hidden among the leaf bases. A quick look was enough for me to realize that the plant represented a new species in the tribe Cryosophileae, as revealed by the central split of the lamina into two halves. The further undivided fans, however, and the tightly packed fruits were unlike anything else known to date in the group. When the patchy distribution of species and genera in the group is considered, the new palm might even represent a new genus. But the images did not include any details of the stem, the leaf bases or the flowers, which were vital details to proceed any further.

Full of excitement, I called Gloria Galeano, my lifetime companion and fellow palm researcher for over 30 years, who was on her way back from a field trip. "You won't guess what I have in front of me," I told her over the phone. As expected, she did not. "A new palm genus," I claimed, speaking out of my intuition and enthusiasm, rather than from any compelling evidence. I told her the story, and, as I later knew, I spoiled (or blessed – she could not identify the feeling) her ten-hour ride out of the forest.

When Gloria watched the images on the computer screen that evening, she matched my thoughts, not yet put into words: "This is the most beautiful of all Colombian palms," she declared. This wasn't a trivial statement, considering the magnificence of our native palm flora, the largest one this side of the world, which includes the majestic wax palms of the Andes, the fascinating *Wettinia* spp. of the cloud forests, and the elegant riverside *Leopoldinia* spp. of the Rio Negro.

We immediately called Saúl to get more information. He had had no time to make any

2. Our airport shuttle in Acandí (No, that's not the plane we arrived on).



3 (top). The Serranía del Darién in the background. 4 (bottom). Our camp at the base of Serranía del Darién.

detailed observations but he did remember that the stem was unarmed, which ruled out *Cryosophila,* distinctive in its adventitious roots modified into branched spines. Was the leaf sheath medially split at the base? He hadn't observed that, and, alas, the photos didn't reveal that detail. He didn't even remember if there was anything else in the hastily grabbed specimen, besides one leaf and an unripe infructescence. Thus, we asked the curator of the Herbarium at the Medellín Botanic Garden, our old friend Álvaro Cogollo, to send the specimens on loan to the National Colombian Herbarium in Bogotá.

After three itchy days, the specimens were finally at hand. By then, we had already considered all taxonomic possibilities and discussed all potential names for the new species and, just in case, the new genus. If it were a new genus, I suggested, we should call it *Sabinaria*, as a gift to our daughter Sabina, who has learnt since her childhood what it means to have as parents a couple of botanists who are away in the forest most of their time. And the specific epithet? Honoring Saúl Hoyos, who had brought the new palm to our attention, seemed obvious.

The herbarium specimen turned out to have an old inflorescence with some flower remains still partially recognizable. These showed some resemblance to the flowers of the beautiful *Itaya amicorum*, a rare palm known from a few scattered localities in the northwestern Amazon, on the other side of the Andes and at least 1300 km away from our conundrum. The discovery of a second, trans-Andean species of *Itaya* would be as surprising, indeed, as finding a new genus.

6. The oily fruits of *Elaeis oleifera.*

There was no time to lose. We immediately planned a field trip with Saúl to the Serranía del Darién, managing to slip a full week of

5. A stand of *Elaeis oleifera* near Capurganá.

7. Habit of *Sabinaria magnifica*.

absence into our previous agendas. We would fly to Acandí, a small town by the coast some 20 km southwest of the Serranía, the nearest operating airstrip after the closer airport at Capurganá ceased commercial operations in 2012. From Acandí we would take a 40 minute boat trip along the Caribbean coast to Capurganá, where a seven-hour walk through the forest would take us to our enigmatic palm. But two days before our departure on May 18, a general strike broke out in Acandí and Capurganá, every kind of transportation was

8. Leaves of *Sabinaria magnifica*.

paralyzed, and the airport was blocked. There was no way to reach the area. By the time the demonstrations ceased four days later, it turned out to be impossible for the three of us to match a suitable gap in our schedules within the next 100 days.

On August 26, 2013, after three long months of expectation, we finally met Saúl at the airport in Medellín, where we would board our plane for Acandí. Saúl was accompanied by Norman Echavarría, an enthusiastic student of biology whose family runs a beach hotel in Capurganá. Norman was in Saul's team when they first collected the palm, and it was he who first called Saul's attention to the strange palm; at the last minute he had managed to join us – if he found an available seat in the fully booked small plane. After a long wait he got the seat of the only passenger who did not show up, and we boarded the small twin-engine propeller aircraft.

After an uneventful flight over the northern end of the Andes, we landed in Acandí, a small and friendly coastal town in the northwestern most corner of South America. The Serranía del Darién with its spectacular forests was in front of us when we got off the plane. A couple of two-wheel buggies took us to the town, where we stopped to buy our supplies. By noon we boarded a boat for Capurganá, a smaller, quiet village, where we stayed at Norman's wonderful family hotel.

Early next morning our mule driver, Orlando, showed up with his brother and three bays, two for our gear and one for himself. By seven o'clock we were already underway in what is considered by many people to be one of the most dangerous crossings in the continent. The trail winds up and down through three forested ranges before reaching the place where our palm grows, and then crosses the Serranía and continues into Panama. Although the distance from Capurganá to our campsite is only eight kilometers as the crow flies, it takes at least five hours to reach there. At a botanist's pace, however, we counted on no less than seven hours. It took us eleven!

The path leaves the village quite soon, and then leads through a narrow coastal plain, where a superb wild stand of the American oil palm, *Elaeis oleifera*, still survives the menacing advance of vacation houses. The thick recurved stem of this palm is prostrate on the ground, and it takes strange forms as the palm crown falls and resumes growth once and again several times throughout the plant's lifetime. The abundant red bunches of ripe, oily fruits reminded us of the paradoxical fate of this promising species, which should have been domesticated long ago, but has seen instead a decline of its wild populations, and is now an endangered species, whereas its African sister, *Elaeis guineensis*, has become one of the country's major crop plants.

After leaving the coastal plain, the mule trail ascends through the moist forest, crossing crystalline creeks here and there. As our mule drivers had to return to Capurganá the same day, we soon agreed that they should better continue at their own pace, leave our sacks at the camping site and return right away, while we proceeded our slow march. We stopped many times to study the various palms and other interesting plants we found on the way,

9 (left). A leaf of *Sabinaria magnifica* held by Angie Henao. 10 (right). Leaf bases of *Sabinaria magnifica*.

11. Young seedlings of *Sabinaria magnifica* showing the silvery undersides of their leaves.

and to look for the fruits of a giant *Magnolia sambuensis*, the tree Saúl and Norman had sought during their previous trip in the area. We also enjoyed following a noisy troop of silvery-brown tamarins, who jumped among the branches, and later we watched a group of large howler monkeys, who observed us as attentively as we observed them, and then bombed us from the canopy with dung.

It was past three in the afternoon when Saúl proudly introduced us to the first individual of the palm that had captured our minds for the past months. *Spectacular* was the first word that came to my mind. The photos we had seen before had revealed but a hint of its actual magnificence. The palm has a stem that is usually about three meters tall, and bears over thirty leaves held on petioles almost that length. Each leaf blade is deeply divided almost to the base into two large fans, so that the whole crown looks like a bouquet of giant butterflies. The leaf undersurface has a beautiful silvery-white color that is not evident at first glance when seen with backlight but which is striking when the crown is lit with a light, as that of a camera flash. The first thing we checked was the petiole base, which turned

12. *Sabinaria magnifica* at its typical habitat.

out to be medially split. This ruled out the genus *Chelyocarpus*, one of the potential candidates, with one species, *Chelyocarpus dianeurus*, well known to us from further south in the Chocó region.

The population had lots of adult palms, as well as many seedlings and juveniles. We eagerly sought flowering plants, but all the palms that we inspected had only old inflorescences that broke into pieces when touched, leaving only the peduncular and rachis bracts. While we inspected the palms, our mule drivers passed by on their way back to Capurganá. They were familiar with the palm, which they call *girasol* (sunflower), and they said they use the large leaves as impromptu umbrellas when surprised on the trail by a downpour. They continued their return and we went on inspecting the palms. After an hour of excitement and avid search, we decided that it was time to proceed our way, as we were still about one hour's walk from our campsite, and daylight was fading. And we had had no lunch so far. Thus, we walked on for a while and made a halt by the diaphanous pool of a forest creek, where we ate the lunch that the hotel's cook had wrapped for us in banana leaves.

The place where the mule drivers had left our gear turned out to be a wonderful settlement in a small forest clearing, with five basic wooden houses, a large and cozy kitchen, nice sanitary facilities and a kind family in charge of the place. There were gardens under

13. The discoverers of *Sabinaria magnifica*. Left to right, Saúl Hoyos, Norman Echavarría, Angie Henao and Gloria Galeano.

14. A ripe infructescence of *Sabinaria magnifica* camouflaged among litter at the leaf bases.

development near the houses, a vegetable patch, and a nursery with all kinds of edible plants, conceived to eventually reach their goal of being close to self-sufficient. As we soon learned, this settlement is one of several similar places owned in wild areas throughout South America by a group of people having a deep sense of oneness with the universe. Their attitude toward nature seems to be more based on their philosophical perception of the world than on sheer conservation or economic grounds. They welcomed us warmly and offered their facilities. Cristina, the housewife, also accepted to cook our food.

15. Fruits of *Sabinaria magnifica* on a leaf of the palm.

Early next day, after breakfast, we were finally ready to look for complete specimens of our wonderful palm. We followed the trail leading into Panama along the crystalline creek, exploring upstream the steep forested slopes here and there, wherever we saw the magnificent butterfly-like leaves. We had been warned by our hosts of the presence of a large jaguar in the area, so we were very cautious, particularly as we were accompanied by Angie Henao, the lovely and avid eleven-year-old daughter of our hosts, who wanted to learn from us and to teach us her knowledge of the forest.

We checked dozens of palms but none had flowers or fruits. In our search we bumped into many other different species of palms, though, including three species previously known from Panama but not yet known to occur in Colombia – the tiny *Bactris charnleyae*, with pencil-thin stems and undivided leaves, the acaulescent *Attalea iguadummat*, with leaves 6 m long and large infructescences that are borne at ground level, and the poorly known *Pholidostachys panamensis*, with thick stems that grow prostrate on the ground like those of *Elaeis oleifera*, and with compact infructescences hidden among the leaves. Despite our excitement with these wonderful discoveries, our concern grew as the day went by and we found no individual of our enigmatic palm with either flowers or fruits. We had only a few more hours for exploration, as next day we had to return to Capurganá.

After a few hours of exploring upstream, we decided to go downstream toward the area where we had seen the first population the day before. We inspected many individuals on the steep slopes along the creek, and we finally found one with two infructescences. These had black fruits about one inch in diameter, tightly packed into a short mass hidden among the leaf bases and covered with litter; they could have been easily overlooked, had we not inspected each palm in detail. These

16. Inflorescence of *Sabinaria magnifica*.

infructescences were unlike any other in related genera, and the closely packed fruits suggested a unique kind of inflorescence. Our excitement grew and we now desperately looked for flowers. We seemed to be actually in the face of a new genus.

By half past two we reached the area where we had found the palm the day before, which we had explored only partially, late as we were to our destination. We spread ourselves throughout the forest, as we had done so far, in order to comb the area. After a few minutes we heard Saul's voice announcing "Flowers!" We all rushed to the place whence his voice had come, some 20 meters north of the trail, and there it was – a palm with a stem 2 m tall, bearing a wonderful inflorescence in full bloom, the numerous whitish flowers being visited by meliponine stingless bees! We all embraced and gave each other high-fives in excitement. We would finally know where our mysterious palm belonged.

After a long session of photography, we were finally able to examine the nice flowers more closely. Our first surprise was to discover that all exposed flowers were only male, but additional flowers were still to be found hidden under the large light brown bracts that covered the lower portion of the flowering branches. Upon carefully opening the bracts to expose the hidden flowers, it was evident that they were different from the ones we had just seen. They looked roughly similar, but they had an evident ovary and the numerous stamens had no anthers – they were female flowers. So, this unusual palm had unisexual flowers, something unknown so far in this branch of the family's evolutionary tree. The palm represented indeed a new genus – *Sabinaria*!

The occurrence of female flowers only on the basal portion of the lower flowering branches accounted for the compact fruit bunches we had found in the morning. This kind of infructescence is not found in related genera, all of which have hermaphroditic flowers, and produce looser bunches with fruits scattered throughout most of the rachillae, and exposed beyond the leaf bases. The hidden female flowers of *Sabinaria* restrict access to the bees that gather pollen from the male flowers, so that they cannot effect pollination. Instead of bees, we found among the female flowers small mystropine beetles, which are probably the true pollinators. These minute, flattish beetles,

17. Detail of the male portion of the flowering branches of *Sabinaria magnifica*.

18. Male flowers of *Sabinaria magnifica* visited by a meliponine bee.

which look as if they are wearing a vest because their front wings are shorter than their bodies, are ubiquitous in palm inflorescences in tropical America, and in some cases a particular beetle species is associated with a single species of palm. In fact, it would come as no surprise if the beetles we found on *Sabinaria* turned out to be a species unknown to science.

We made specimens of the palm for herbaria, with detailed measurements of all its structures, and then continued our search of additional individuals in flower. After some time of unsuccessful exploration, we decided that it was time to return to our base. On our way back we spared time to take a short swim in a gorgeous large pool of the creek and to receive a much-needed massage from the snow-white cascade that flowed into it. While we swam in the pool, we kept thinking of the evolutionary meaning of the discovery we had just made and of the name the new species should bear. Although we had initially planned to name it after Saúl, we were now aware that the name this unique palm would be given might be vital for its future conservation, so it should be an appealing name, one that properly bespoke its magnificence. We kept thinking of it as we walked upstream along the diaphanous creek, and by the time we reached our camp with the last rays of daylight, we had come up with a beautiful name – *Sabinaria magnifica*.

That evening we pressed the specimens of the new palms we had found, but left those of *Sabinaria magnifica* to be pressed with daylight next morning, as our mule drivers were expected to arrive at 10 am. After a pleasant night we woke up early next morning and started pressing the specimens, making additional photos of details, and examining carefully the inflorescence we had at hand. We could hardly believe that we were actually in front of a new genus, but there remained no doubt. The two most similar species, and probably also the closest relatives, are the above-mentioned *Itaya*, of the Amazon, and the Central American *Schippia*, from Belize and Guatemala.

Itaya has hermaphroditic flowers throughout the whole inflorescence, with no large rachis bracts hiding the flowers; the fruits are scattered throughout the flowering branches, and clearly exposed beyond the leaf bases. The leaves are also divided in two halves, but each half is additionally split into several roughly similar groups of segments, the whole leaf blade thus evoking a cart wheel. *Schippia*, on the other hand, has her-maphroditic flowers in the basal portion of the branches and male flowers in the upper portion, and its fruits are also loosely arranged and exposed beyond the leaf base. The leaves are divided to the base into numerous narrow segments, so that the division of the blade into two halves is scarcely noticeable at first sight. Populations of *Schippia concolor* are found 1500 km northwest from those of *Sabinaria magnifica*.

Unlike most other palms, populations of several genera in this group are usually quite local, and one can walk many hours through the forest in the regions where they thrive without finding a single individual until reaching the very spot where they grow. At that place they are extremely abundant, but a few kilometers farther they disappear altogether, and the next population may be dozens, or even hundreds, of kilometers away. No wonder, *Schippia*, *Itaya* and most species of *Chelyocarpus* remained undiscovered until the 20th century. As a matter of fact, in 2001 Gloria and I had made extensive collections of palms in the Serranía del Darién, only eight km north of the place where *Sabinaria magnifica* grows, and we never spotted a single individual of this species.

This time we had found it, and we now had a complete specimen well pressed, carefully packed, and loaded onto the mules. At 11 am we said goodbye to our friendly hosts, and took the trail to Capurganá, where we arrived in the early evening, exhausted but joyful. Next day we flew back to Medellín, where we bid farewell to Saúl and Norman, and continued our way to Bogotá.

Ten days later, the paper presenting *Sabinaria magnifica* to science was already in the hands of the Editor of the New Zealand journal *Phytotaxa*. One month of expectation went by before we got any response. Finally, by mid-October we received three extremely positive reviews, with some recommendations that substantially improved the manuscript. The paper describing the new genus was finally published in *Phytotaxa* in November 2013, and is now freely available in the internet.

Research on *Sabinaria* has still a long way to go. We are now planning to do molecular studies to clarify its position within the tribe Cryosophileae, as well as studies of floral development to understand the nature of the petals and sepals, which have characters not found in other palm genera. Additionally, a study of the palm's reproductive biology is most desirable. For the time being, Norman is planning to do a demographic study under my supervision, in order to understand the state of the population and the extent of its distribution and to provide tools for its future conservation.

But the discovery of *Sabinaria* was to have an unexpected epilogue, as surprising for us as the finding itself. In the course of our search for the palm, we fell in love with the lush forests of the Serranía, with its crystalline creeks and its jaguars and wonderful monkeys and toucans, the giant magnolias and the numerous and fascinating palms, and with its pivotal role as a bottleneck in the route of biotic exchange between North America and South America. As Saúl and Norman had already been captured by the charm of this jungle, and they knew a man selling a large piece of land, the four of us decided to spend as much money as we were able to put together, and we are now in the process of buying a 100 hectares (250 acres) piece of forest on the Serranía, for establishing a natural reserve. Furthermore, we are trying to raise further resources for buying yet another piece of 1000 hectares (2500 acres) that is being sold, before it is bought by some greedy logger. By establishing a private preserve, we intend to promote knowledge of this fascinating region, and to protect at least a small piece of the lush forests where *Sabinaria magnifica* grows, before the relentless advance of fake progress wipes them out forever from Earth.

Palm Species in the Diet of the Northern Cassowary (*Casuarius unappendiculatus*) in Jayapura Region, Papua, Indonesia

MARGARETHA PANGAU-ADAM
Biology Department, Faculty of Natural Sciences and Mathematics, Cenderawasih University, Papua, Indonesia
(Current address: Department of Conservation Biology, Institute of Zoology Georg-August-Universität Göttingen Bürgerstrasse 50, 37073 Göttingen,Germany mpangau1@gwdg.de)

AND

MICHAEL MÜHLENBERG
Department of Conservation Biology,
Institute of Zoology
Georg-August-Universität Göttingen
Bürgerstrasse 50, 37073 Göttingen, Germany
mmuehle@uni-goettingen.de

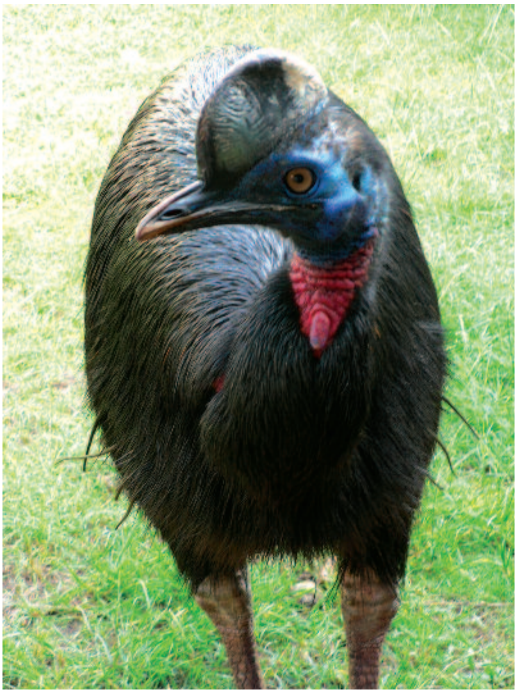
This is the first study on the interaction between frugivorous birds and palms in Papua, Indonesia on the island of New Guinea. The study was aimed to investigate the palm species in the diet of the northern cassowary (*Casuarius unappendiculatus*) by identifying the seeds and fruits in fecal droppings encountered on a set of transects in the lowland forest. A total of 2681 palm seeds and fruits was found in 147 droppings collected from primary forest and human-altered habitats. Ten palm species from nine genera were identified among the diet items of the northern cassowary in Jayapura region. Palm seeds were encountered in all habitats studied, but the number of seeds was significantly different between habitats. The highest number of seeds was obtained from natural forest and the lowest was in logged forest. These results suggest the importance of palms as food resources for the northern cassowary and the birds as keystone species, which play a significant role in palm dispersal.

Mutual plant-frugivore interactions such as palm seed dispersal are key components of forest ecosystems, especially in the tropics. The modification or loss of such interactions may have serious implications for conservation (Silva et al. 2002). A number of species of fruiting plants may play critical roles for maintaining frugivore populations during lean periods, when other species are not producing fruits (Terborgh 1986, Wright 2005). On the other hand, reduced or loss of the frugivore populations from their ecosystem could lead to a failure in seed dispersal of forest vegetation (Bleher & Böhning-Gaese 2001).

Lowland forest in Papua has a high diversity and endemism of flora and fauna including palms. This plant group inhabits principally the primary rainforest from sea level to 2800 m, but the total species diversity decreases with increasing elevation (Baker & Dransfield 2007). Because palms may produce large fruits with high nutrition content (Snow 1981) and they are mainly zoochorous (Zona & Henderson 1989), this plant group may contribute to the diet of frugivorous animals in New Guinea, especially birds.

Among the major frugivorous birds in New Guinea are the well-known large flightless cassowaries. There are three species in the family Cassuaridae, and the northern cassowary (*Casuarius unappendiculatus*) (Fig. 1) is endemic to northern New Guinea. Cassowaries play a significant role in seed dispersal of numerous forest plants and have been considered as keystone species in forest ecosystems of New Guinea and Australia (Mack & Wright 2005, Crome & Moore 1990). All cassowary species are obligate frugivores (Stocker & Irvine 1983) with about 90 to 99% of their diet dependent on fruits (Bentrupperbaumer 1997, Wright 2005). Studies on the southern cassowary (*Casuarius casuarius*) in northern Australia, and on the dwarf cassowary (*Casuarius bennetti*) in Papua New Guinea have recorded the occurrence of palm fruits among the diet of cassowaries (Stocker and Irvine 1983, Wright 2005). The northern cassowary (*Casuarius unappendiculatus*) is restricted to the lowland forest and may very likely consume a variety of palm fruits that occur in the lowlands of northern New Guinea.

To date, there is no report of the relationship between palms and the northern cassowary. The aim of this study was to identify palm species in the diet of cassowary and to assess if the diversity and number of seeds dispersed are varying with habitat types.



1. The northern cassowary: the adult bird may weigh up to 50 kg (110 lbs). (Photo: M. Pangau-Adam)

Study sites and methods

The study was conducted in Nimbokrang and Nimboran rainforest in the northern part of Papua. These forest areas are located in Jayapura regency, about 110–120 km west of Jayapura, the capital of Papua Province. The lowlands consist of a mosaic of forest habitats including a large part of intact forest. Due to the high diversity of endemic Papuan birds, Nimbokrang forest has become one of the international bird-watching spots in Indonesia. Although forest around the villages has been cleared for timber and agriculture, large primary forest areas still remain. At an elevation ranging from 50–200 m above sea level, the vegetation of the study area is humid (lowland) tropical rainforest subject to inundation (CI 1999). Typical canopy tree genera were *Intsia*, *Terminalia, Pometia, Ficus, Canarium* and *Alstonia* while understory trees included palms, *Myristica, Syzygium, Garcinia, Diospyros* and *Pandanus*. Significant areas of the forest are claimed as traditional or clan forest of local people resulting in several land use systems and marginal forests. These forest areas were selectively logged by timber companies during the 1980s.

Primary forest and three different habitat types representing a gradient of disturbance were chosen: unlogged but hunted natural forest

Table 1. Palm species found in the diet of the northern cassowary (*Casuarius unappendiculatus*): the number of seeds and fruits, and habitat where they were found (Primary forest, P; Natural forest, N; Secondary forest, S; Logged forest, L).

Species	No. seeds	No. fruits	Habitat
Actinorhytis calapparia	72		P, N, S, L
Areca macrocalyx	1003		P, N, S, L
Borassus heineanus	19		P, N, S, L
Caryota rumphiana	1192		P, N, S, L
Calamus aruensis	6	3	N, S
Licuala sp.	90		P, N, S
Licuala lauterbachii	90	45	N
Metroxylon sagu	2	1	N
Orania sp.	3		S
Ptychococcus paradoxus	155		P, N, S

(henceforth referred to simply as "natural forest"), >30 year old secondary forest and less than 3 year old selectively logged forest. The census of cassowary fecal droppings was conducted in October–November 2011 and April–June 2012 using the line transect method. Nine transects were established systematically in each of four habitats, resulting in a sample size of 36 transects across the whole study area. The transects were located at least 500 meters apart from one another, and the length of each transect was 2.5 km. Transects were walked slowly and scanned ca. 2 m each side to census and collect the fecal droppings of cassowaries. We recorded the species of palm seeds and fruits in the droppings. The identification of palm seeds was mainly undertaken by Dr. William Baker and Dr. John Dransfield from the Herbarium Royal Botanic Garden Kew, Great Britain. We counted the number of seed and fruit of each species and assessed the difference in seed numbers between habitats using the Kruskal-Wallis test.

Results

We obtained a total of 2632 seeds and 49 intact fruits of palms from 147 cassowary droppings and identified ten palm species from these seeds and fruits (Table 1). All species recorded were fleshy and the fruits had mainly red, orange and purple color. Eight of 10 palm species were large-seeded as defined by Westcott et al. (2005). Four species, *Actinorhytis calapparia, Borassus heineanus, Caryota rumphiana* and *Areca macrocalyx*, were found in all habitat types, while *Licuala lauterbachii* and *Metroxylon sagu* were observed in natural forest, and *Orania* sp. was recorded only from the secondary forest (Table 1). Nine of ten palm species were recorded from natural forest, and only four species were found in logged forest.

The number of palm seeds and fruits dispersed by the northern cassowary was significantly different between habitat types (Kruskal-Wallis ANOVA, $H = 16.93$, $df = 3$, $P < 0.01$). The highest number of seeds and fruits was found in natural forest and primary forest, intermediate level was in secondary forest, and the lowest number was in the logged forest (Table 1). The intact palm fruits recorded in the droppings were from *Calamus aruensis, Licuala lauterbachii* and abortive *Metroxylon sagu,* whose fruits were relatively small.

Palm seeds were the smallest and the largest among the other plant seeds collected during the study (Pangau-Adam, unpubl.). The smallest palm seeds belonged to *Licuala lauterbachii*, diameter ≤ 0.5 cm and < 5 g weight, and the largest seeds were from *Borassus heineanus*, 6–8 cm in diameter, 14–16.5 cm long and ca. 235–265 g in weight.

Borassus heineanus

This species produces large fruits (Figs. 2 & 3) and the cassowary seemed to consume the ripe fruits that fall down. The seeds of *Borassus heineanus* were found in 14 droppings, among which 2 droppings contained only the seeds of this species (Fig. 4). *Borassus* seeds were found in all habitat types including logged forest.

2 (top). Fruit of *Borassus heineanus.* (Photo: M. Pangau-Adam)

3 (middle). Fruit of *Borassus heineanus,* broken into three pieces. (Photo: M. Pangau-Adam)

4 (bottom). *Borassus heineanus* in cassowary droppings. (Photo: M. Pangau-Adam)

This species produces edible fruit, and local people usually consume the white immature endosperm during their activities of gathering forest products. The Genyem people named this plant *kelapa hutan* (wild coconut). During the survey, the researcher and field assistants tasted the fleshy endosperm, and it was indeed similar to the taste of coconut. All seeds were found intact except one seed in secondary forest that was probably broken before it was consumed by the cassowary. It seemed that the ingestion process of the bird might uncover the exocarp and mesocarp of fruits, but it was difficult to open the edible seed.

Caryota rumphiana

The most frequent palm species recorded in the droppings was *Caryota rumphiana* or *nibung* in the local language (Fig. 5). A total of 1192 *Caryota* seeds were found dispersed by the northern cassowary in all habitat types. The seeds were found in 75 droppings and mostly in combination with other plant seeds and/or seeds of its relatives (Fig. 6).

Licuala lauterbachii

With a diameter of ca. 0.5 cm, the seeds of *Licuala lauterbachii* were the smallest palm seeds found in cassowary droppings during the survey (Fig. 7). This species was recorded only from natural forest. A high number of its fruits were observed in the droppings. The fruit could probably pass the gut of cassowary undamaged, and it remained intact because of its small size.

Ptychococcus paradoxus

Two varieties, red fruit and orange fruit, of *Ptychococcus paradoxus* were recorded in the cassowary droppings. Different color of the pulp in the dropping may indicate the variety of *Ptychococcus paradoxus* among the diet of cassowary (Figs. 8 & 9).

Discussion

This study may suggest that palm species are significant food resources for the northern cassowary, because they provide a variety of fruits in the lowland Papuan forest. Palms and Myrtaceae are the most frequent families found in the diet of the northern cassowary. Ten palm species identified in the droppings may indicate the diet preference of cassowary toward this plant group. Two studies in Australia reported the seeds of four and two palm species in the diet of the southern cassowary (Stocker & Irvine 1983, Bradford et al. 2008, respectively), although the most common families found in the droppings of this species were Elaeocarpaceae, Lauraceae, Myrtaceae and Rutaceae (Bradford et al. 2008). Studies on the dwarf cassowary in Papua New Guinea showed no particular families dominated the diet of the birds (Pratt 1982), but the fruits of two palm species were amongst 30 important species by number of items in the diet of the dwarf cassowary (Wright 2005).

The northern cassowary foraged on the variety of palm fruits that are available in lowland forest, ranging from the small fruit of *Licuala lauterbachii* to the largest fruit of *Borassus heineanus*. Although the fruits of Borasseae are mainly large, fibrous and heavy, and unexpectedly dispersed by birds (Zona & Henderson 1989), this study has shown that the wide-gaped northern cassowary is able to disperse the seeds of *Borassus heineanus*. Wide distribution and high fruit availability of *Caryota rumphiana* during the survey may be the main reason for the large amount of *Caryota* seeds found in the droppings. Heatubun (2000) recorded the seeds of *Caryota* sp. in cassowary droppings at an altitude > 900 m asl, and it was considered to be fruits of *Caryota zebrina*. Because the northern cassowary inhabits lowland forest up to 700 m asl (Beehler et al. 1986) and *C. rumphiana*

5. *Caryota rumphiana* (Photo: M. Pangau-Adam)

6 (top). Seeds (small, gray) of *C. rumphiana* in cassowary dropping. (Photo: M. Pangau-Adam). 7 (bottom). Fruits of *Licuala lauterbachii*. (Photo: M. Pangau-Adam)

grows at elevations up to 500 m asl (Heatubun, pers. comm.), it could be the dwarf cassowary that foraged on *Caryota zebrina*.

Fruit availability throughout the year, high nutrient content and bright color of palm fruits may be the main reasons for the fruit choice by the cassowary. Gautier-Hion et al. (1985) reported that diurnal frugivorous birds have good color vision and discrimination of red wavelengths, so they prefer to consume the fruits in red and purple color. Palms are

8 (lfeft). *Ptychococcus paradoxus* in dropping – red fruit. (Photo: M. Pangau-Adam). 9 (right). *Ptychococcus paradoxus* in dropping – orange fruit. (Photo: M. Pangau-Adam)

among the important plant families for specialist frugivores such as cassowaries, because their fruits have high values for protein and fat content (Snow 1981). Palm fruits may also play a critical role as key resources for frugivores during seasonally lean periods, because these plants usually have continual phenology patterns at the population level (Peres 1994, Wright 2005).

Logged forest contained fewer palm species and lower numbers of seeds than primary forest. The lower number of fruiting palm trees in logged forest was also shown by the field surveys on fruiting trees in different habitats (Pangau-Adam, unpubl.). We assume that low diversity of palm is affected by the intensive logging practices in lowland forest of Papua. High temperature in large gaps of logging areas may increase soil desiccation, and therefore may probably reduce the survival and reproduction of certain palm species.

Even though our data cannot explain the distance of palm dispersal by the northern cassowary, it might be possible that cassowaries carried the palm seeds from one forest site to another, because the habitats were adjacent to one another. Cassowaries can disseminate a variety of plant species over long distances in large quantities (Wright, 2005), so they may contribute to the palm colonization in degraded areas.

This study has shown that the northern cassowary includes a large proportion of large-fruited and large-seeded palm species in their diet. Large fruits are favored by frugivorous birds because the pulp content increases with fruit diameter (Wheelwright 1993). Many palm species in Papuan lowland forest have relatively large fruits and seeds. This indicates the importance of cassowaries having a large gape, because Papua lacks large-bodied frugivorous mammals that would be important for dispersing large seeds (Mack & Wright 2005). In the way they interact with palms, the cassowaries may behave more like terrestrial mammals than birds (Zona & Henderson 1989). The disappearance of the northern cassowary as a keystone species may affect the abundance and extinction probability of the palm species that depend on wide-gaped frugivores. The mutual interaction between palms and the northern cassowary may play important roles for palm conservation and the forest regeneration in Papua.

Acknowledgments

The study was financially supported by the Dorothea-Schlözer Fellowship Programme, University of Göttingen. We would like to thank William Baker and John Dransfield for palm identification. Many thanks to Supeni Sufaati, Pak Dance Kencim, Pak Agus Waromi and our field assistants for support and help during the fieldwork.

Literature Cited

Baker, W.J. and J. Dransfield. 2007. Arecaceae of Papua. In A.J. Marshall and B.M. Beehler (Eds.) The Ecology of Papua. Periplus Editions, Singapore. Pp. 359–370.

BENTRUPPERBAUMER, J. 1997. Reciprocal Ecosystem Impact and Behavioural Interactions Between Cassowaries, *Casuarius casuarius* and Humans, *Homo sapiens*. Ph.D. Thesis, James Cook University, Townsville, Australia.

BEEHLER, B.M., T.K. PRATT AND D.A. ZIMMERMAN. 1986. Birds of New Guinea. Princeton University Press, Princeton, USA.

BLEHER, B. AND K. BÖHNING-GAESE. 2001. Consequences of frugivore diversity for seed dispersal, seedling establishment and the spatial pattern of seedlings and trees. Oecologia 129: 385–394.

BRADFORD, M.G., A.J. DENNIS AND D.A. WESTCOTT. 2008. Diet and dietary preferences of the southern cassowary (*Casuarius casuarius*) in North Queensland, Australia. Biotropica 40: 338–343.

CONSERVATION INTERNATIONAL (CI). 1999. The Irian Jaya Biodiversity Conservation Priority-Setting Workshop. Final Report, Washington, D.C., USA.

CROME, F.H.J. AND L.A. MOORE. 1990. Cassowaries in north-eastern Queensland: report of a survey and a review and assessment of their status and conservation management needs. Australian Wildlife Research 17: 369–385.

GAUTIER-HION, A., J.M. DUPLANTIER, R. QURIS, F. FEER, C. SOURD, J.P. DECOUX, G. DUBOST, L. EMMONS, C. ERARD, P. HECKETSWEILER, A. MOUNGAZI, C. ROUSSILHON AND J.M. THIOLLAY. 1985. Fruit characters as a basis of fruit choice and seed dispersal in a tropical forest vertebrate community. Oecologia 65: 324–337.

HEATUBUN, C.D. 2000. In search of *Caryota zebrina* – A palm expedition to the Cyclops Mountains. Palms 44: 187–193.

MACK, A.L. AND D. WRIGHT. 2005. The frugivore community and the fruiting plant flora in a New Guinea rainforest: identifying keystone frugivores. Pp. 185–203. In J.L. DEW AND J.P. BOUBLI (Eds.) Tropical Fruits and Frugivores: The Search for Strong Interactors. Springer, the Netherlands.

PERES, C.A. 1994. Composition, density and fruiting phenology of arborescent palms in an Amazonian terra firme forest. Biotropica 26: 285–294.

PRATT, T.K. 1982. The diet of the dwarf cassowary, *Casuarius bennetti picticollis*, at Wau, Papua New Guinea. Emu 82: 283–285.

SILVA, W.R, P. DE MARCO JR, E. HASUI AND V.S.M. GOMES. 2002. Patterns of fruit-frugivore interactions in two Atlantic forest bird communities of south-eastern Brazil: implications for conservation. Pp. 423–435. In D.J. LEVEY, W.R. SILVA AND M. GALETTI (Eds.) Seed Dispersal and Frugivory: Ecology, Evolution and Conservation. CABI Publishing UK.

SNOW, D.W. 1981. Tropical frugivorous birds and their food plants: a world survey. Biotropica 13: 1–14.

STOCKER, G.C. AND A.K. IRVINE. 1983. Seed dispersal by cassowaries (*Casuarius casuarius*) in North Queensland's rainforests. Biotropica 15: 170–176.

TERBORGH, J. 1986. Keystone plant resources in the tropical forest. Pp. 330–344. In M.E. SOUL (Ed.). Conservation Biology: The Science of Scarcity and Diversity. Sinauer, Sunderland, Massachusetts.

WESTCOTT, D.A., M.G. BRADFORD, A.J. DENNIS AND G. LIPSETT-MOORE. 2005. Keystone fruit resources and Australia's tropical rainforests. Pp. 237–260. In J.L. DEW AND J.P. BOUBLI (Eds.) Tropical Fruits and Frugivores: the Search for Strong Interactors. Springer, the Netherlands.

WHEELWRIGHT, N.T. 1993. Fruit size in a tropical tree species: variation, preference by birds, and heritability. Vegetatio 107–108: 163–174.

WRIGHT, D. 2005. Diet, keystone resources and altitudinal movement of dwarf cassowaries in relation to fruiting phenology in a Papua New Guinean rainforest. Pp. 205–236. In J.L. DEW AND J.P. BOUBLI (Eds.) Tropical Fruits and Frugivores: The Search for Strong Interactors. Springer, the Netherlands.

ZONA, S. AND A. HENDERSON. 1989. A review of animal-mediated seed dispersal of palms. Selbyana 11: 6–21.

Two of Madagascar's Most Threatened Palms: *Voanioala gerardii* and *Lemurophoenix halleuxii*

ALISON SHAPCOTT*,
JANE QUINN
Faculty of Science Health Education and Engineering, University of the Sunshine Coast, Maroochydore DC 4558 Queensland, Australia
**Author for correspondence*

AND

MIJORO RAKOTOARINIVO
Kew Madagascar Conservation Centre, Antananarivo, Madagascar

Madagascar has a high diversity of endemic palm species and the Masoala Peninsula is a hotspot for their diversity. Several species are critically endangered, and their populations are known to be in decline due to a combination of land clearance, destructive harvesting for heart of palm and potentially unsustainable commercial seed collection. The critically endangered *Voanioala gerardii* and the endangered *Lemurophoenix halleuxii* are two palm species from monospecific genera endemic to Madagascar that overlap in their distribution within this region.

Madagascar is known around the world for its unique flora and fauna. It contains 199 species of palms, 97 percent of which are endemic to the island (Rakotoarinivo & Dransfield 2010). Unfortunately, 145 species of the currently known palms of Madagascar are now threatened with extinction according to the IUCN Red List criteria (Rakotoarinivo & Dransfield 2011). Currently very little is known about the ecology or genetics of Madagascan palm species (Dransfield & Beentje 1995, Ratsirarson et al. 1996, Shapcott et al. 2007). The eastern escarpment region contains the greatest diversity of palms in Madagascar, many species being restricted to this area (Dumetz 1999, Rakotoarinivo et al. 2007, Rakotoarinivo & Dransfield 2010). The Masoala Peninsula, which is partially protected within a National Park, is a hotspot for palm diversity where several species are critically endangered and their populations known to be in decline due to a combination of land clearance, destructive harvesting for heart of palm and potentially unsustainable commercial seed collection.

Some of the most threatened species in this region are large and charismatic and have been sought after by palm enthusiasts around the world. Two such species are the critically endangered *Voanioala gerardii* (IUCN 2009) and the endangered *Lemurophoenix halleuxii* (IUCN 2009), both from monospecific genera that are endemic to Madagascar and overlap in their distribution within this region. *Voanioala gerardii* and *L. halleuxii* are known to exist only in small, isolated populations within rainforests on the Madagascan "vanilla coast" surrounding the Bay of Antongil in northeastern Madagascar. The palms are known to be found in the Masoala National Park, but new unprotected populations were discovered in 2005 during comprehensive palm inventory studies undertaken by Royal Botanic Gardens Kew/Madagascar (Rakotoarinivo 2008).

Voanioala gerardii, a member of subfamily Arecoideae, tribe Cocoseae, subtribe Attaleinae (Dransfield et al. 2008) (Figs. 1–3) is a majestic palm known as the "forest coconut" and is sought after by palm enthusiasts around the world leading to a trade in the seeds of this species and a source of income for local people. It was CITES listed in an attempt to assist with its conservation in the wild. The heart of palm is also harvested by local people. *Lemurophoenix halleuxii*, the "red lemur palm," belongs to subfamily Arecoideae, and tribe Areceae, subtribe Dypsidinae (Dransfield et al. 2008) (Fig. 4). The fruit grows to approximately 5 cm in diameter and is said by villagers to be eaten by lemurs (Dransfield et al. 2008).

Palms are an important resource for indigenous people in Madagascar, for food, fiber and construction (Dransfield & Beentje 1995, Byg & Balslev 2001a). Palm heart is widely harvested in the region, and the seeds of many palm species are collected for the ornamental trade (IUCN 2009, Rakouth & Roger 2011). However, this puts single stemmed species at risk as harvesting for seed or palm heart often results in trees being cut down leading to tree death (Byg & Balslev 2001a & b, Dransfield et al. 2008). Even though Madagascar has established numerous National Parks, less than 15% of Madagascar's natural forests remains intact (Cadotte et al. 2002, Marie et al. 2009), and many species located within National Parks are still harvested. Recent political events have put even greater pressure on the existing protected areas, according to reports of logging and other illegal activities.

1 (left). *Voanioala gerardii,* the forest coconut, growing in Masoala National Park. 2 (right). The distinctive trunk of an adult plant.

We undertook searches to find these palms in remote rainforest in eastern Madagascar shortly after the political upheavals in 2009. We aimed to document the population size and demographic structure and to collect samples for genetic studies in order to gain a better understanding of the species and its conservation requirements and to engage with the local ANGAP (Madagascar Protected Areas) staff and local villagers to raise their awareness of these species and their conservation. The detailed genetic results can be found in Shapcott et al. (2012).

Methods

Lemurophoenix halleuxii grows to 20 m tall; it has a distinct pink and grey crownshaft and red newly exposed leaves (Dransfield et al. 2008). It is monoecious and protandrous with flowers borne in triads; inflorescences grow to 2 m in length with over 100 flower-bearing branches (Dransfield et al. 2008). Nothing is known about its pollination biology. *Voanioala gerardii* grows to 15–20 m and is found in primary rainforest to an elevation of approximately 400 m (Dransfield & Beentje 1995, Dransfield et al. 2008). It is monoecious, with solitary inflorescences that are apparently protandrous; the pollinators are unknown (Dransfield 1989). The large single-seeded fruit (7–8 cm by 4–5 cm) is rich red-brown when ripe with a fibrous outer and fleshy inner mesocarp, and grows in large bunches at the crown (Dransfield 1989, Dransfield & Beentje 1995). The dispersal mechanisms are unknown; fruit is often found at the base of trees (Dransfield et al. 2008). It seems possible it could be dispersed by water or by large frugivores and it has been hypothesized it may have been dispersed by the now extinct giant elephant bird (Dransfield & Beentje 1995). *Voanioala gerardii* is one of only four palms known to be polyploid and has the highest number of chromosomes ($2n$ = 550–600 ± 3) of all the monocotyledons (Johnson 1989, Röser 1994).

The political upheavals at the time restricted air travel to this remote area. The first trip to revisit the newly discovered populations was taken after delays due to the closure of the main airport in Antananarivo due to political unrest. The second trip was undertaken overland due to uncertainty of air travel and luggage restrictions. This adventurous route, complete with multiple barge crossings and bridge repairs (bring your own planks!) (Fig. 5), took four days in either direction to the port town of Maroantsetra, from where a day long trip by speedboat through rice paddies took us to our base camp in a remote part of the Masoala National Park to survey *Lemurophoenix halleuxii*. We undertook day long surveys to each of the known populations in this area. After return to Maroantsetra, we headed out again to the Masoala peninsula on another day long speedboat trip where we set up another base camp from which to make our surveys. We were assisted by botanist Jao Aridy from ANGAP, who acted as an important liaison with the local villagers, who knew the location of all populations and who was able to lead us to a new previously unknown population of *V. gerardii* in the Masoala National Park. We were also assisted with our base camp set up and surveillance by ANGAP staff and local villagers as there had been reports of local poachers in the area. We also hired local guides to assist us navigate the forest at each location.

3. *Voanioala gerardii* seedling in Masoala National Park.

All known populations of *V. gerardii* (VG) and *L. halleuxii* (LH) were surveyed during this study to document population size and structure, reproductive activity and sample for genetic analysis (see Shapcott et al. 2012). There is an additional herbarium record of seedlings of *V. gerardii* (in Masoala Peninsula), but this was not visited due to difficulty of accessing this remote site. Populations at each site were systematically surveyed in their

4. *Lemurophoenix halleuxii*, the red lemur palm, with developing fruit growing in Masoala National Park.

entirety for either *V. gerardii* or *L. halleuxii* and the location recorded at the start and finish using a GPS. The relative locations of each plant were also recorded. The relatively large numbers of small sized plants of *L. halleuxii* meant some plants may have been missed in the steep, highly dissected terrain. Data recorded for each individual included trunk height to the crown shaft, or total height for plants without a trunk, trunk diameter at breast height (DBH) if present, and evidence of reproductive activity, such as presence of flowers, fruit or old inflorescences. Individuals were categorized according to life stage class as follows: seedlings with entire bifid leaves; juveniles with pinnate leaves but no apparent trunk; sub-adults with pinnate leaves and a trunk, but not yet reproductive; adults with pinnate leaves, a trunk and evidence of reproduction or a size shown to be capable of reproduction. Populations were systematically sampled for genetic analysis from across their spatial distribution (see Shapcott et al. 2012).

Results

We confirmed the largest population of *L. halleuxii* (LH01; from the Ampotaka region that was originally discovered in 2005) comprised only 10 adults (20–35 m tall and 30–50 cm DBH), 6 sub-adult trunked plants and dominated by seedlings (280 of 320 plants). This population is not currently protected, and only three plants retained evidence of recent reproductive activity. However, the large number of seedlings found indicates viable fruit has been produced recently and that germination is successful in the wild. We were not able to confirm the single historical recording of this species from the Masoala Peninsula (LH2) or indeed find any evidence of this species from that area. We found two populations close to each other (LH3, LH4) in another part of the Masoala National Park. These populations also had few trunked adult plants (LH3, 6 adults; LH4, 12 adults) and were conspicuous in their lack of sub-adult plants with only two of these present in LH3. However, these populations had higher reproductive output with 5 of the 6 adults in LH3, and 10 of the 12 adult plants in LH4 with fruits present. The large numbers of seedlings found indicate that the fruit produced in these populations is viable and germinates in the wild at these sites also. However, these populations had a greater number of juvenile plants indicating that recruitment to larger sizes has been taking place. It was hypothesized that the lack of sub-adult sized plants may be a result of past harvesting of this size plant prior to National Park protection. We observed one dead fallen tree in our surveys (Fig. 6) and observed considerable evidence of human activity within close proximity of the National Park boundary. The total number of *L. halleuxii* recorded was only 28 adult plants and a total of 729 plants documented. The populations are quite compact and dense. The largest population, LH01, was the densest with the average distance between adult plants 4.7 m, the most sparse population was also the smallest, LH3, where adults trees were 14.2 m apart on average (see Shapcott et al. 2012). It is expected that this species is pollinated by insects. The close proximity of adult trees and high reproductive activity appears to have enhanced outcrossing, and the populations are generally not inbred; however, where the trees are further apart there was evidence of inbreeding suggesting fewer pollinators fly these distance between flowers (Shapcott et al. 2012).

While the populations were clumped there was clear evidence of localized dispersal away from adult trees. The large fleshy fruit is thought to be attractive to lemurs, and we saw evidence that *Daubentonia madagascariensis* (the Aye-Aye lemur) had fed on its fruit (Fig. 7).

We documented a total of 135 *V. gerardii* plants from four populations. However, only seven adult plants and 13 sub-adults were recorded. The newly discovered and unprotected populations located in the Ampotaka region (VG1, VG2) had no adult plants present. These had apparently been felled between the time of original population discovery (in 2005) and the 2009 survey for this study (pers. obs. Rakotoarinivo). The relatively large number of seedlings and all life stages except adults in VG1 indicated that prior to the recent felling this is likely to have been the largest population of *V. gerardii.* In our survey VG1 consisted of 71 plants, of which 31 were seedlings, 33 juveniles and 7 sub-adult plants. The second population nearby (VG2) consisted of only six sub-adult plants (see Shapcott et al. 2012). The lack of small plants suggests either adults were felled much longer ago or it has arisen relatively recently from some multiple dispersal events. In the Masoala National Park we identified two populations (VG3, VG4). The newly discovered population (VG3) consisted of only four adult plants and 22

5. We brought our own planks to repair broken bridges along the Vanilla Coast of Madagascar en route to the Masoala National Park.

seedlings, 20 of these were located close to one tree. Three of the four adult plants were, or had recently been reproductively active with fruit present at the time of the study. Genetic results indicated that the 20 seedlings had not arisen due to self-pollination of the maternal tree and confirmed that another tree has pollinated at least some flowers of this tree (Shapcott et al. 2012). The adult trunked plants were of varying sizes/ages ranging from 4.5 m to 28 m to the base of the leaf sheath, and ranging from 50 to 120 leaf scars present. The second population in the Masoala National Park (VG4) was spatially clustered into two distinct sub-populations (VG4a, VG4b). The first subpopulation (VG4a) with 25 plants consisted only of seedlings and immature non-trunked plants. There were 20 seedlings less than 1 m tall; 2 plants 1–3 m tall; and 3 non-trunked plants 4 m or taller, all located within a small area. Genetic studies found several seedlings and a sub-adult from the VG4a subpopulation contained an allele at one genetic locus that was not found in the neighboring VG4b or VG3 populations (Shapcott et al. 2012). This suggests that these seedlings arose from adults either recently felled or from an as yet undiscovered nearby population. In the second sub-population (VG4b) there were no seedlings present. It had seven plants in total, of which three were adult trunked trees 4, 8 and 15 m to the base of the leaf sheath respectively and ca. 20–25 cm in diameter, and four non-trunked plants 4 m or taller. Two of the three adult plants were reproductively active at the time of the survey. In the 1980s, ten *V. gerardii* adults were recorded in VG4 (Dransfield 1989), but now only 3 remain indicating population decline. The results provide some evidence that there may be more as yet undiscovered populations within the Masoala region, which is supported by evidence of seedlings reported from another site within the region.

Despite the smaller population sizes there was approximately twice as much genetic diversity found in populations of *V. gerardii*, compared with *L. halleuxii* (Shapcott et al. 2012). There was little difference in levels of diversity among populations in *L. halleuxii*, whereas, in *V. gerardii* allelic diversity was apparently correlated with increasing population size and was unexpectedly high given the extremely small population sizes, nevertheless all populations were inbred (Shapcott et al. 2012). We also found that the two groups of *V. gerardii*

6. A fallen *Lemurophoenix halleuxii* in Masoala National Park.

populations were surprising genetically similar given their isolation from each other. In contrast, *L. halleuxii* populations were genetically distinct between regions (Shapcott et al. 2012).

Discussion and conclusions

We found extremely small population sizes for both species; in particular, the number of trunked adults was very small for both species, especially *V. gerardii*. This is most likely a consequence of harvesting and fragmentation. A study of the palm *Astrocaryum mexicanum* revealed a major decline in adults in its populations due to fragmentation (Arroyo-Rodriguez et al. 2007). Other Madagascan palm species have had populations reduced to immature plants due to harvesting (Shapcott et al. 2007). Both species display evidence of active recruitment of seedlings and juvenile plants, but there is a noticeable lack of recruitment of trunked plants to sub-adult sizes in several populations. Both species are traditionally harvested for heart of palm; this practice targets sub-adults (pers. comm. local guides), which may account for some regeneration failure. Adult trees are also felled to obtain seeds for commercial sale, particularly to the overseas market. We encountered seed collectors claiming to be looking for these species during our surveys. Even if protected from harvesting, survival to reproductive maturity is variable among populations and only a small proportion of the current immature crop may reach maturity. Given the likely long time from seedling to reproductive maturity any harvesting of this species that leads to tree death is unsustainable for the foreseeable future and could lead to extinction of the species. Given their very small population sizes and slow maturity, these two species should be considered at great risk of extinction.

Low genetic variation was found in *L. halleuxii*, consistent with expectations (Shapcott et al. 2012). However, in contrast to expectations very high levels of genetic diversity, in comparison to other palm species, were found in *V. gerardii* (Shapcott et al. 2012). The relatively high levels of genetic diversity found within populations of *V. gerardii* are consistent with results found for some of its closest relatives, such as *Cocos nucifera* (Teulat et al. 2000) and *Beccariophoenix madagascariensis* (Shapcott et al. 2007; Shapcott et al. 2012). It has been suggested that high genetic diversity in rare and endangered species is an indication

7. *Lemurophoenix halleuxii* fruit showing evidence of feeding by Aye-Aye lemur.

of historically larger populations (Shapcott et al. 2007) or populations linked by gene flow (Shapcott 1998). The results could indicate that more populations are located nearby that have yet to be found, or that the species had until recently been more abundant.

An active program involving local villagers and land managers in the conservation and restoration of these species would be required to prevent their extinction. Significant populations of both species are currently protected within the Masoala National Park but park managers need support to maintain their protection. Conservation should focus on conserving populations from both regions of *L. halleuxii* given their genetic distinctiveness, while in *V. gerardii* more focus could be placed on conserving the largest number of adults of this species and enabling smaller plants to mature. An active program to change methods of seed collection to stop the destructive seed harvesting practices replacing this with more sustainable approaches is important for these species. A reduction in demand for the seed of these species by palm enthusiasts internationally could greatly assist in reducing the pressure on wild harvesting of seeds of these species.

Acknowledgments

This project was funded by the International Palm Society Endowment Fund and the University of the Sunshine Coast (USC), with in-kind support from The Royal Botanic

Gardens (RBG) Kew. We thank Dr John Dransfield, Dr Bill Baker, Stuart Cable, Dr Helene Ralimanana, Andrianaivoravelona, Bakoly and Rajaovelona Landy, Jao Aridy ANGAP, Dr Franck Rakotonasolo Parc Botanique et Zoologique de Timbazaza, and field guides Regis, Oclino, Be Leonor and Tsimanimba, and the USC Genecology Research Centre, especially Rob Lamont, Anna Kuballa and Daniel Powell.

LITERATURE CITED

BYG, A. AND H. BALSLEV. 2001a. Diversity and use of palms in Zahamena, eastern Madagascar. Biodiversity and Conservation 10: 951–970.

BYG, A. AND H. BALSLEV. 2001b. Traditional knowledge of *Dypsis fibrosa* (Arecaceae) in Eastern Madagascar. Economic Botany 55: 263–275.

CADOTTE M., F. RAKOTONASOLO , L. REZA AND J. LOVETT-DOUST. 2002. Tree and shrub diversity and abundance in fragmented littoral forest of southeastern Madagascar. Biodivsity and Conservation 11: 1417–1436

DRANSFIELD, J. 1989. *Voanioala* (Arecoideae: Cocoeae: Butiinae), a new palm genus from Madagascar. Kew Bulletin 44: 191–198.

DRANSFIELD, J. AND H. BEENTJE. 1995. The Palms of Madagascar. Royal Botanic Gardens Kew and the International Palm Society, Kew, UK.

DRANSFIELD J., N. UHL, C. ASMUSSEN , W. BAKER , M. HARLEY AND C. LEWIS. 2008. Genera Palmarum: The Evolution and Classification of Palms. Kew Publishing, Royal Botanic Gardens, Kew, UK.

DUMETZ, N. 1999. High plant diversity of lowland rainforest vestiges in eastern Madagascar. Biodiversity and Conservation 8: 273–315.

IUCN 2009 IUCN Red List of Threatened Species: Version 2009.2. www.iucnredlist.org. accessed 8 March 2010.

JOHNSON, M.A.T. 1989. An unusually high chromosome number in *Voanioala gerardii* (Palmae: Arecoideae: Cocoeae: Butiinae) from Madagascar. Kew Bulletin 44: 207–210.

MARIE, C., N. SIBELET, M. DULCIRE, M. RAFALIMARO, P. DANTHU AND S. CARRIERE. 2009. Taking into account local practices and indigenous knowledge in an emergency conservation context in Madagascar. Biodiversity and Conservation 18: 2759–2777.

RAKOTOARINIVO, M., T. RANARIVELO, AND J. DRANSFIELD. 2007. A new species of *Beccariophoenix* from the High Plateau of Madagascar. Palms 51: 63–75.

RAKOTOARINIVO, M. 2008. Analyse de la distribution et de la conservation des palmiers (Arecaceae) de Madagascar par l'utilisation du système d'information géographique. Thèse de Doctorat, Université d'Antananarivo.

RAKOTOARINIVO, M. AND J. DRANSFIELD. 2010. New species of *Dypsis* and *Ravenea* (Arecaceae) from Madagascar. Kew Bulletin 65: 279–303.

RAKOUTH, B. AND E. ROGER. 2011. Guide pour l'identification des graines de palmiers malgaches commercialisees. Autorité Scientifique Flore CITES, p 60.

RATSIRARSON, J., J. SILANDER AND A. RICHARD.1996. Conservation and management of a threatened Madagascar palm species, *Neodypsis decaryi*, Jumelle. Conservation Biology 10: 40–52.

SHAPCOTT, A. 1998.The patterns of genetic diversity in *Carpentaria acuminata* (Arecaceae), and rainforest history in northern Australia. Molecular Ecology 7: 833–847.

SHAPCOTT, A., M. RAKOTOARINIVO, R. SMITH, G. LYSAKOVA , M. FAY, AND J. DRANSFIELD.2007. Can we bring Madagascar's critically endangered palms back from the brink? Genetics, ecology and conservation of the critically endangered palm *Beccariophoenix madagascariensis*. Botanical Journal of the Linnean Society 154: 589–608.

SHAPCOTT, A., J. QUINN, M. RAKOTOARINIVO AND J. DRANSFIELD. 2012. Contrasting patterns of genetic diversity between two endangered palms with overlapping distributions, *Voanioala gerardii* (Arecoideae) and *Lemurophoenix halleuxii* (Arecoideae), from north-east Madagascar. Conservation Genetics 13: 1393–1408.

TEULAT, B., C. ALDAM, R. TREHIN, P. LEBRUN, J. BARKER, G. ARNOLD, A. KARP , L.BAUDOUIN AND F. ROGNON. 2000 An analysis of genetic diversity in coconut (*Cocos nucifera*) populations from across the geographic range using sequence-tagged microsatellites (SSR's) and AFLPs. Theoretical and Applied Genetics 100: 764–771.

Two New, Overlooked Species of *Bactris* Endemic to the Colombian Chocó

RODRIGO BERNAL

GLORIA GALEANO
Instituto de Ciencias Naturales, Universidad Nacional de Colombia, Apartado 7495, Bogotá, Colombia
rgbernalg@gmail.com

JUAN CARLOS COPETE
Programa de Biología, Universidad Tecnológica del Chocó, Cra.22 N°18B –10 Quibdó, Chocó, Colombia

AND

RODRIGO CÁMARA-LERET
Departamento de Biología, Área de Botánica, Universidad Autónoma de Madrid, Campus de Cantoblanco, Calle Darwin, 2, 28049 Madrid, Spain

Recent palm exploration in the Pacific lowlands of Colombia has revealed two species of *Bactris* that had been overlooked so far, having been mistaken for the sympatric and strikingly similar *Bactris hondurensis*. However, both species differ from *Bactris hondurensis* and from each other in many respects. They both grow side by side in Central Chocó, where they can be easily contrasted.

Bactris chocoensis *R. Bernal, Galeano, Copete & Cámara-Leret*, **sp. nov.** Small, slender clustering palm with simple leaves, differing in the combination of large, simple, cuneate, membranaceous leaf blades that have prominent and conspicuous cross-veins and are white pilose below, the small inflorescence with recurved peduncle, and the small fruits. Type: COLOMBIA. CHOCÓ: Corregimiento de Puerto Pervel, on trail to Guapandó, 5°23’N, 76°43’W, 63 m, 10 November 2010, *R. Cámara-Leret & J.C. Copete Maturana 1733* (holotype: COL; isotypes: CHOCO, FMB); (Figs. 1–4, 11, 12).

Solitary or cespitose. Stem 0.4–1.2 m tall, 2 cm diameter, with scattered to dense black spines 2–4 cm long. Leaves 8–10, simple. Sheath 18–21 cm long, densely armed with black spines to 6 cm long; ocrea 2 cm long; petiole up to 69 cm long, 1.5 cm wide when fresh, 6 mm wide when dry, unarmed, grooved adaxially, with scattered, minute, reddish scales; blade cuneate, membranaceous, 71–105 cm long, 27–29 cm wide, bifid for ca. 1/3 its length, the lobes acute; rachis 48–70 cm long, unarmed; primary veins 23–25, forming with the rachis an angle of 20°, cross-veins numerous, conspicuous; surface softly white-pilose below, the margins toward apex provided with scattered, appressed, black spines 2.5 mm long. Inflorescence interfoliar; prophyll 7–10 cm long, 2–3 cm wide, with deciduous, brown scaly tomentum; peduncle 7–11 cm long, 0.4–1 cm wide, recurved, with scattered to dense black spinules; peduncular bract 21–22 cm long, with scattered black spines to 8 mm long; rachis 1–2 cm, covered, like the rachillae, with whitish or brownish moniliform trichomes; rachillae 16–24, 3.5–9 cm long, 1 mm diam. Staminate flowers solitary along the distal half of the rachilla, 2–2.5 mm long; calyx lobes triangular, cucullate, acuminate 1 mm long; petals elliptic, 2–2.4 mm long; stamens not seen; pistillate flowers restricted to the proximal half of the rachillae, 3–4 mm long; calyx cupular,1.5 mm long, with three short lobes; corolla tubular, 3–4 mm long, with three short lobes; staminodes absent. Fruits obovoid, 9 mm long, including a beak 1 mm long, 5 mm diam.; endocarp obovoid, 8–9 mm long; endocarp fibers few. Fruiting corolla with three cleft lobes.

1. Habit of *Bactris chocoensis*. Puerto Pervel, Chocó, Colombia.

2. Cross-veins of *Bactris chocoensis*. Puerto Pervel, Chocó, Colombia.

3. Inflorescence of *Bactris chocoensis* with pistillate flowers. Puerto Pervel, Chocó, Colombia.

4. Ripe fruits of *Bactris chocoensis*. Puerto Pervel, Chocó, Colombia.

COLOMBIA. CHOCÓ: [Munic. Cantón de San Pablo], Corregimiento de Puerto Pervel, on trail to Guapandó, 5° 23'N, 76° 43'W, 63 m, 10 November 2010, *R. Cámara-Leret & J.C. Copete Maturana 1714* (CHOCO, COL, HUA), 10 November 2010, *R. Cámara-Leret & J.C. Copete Maturana 1733* (COL, CHOCO, FMB); 3 km S of Quibdó, 70 m, 9 January 1979, *A. Gentry & E. Rentería 23865* (COL, MO, n.v.); Munic. Quibdó, km 7 on rd. to Yuto, 5°39'N, 76°38'W, 105 m, 23 April 2011, *J.C. Copete Maturana & S. Arias Guerrero 7* (CHOCO); Munic. Acandí, Vereda Coquital, 150–200 m, 23 May 1989, *R. Fonnegra et al. 2868* (CHOCO, HUA, n.v.).

Etymology. The specific epithet refers to the Department of Chocó, Colombia.

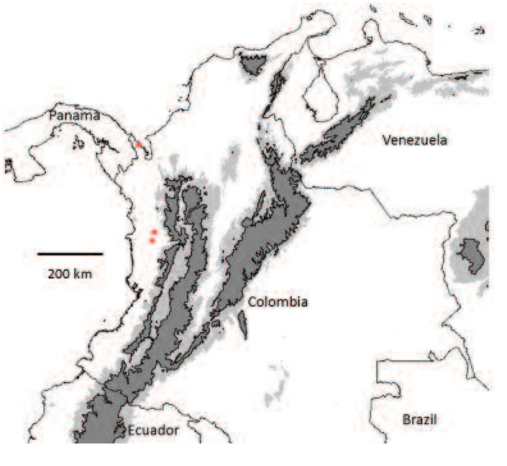
Distribution. Known only from a few localities in the central and northern Chocó Department (Fig. 5), where it has been found in rainforest, between 5°23' and 8°20' N.

Conservation status. According to the IUCN criteria (IUCN 2011) *Bactris chocoensis* is considered as Least Concern (LC), because it has a large distribution in a region where there are still many forested areas.

Bactris chocoensis belongs to Henderson's (2000) 'orange-fruited species group'. It appears to be related to a group of species distributed in Central America and the Pacific coast of Colombia, including *B. grayumii, B. hondurensis, B. kunorum, B.manriquei* (described below as new), *B. neomilitaris* and *B. panamensis*. It differs from these species in the combination of large, simple, cuneate, membranaceous leaf blades that have prominent and conspicuous cross-veins and are white pilose below, the small inflorescence with recurved peduncle, and the small fruits.

A sterile duplicate of *Gentry 23865* (MO) was studied by Henderson (2000), who considered that it might belong to *Bactris coloradonis*. However, the latter is a completely different species, differing from *B. chocoensis* in its larger habit (stems 1.5–10 m tall vs. 0.4–1.2 m), its usually pinnate leaves with 17–38(–80) pinnae per side, the densely white wooly petiole, the glabrous blade undersurface, the more numerous rachillae (20–51 vs. 16–24), which are much longer (14–29 cm vs. 3.5–9 cm), and the smaller fruits (1.5(–2.5) × 1.4–1.7(–2) cm vs. 0.9 × 0.5 cm). A duplicate of Gentry's specimen at COL is fairly complete, with an inflorescence and loose fruits, and it had been filed under *Bactris hondurensis*. Although the latter is reminiscent of *B. chocoensis* in its simple leaves and the pilose blade undersurface, the two species are quite distinct. To begin with, the simple leaves of *B. chocoensis* are much larger than those of *B. hondurensis* (blade 71–105 cm long, 27–29 cm wide vs. blade 36–71 cm long, 26–39 cm wide), and are cuneate instead of obovate. On the other hand, the cross-veins of *B. chocoensis* are abundant and conspicuous (vs. scarce and inconspicuous). Additionally, the inflorescence has a recurved peduncle (vs. erect or arched), and more rachillae (16–24 vs. 3–7) that are longer on average (3.5–9 cm vs. 2–5 cm), and the fruits are smaller (9–5 mm vs. 12–15 mm).

5. Distribution of *Bactris chocoensis*.



6. Individual of *Bactris manriquei* (*Bernal 4839*) with simple and partially divided leaves on the same stem. Bahía Málaga, Valle del Cauca, Colombia.

Bactris manriquei *R. Bernal & Galeano* **sp. nov.** Small, slender clustering palm with simple or pinnate leaves, differing from *Bactris hondurensis* in its more robust habit, the petiole and leaf rachis with brown indumentum, the leaves glabrous beneath, the inflorescence with short and broad, recurved, strongly flattened peduncle, the larger fruits and the fruiting corolla with scarcely cleft petals. Type: COLOMBIA. VALLE. Munic. de Buenaventura,

7. Pinnate leaf of *Bactris manriquei*. Bahía Málaga, Valle del Cauca, Colombia.

Bahía Málaga, Sector La Zanja, 4°3'41.9''N, 77° 11'11.5''W, 33 m alt, 24 February 2013, *R. Bernal, H.F. Manrique & L. Mosquera 4864* (holotype: COL; isotypes: CUVC, FMB). (Figs. 6–9, 11, 12)

Cespitose, with 1–4 stems developed and several basal shoots. Stem 0.8–4 m tall, 1.5–3 cm diam., dark brown, with internodes 1.5–6 cm, unarmed or with a few black spines to 1 cm long. Leaves 4–9, simple or pinnate. Sheath

8. Infructescences of *Bactris hondurensis* (left) and *Bactris manriquei* (right) at Bahía Málaga, Valle del Cauca, Colombia.

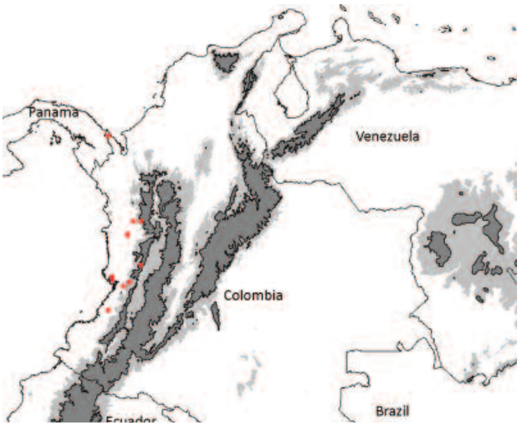
17–34 cm long, with scattered black spines to 1 cm long; petiole 22–53 cm, 5–6 mm diam., cylindrical, with a narrow central groove adaxially, covered in new leaves by a dense, deciduous, brown tomentum that extends along the rachis, unarmed; blade simple or pinnate; rachis 14–68 cm long, unarmed; simple leaves obovate, cuneate at base, 49–76 cm long, 26–34 cm wide, bifid for 1/2–2/3 of its length, glabrous beneath, with 10–17 primary veins; pinnate leaves with 2–12 pinnae on each side, sometimes one leaf side undivided and the other one with up to 4 pinnae; pinnae lanceolate to slightly falcate, acuminate, with 1(–3) primary veins, the apical pair broader and with 5–11 veins; basal and middle pinnae 30–44 cm long, 2.4–2.8 cm wide, with a few minute, appressed spines along the margin near apex, membranaceous, with scattered, inconspicuous cross-veins visible under the lens, glabrous beneath. Inflorescence interfoliar, appearing in the sheath of old, persistent leaf; prophyll 2.7–7 cm long, 1.2–3 cm wide, unarmed; peduncle 4–7 cm long, 4–7 mm wide, strongly recurved, flattened, covered at anthesis, like rachis and rachillae, with a dense indumentum of brown and white moniliform trichomes, unarmed or with a few, brown spines to 3 mm long; peduncular bract 10–15 cm long, with black spines 3–4 mm long, persistent in the infructescence and partially frayed with age; rachis 2–4.5 cm long, 3–4 mm diam.; rachillae 4–5, 2.5–4 cm long, ca. 2 mm diam.; flower triads densely arranged in the proximal one half of the rachillae, the distal half with staminate flowers. Staminate flowers 4–5 mm long; calyx 2 mm long, the lobes narrowly triangular, 1 mm long; petals elliptic, 4 mm long, 2 mm wide, strongly fibrous; anthers 1.5 mm long; pistillate flowers 5 mm long, with cupular calyx 1 mm long, and tubular corolla 3 mm long. Fruits globose when fresh, obovoid when dry, 1.5–2.5 cm long., ripening from green to yellow, orange and finally red, with a scant, strongly acidic pericarp; endocarp turbinate, often tricuspidate, 1–1.3 cm long, without fibers. Fruiting corolla with three usually non-cleft lobes.

COLOMBIA. CHOCÓ: Munic. Acandí, vereda El Brillante, Río Muerto, 8°34′49.9″N, 77°24′26.2″W, alt. 171 m., 19 November 2013, *Bernal et al. 4937* (COL); Munic. El Carmen, Vereda El Doce (carretera Medellín-Quibdó km 151), Río Atrato, 700 m, 10 January 1980, *R. Bernal & G. Galeano 93* (COL); Munic. Quibdó, San Francisco de Ichó, 150 m, 11 July 1981, *G. Galeano & R. Bernal 456* (COL); ca. 10 km NW of Las Animas, on Panamerican rd. ca. 100 m, 9 July 1986, *R. Bernal et al. 1095* (COL, FTG); [Munic. Cantón de San Pablo], Corregimiento de Puerto Pervel, on trail to Guapandó, 5°23′N, 76°43′W, 63 m, 10 November 2010, *R. Cámara-Leret & J.C. Copete Maturana 1712* (CHOCO, COL), *1720* (COL), *1724* (COL), *1734* (COL); Río Pichimá, Wounaan Indigenous community, 4°25′N, 77°17′W, 100 m, 11 November 1976, *L.E. Forero 622* (COL). VALLE: Cordillera Occidental, Río Calima Basin, Quebrada El Chanco, 450–600 m, 16–19 February 1989, *R. Bernal et al. 1530* (COL, TULV); Munic. de Buenaventura, Bahía Málaga, Sector La Zanja, 4°3′41.9′′N, 77°11′ 11.5′′W, alt. 33 m, 24 February 2013, *R. Bernal, H.F. Manrique & L. Mosquera 4864* (COL, FMB); *ibidem*, Sector La Caleta de Paula, 4°2′ 12.06′′N, 77°11′34.4′′ W, alt. 36 m, 21 February 2013, *R. Bernal, H.F. Manrique & L. Mosquera 4839* (COL, CUVC, FMB); *ibidem*, Sector El Morro, 4°2′49.5′′N, 77°10′25.4′′W, alt. 4 m, 24 February 2013, *R. Bernal, H.F. Manrique & L. Mosquera 4861* (COL); *ibidem*, Sector La Sierpe, 3°59′6.7′′N, 77°12′47.1′′W, alt. 75 m, 22 February 2013, *R. Bernal, H.F. Manrique & L. Mosquera 4849* (COL), 4851 (COL, VALLE), 3° 57′27.5′′N, 77°11′12.1′′W, alt. 62 m, 25 February 2013, *R. Bernal, H.F. Manrique & L. Mosquera 4871* (COL, CUVC); *ibidem*, Sector Secadero, 3°59′34.1″N, 77°12′39.8″W, 41 m, 30 April 2011, *G. Galeano et al. 8141* (COL); *ibidem*, Sector El Corozal, 77°16′6.4′′W, 4°5′

9. Fruiting perianth of *Bactris hondurensis* (left) and *Bactris manriquei* (right) at Bahía Málaga, Valle del Cauca, Colombia.

Table 1. A comparison of *Bactris hondurensis, Bactris chocoensis* and *Bactris manriquei.*

Bactris hondurensis	***Bactris chocoensis***	***Bactris manriquei***
Stem 0.5–1.5 m diam.	Stem 2 cm diam.	Stem 1.5–4 cm diam.
Leaf sheath usually without spines	Leaf sheath with black spines to 6 cm	Leaf sheath with black spines to 1 cm
Petiole green, glabrous or with scarce indumentum not hiding the surface	Petiole with scattered, minute, reddish scales	Petiole with dense brown indumentum that hides the surface
Leaves simple or with up to 8 pinnae per side	Leaves simple	Leaves simple or with 2–12 pinnae per side
Simple leaves bifid to 1/3–1/2 their length	Simple leaves bifid to 1/3 their length	Simple leaves bifid for 1/3–1/2 their length
Lamina white pubescent below	Lamina white pubescent below	Lamina scattered, inconspicuous
Lamina with cross-veins scattered, inconspicuous, but visible under the lens	Lamina with numerous, conspicuous cross-veins	Lamina with ross-veins scattered, inconspicuous, but visible under the lens
Peduncle straight	Peduncle recurved	Peduncle recurved
Peduncular bract deciduous in ripe infructescences	Peduncular bract persistent in ripe infructescences	Peduncular bract persistent in ripe infructescences
Fruiting corolla with lobes scarcely differentiated, irregularly cleft	Fruiting corolla with three cleft lobes	Fruiting corolla with three evident, rounded, non-cleft lobes
Fruits 12–15 mm long	Fruits 9 mm long	Fruits 15–25 mm long
Fruits ripen from green to red	Fruits ripen from green to red	Fruits ripen from red to yellow to orange and finally red



10. Distribution of *Bactris manriquei*.

25.7''N alt. 45 m, 18 August 2011, *G. Galeano et al. 8164* (COL); *ibidem*, Sector Los Indios, 77°9'53.362''W, 4°3'49.23''N, 9–80 m, 21 August 2011, *G. Galeano et al. 8204* (AAU, COL, CUVC), *8217* (COL); Bajo Anchicayá, 3°45'N, 76°50'W, 300 m, 19 October 1989, *A. Gentry et al. 68561A* (COL); Río Calima, La Trojita, 5–50 m, 24 February 1944, *J. Cuatrecasas* 16407 (COL); CAUCA: Munic. López de Micay, Indigenous community Playa Bendita, Quebrada Arenal, 12 September 2000, *G. Reina et al. 745* (COL).

Etymology. *Bactris manriquei* is named after Héctor Favio Manrique, Director of the Jardín Botánico del Quindío, Calarcá, Colombia, who has traveled with the first author throughout much of Colombia in search of specimens for the Colombian National Collection of Palms, of which he is a fervent keeper.

Distribution. Known only from the Pacific region of Colombia, between 3° and 8°35' N and 76°17' and 77°24' W, in the departments of Chocó, Valle and Cauca (Fig. 10). It grows in rainforest, from sea level to 700 m. This species also probably occurs in Panama, as it has been collected just at the border.

Common names. *Chontaduro de tunda*, *sia* (epena saija language) (Cauca); *chacarrá de cholo* (Chocó).

Conservation status. According to the IUCN criteria (IUCN 2011) *B. manriquei* is considered as Least Concern (LC), because it is known from many localities in a large, mostly forested area.

Bactris manriquei has been confused in the past with the similar *Bactris hondurensis*, and indeed specimens of the new species (*De Leon 122*, BH; *Moore 9474*, BH; *Bernal 1095*, COL; *Gentry 53649*, MO) were treated as that species by

11. *Bactris chocoensis* (left) and a simple-leaved individual of *Bactris manriquei* (right) at Puerto Pervel, Chocó, Colombia.

12. Leaf and infructescence of *Bactris manriquei* (left) and *Bactris chocoensis* (right) at Puerto Pervel, Chocó, Colombia.

Henderson (2000), who, however, pointed out the densely brown tomentose petioles and rachis, and the larger simple leaves in some of them. There are other differences (see Table 1), and the two species are clearly distinct. Confusion arises in the small, compact inflorescences and infructescences, which at first sight look similar. Nevertheless, a closer inspection (Fig. 8) reveals clear differences in peduncle structure, persistence of peduncular bract in the infructescence, and shape of the fruiting corolla (Table 1).

In Henderson's monograph of *Bactris*, specimens of *B. manriquei* key out to *Bactris hondurensis*. In the de Nevers et al. (1996) treatment of Mesoamerican *Bactris*, the new species cannot be keyed out.

None of the names included by Henderson under synonymy of *Bactris hondurensis* corresponds to *B. manriquei*; the long, slender peduncle is evident in all the type specimens or in the corresponding protologues.

Acknowledgments

Field work was supported by the European Union, project Palm Harvest Impacts in Tropical Forest – PALMS (FP7-ENB-2007-1). Exploration of the Bahía Málaga area was additionally supported by the Jardín Botánico del Quindío and Universidad Nacional de Colombia.

Literature Cited

de Nevers, G., A. Henderson and M. Grayum. 1996. Mesoamerican *Bactris* (Palmae). Proc. Calif. Acad. Sci. 49: 171–210.

Henderson, A. 2000. *Bactris* (Palmae). Fl. Neotr. 79: 1–181.

IUCN Standards and Petitions SubCommittee. (2011) Guidelines for Using the IUCN Red List Categories and Criteria.Version 9.1. Prepared by the Standards and Petitions SubCommittee of the IUCN species survival Commission September 2011. Available from http://www.iucnredlist.org/documents/RedListGuidelines.pdf

Desiccating Palm Pollen – a Technique for Pollinating Rare Palm Species Over Long Distance

G. STAPLES
Singapore Botanic Gardens,
National Parks Board,
1 Cluny Road,
Singapore 259569

AND

W. SINGEO
Honolulu Botanical Gardens,
50 N. Vineyard Blvd.,
Honolulu, Hawaii 96817
USA
wsingeo@honolulu.gov

1. Young fruits developing on female tree at HBG; on left, single fruit from May 31 pollination; on right, cluster of 8 fruits from July 26, 27, 29 pollinations.

The Honolulu Botanical Gardens (HBG) has 2 mature female double coconut palms, *Lodoicea maldivica* (also known as coco-de-mer; Fig. 1), in the living collections. Until recently, neither tree bore fruit because there is no male in the Hawaiian Islands capable of providing pollen for hand pollination.

Previous attempts to effect pollination (in 1984, 1996, and 2000) with staminate flowers obtained from botanic gardens in Sri Lanka, the Seychelles and Singapore, respectively, all failed because the staminate flowers became moldy during transit, and the pollen was not viable when received at Honolulu (Singeo 2011). In 2010, another attempt was decided on, and we asked several palm biologists if there was any technique they were aware of for sending palm pollen over long distance. Dr. John Dransfield, RBG Kew, drew our attention to a paper published by Bob Read in the 1970s (Read 1979) that described a method for sending palm pollen through the post.

The palm species highlighted in that paper, *Chamaerops humilis*, *Phoenix dactylifera* and *Thrinax* sp., are all native to low-humidity areas where desiccation of pollen would be a natural process encountered by the palm. The technique had not been tried for palm species from the ever-wet tropics, but it seemed worth a try. This note reports our results and a modification of Read's technique that could be used for rare palm species growing at distance from pollen sources.

Methods

1. Collecting pollen at Singapore Botanic Garden

Singapore Botanic Garden (SBG) has three mature *Lodoicea* palms and several juveniles. Hand pollination has been carried out numerous times, with good success rates, and the female tree has fruits at all stages of development. The mature male tree is located several hundred meters away from the female tree, and a lift truck (aka cherry picker) would be necessary to collect male flowers as the inflorescences are now too high to reach safely with a ladder. So in May 2011 the lift truck was hired, SBG staff collected male flowers and inflorescences (Fig. 2), and the female tree in SBG was hand pollinated. Additional pollen was taken to the SING herbarium for drying and processing before sending to Honolulu (Staples & Aung Thame 2012).

2. Drying and processing pollen

The male flowers were removed from the massive inflorescence and spread out in a single layer in a shallow cardboard box (Fig. 3) lined with waxy paper (normally these sheets of heavy paper are cut up and used to cover delicate parts of herbarium specimens when these are mounted). The box was placed on top of and outside a drying oven that operates at 70° C, overnight (about 8–10 hours). After that time the box was shaken and tapped firmly on the table top to dislodge pollen from the anthers in the male flowers. A thin layer of yellow pollen was visible on the paper after a few minutes of such tapping. Next all the male flowers, broken bits of flowers and other debris were removed by hand using forceps. A fine paint brush was then used to sweep the pollen together into the center of the box (Fig. 4).

2. Staminate inflorescence from male tree at SBG.

3 (top). Staminate flowers removed from inflorescence, drying on waxed paper in box. 4 (bottom). Pollen after removal of male flowers and floral debris.

3. Packing and shipping pollen

For packing the pollen, Read (1979: 34) recommended gelatin caplets available from drug stores or pharmacies. While these may have been readily available in the 1970s, gelatin caplets could not be found in Singapore in 2011; when queried, the pharmacists said these caplets are obsolete and no longer sold. If they are available in other places, they can be tried. Instead, GS substituted small plastic vials used for collecting specimens in the field (Fig. 5), each with a screw-on cap attached by a short plastic leash. Pollen was swept into three of these plastic vials, the caps were then cut off, and clean sterile cotton (such as used for first aid and for cosmetic use) was loosely packed into the mouth of the vial. Pollen grains are alive and must have oxygen to remain so, thus closing the vial with a screw cap would cut off the oxygen supply and might cause the pollen to die in transit. The cotton stopper allows gaseous exchange between the contents of the vial and the ambient air, much as the porous gelatin caplets would have done.

The cotton-stoppered vials were then placed inside a closable fiber tea bag (sold in many Asian supermarkets for packing tea for home use); the fiber tea bag was then placed into a small plastic sandwich bag with a sealable top. About 10–15 ml (about 2 or 3 teaspoons) of silica gel beads were poured into the plastic bag, which was then partly closed but not sealed tightly; again air exchange is needed to allow oxygen to reach the pollen inside. The fiber tea bag (adapted from field collecting leaf samples for DNA analysis) keeps the samples separated from the silica gel, which maintains low-humidity inside the plastic bag. The silica gel crystals used in this case are sold for field collecting leaf samples to be quick-dried for later use in DNA extraction. This type of silica gel has colored beads included that change from yellow when dry to dark green when the silica gel has become saturated with moisture. This reagent grade of silica gel is available only from chemical supply companies and might not be easy to find world-wide. A suitable substitute is finely powdered silica gel sold at wholesale floral supply houses. Meant for rapid drying of cut flowers at home (to be used in dried floral arrangements), this type of silica gel is widely available and inexpensive. A similar product that is meant for use with small electronics is sold in camera and electronics stores.

5. Pollen packed into plastic vial, stoppered with cotton, resting on fabric tea bag.

The plastic bag and contents were then placed into a padded mailing envelope and addressed; this in turn was passed over to an overnight shipping company and sealed into one of their shipping envelopes.

4. Receiving at HBG end

Although the overnight shipping company selected promised the parcel would travel from Singapore to Honolulu in 48 hours or less, in fact the shipping took about 5 days (>120 hours) to be delivered. Due to holidays and working schedules, plus crossing the International Date Line, the delivery time was seriously compromised. In this case, the delay was unavoidable but anyone wishing to try this technique is advised to check ahead to ascertain that the receiving party will be available to accept delivery.

The parcel containing the three vials of pollen was delivered on the afternoon of May 31, 2011, and immediately inspected. Pollen in all the vials was a light yellow color, dry and powdery, with no sign of mold. Two vials were kept for pollination of flowers in the future; i.e., not for use on the current inflorescence. More silica gel crystals in the form of Fresh

Step cat litter crystals, newly purchased from a nearby drug store was added to the bag received from SBG. About 4 tablespoons of the crystals were placed in a small plastic bag, kept slightly open, and added to the bag containing the two pollen vials and original silica gel beads. The entire bag was then immediately refrigerated. The contents were kept refrigerated, unopened, for eight weeks. Stored pollen was used eight weeks later, when flowers from a second developing inflorescence were ready for pollination.

5. Pollination of HBG female flowers

The entire content of a single vial of pollen was used on the same day it arrived from SBG. On May 31, 2011, the female flowers were already dry at the tips and appeared to be past optimal time for successful pollination. Nevertheless, pollen was applied to the tips of each of the 10 female flowers using a small, pointed paintbrush moistened with tap water (Fig. 6). Flowers were pollinated once only. Honolulu Botanical Gardens history was made when a single fruit developed from the 10 flowers pollinated. The fruit was positioned close to the apex of the pistillate inflorescence.

About two months later a second inflorescence was ready for pollination. All 10 flowers were pollinated three times: on July 26 (at 2:15 p.m.), 27 (12:30 p.m.) and 29 (9:30 a.m.). Flowers on all three days showed some degree of oozing of sap from the tips of the flowers, which has been interpreted to indicate receptivity. On the first day of pollination, all flowers were open and slightly oozing in various degrees. Flowers exuded the most sap on July 29. One of the two stored vials of pollen was removed from the refrigerator and used on the first day and returned to the refrigerator, to be used the second day. On the third day of pollination, the third and last vial of pollen was removed from the refrigerator and used entirely. On this second inflorescence, eight of the 10 flowers were successfully pollinated and young fruits are now developing (Fig. 6).

6. Storage of pollen for later use

Pollen was harvested at SBG on May 26, 2012 and stored in the refrigerator at Foster Botanical Garden at 1.1°C (34°F) with a desiccant until July 29, 2011: nine weeks in total. Read (1979) estimated that by this time, under natural conditions, pollen viability could have been as low as 1%. This measure was obtained by testing stored pollen germination by sowing it on nutrient medium and counting how many pollen grains successfully produced a pollen tube. Despite this very low potential for successful fertilization after storage for nine weeks, pollination of 10 female flowers over three days resulted in eight developing fruits. While we did not measure pollen viability in the same way Read (1979) did, and so have no comparable figure for pollen viability, 80%, or eight of the 10 female flowers were successfully pollinated. This was a far better result than anything we could have hoped for when we began. It must be that the paint brush carrying pollen to pistil contains hundreds if not thousands of grains, increasing the potential that at least a single viable pollen grain would be able to fertilize each individual flower. Plus multiple pollination over 2 days, when the female flowers were oozing mucus (assumed to indicate maximum receptivity), and using up all the pollen available, no doubt increased the chances of a single viable pollen grain achieving fertilization.

Closing remarks

This experiment demonstrates that with slight modifications, Read's (1979) technique for drying palm pollen can be used successfully for sending pollen through the post as well as for storing the pollen for a period of weeks to months with only gradual loss of viability. With careful preparation, desiccation of pollen and storage in low humidity, refrigerated conditions could be a valuable technique for long-distance pollination of tropical dioecious palm species growing in botanical gardens or protected natural sites where only one sex is present.

Double coconut is a highly sought-after, endangered species (IUCN Red List); poaching of mature seeds for consumption or sale to collectors (Gollner 2008) remains a serious threat to this palm species' survival. The possibility for long-distance pollination of these dioecious trees adds one more tool to the conservation tool kit for ensuring the species' continued existence. A number of botanical gardens grow *Lodoicea maldivica* (Blackmore et al. 2012); up until now isolated individuals in cultivation were cut off from the gene pool for the species and unable to reproduce. This simple technique for long-distance pollen transfer removes that barrier. By hand pollinating cultivated palms and enabling seed production by cultivated individuals it lessens pressure on the wild

6. Pollinating pistillate flowers at HBG.

populations, adds individuals to the gene pool that would otherwise be excluded from it, and introduces a new source of seeds for propagation.

This technique could have conservation applications for other rare/endangered wild palm species that have limited population sizes and geographic barriers to natural pollination. It would seem especially useful for palm species originating on islands, where physical, geographical barriers may compound endangerment due to habitat loss and human disturbance. By identifying cultivated individuals of such palms, it would be possible to send pollen between botanical gardens or nature reserves where only one sex is present, thereby enabling reproduction and increase of population size to take place. This technique has considerable potential to alleviate problems of limited gene pool diversity and consequent inbreeding depression by enabling exchange of genes between physically remote populations, either in botanic gardens or in the wild. For botanic gardens attempting to conserve rare palm species this simple technique has the potential to be a game-changer.

Finally, as pointed out elsewhere (Singeo 2011) this case study exemplifies how international collaboration between plant specialists around the world, sharing their information and expertise through information technology, can change the conservation picture in new and surprising ways: suddenly the impossible becomes possible. The network of personal relationships built up through field work, attendance at scientific meetings and symposia, and participation in online forums and social media is invaluable for coming up with innovative solutions to problems; the importance of such connectivity between people cannot be overemphasized.

And in addition to the personal relationships that underpin the sharing of ideas and information leading to innovative solutions there is the long established tradition of cooperation between botanical gardens. In this case, the authors and everyone they contacted for help to solve this problem is affiliated with or employed by a botanical garden – in places as far flung as England, Switzerland, Singapore, and Hawai‘i. Partnerships between botanical gardens have been a given for centuries and we can only hope such cooperation will continue indefinitely into the future. However, the changing political landscape brought about by the Convention on Biodiversity (CBD) and the increasingly strident nationalistic approach to "who owns biodiversity" is posing a serious threat to the free exchange between botanic gardens that has been the norm for centuries. We can only hope that strong personal relationships among plant scientists and a centuries-long tradition of cooperation between botanical gardens will outweigh the politics and legalities that would divide them, lest endangered plant species such as the double coconut pay the price for such short-sightedness based on some perceived (and often fallacious) benefit to one party at the expense of others.

Acknowledgments

We thank John Dransfield, Bill Baker, Anders Barfod and Fred Stauffer for their help with the palm literature. An anonymous reviewer provided feedback on improving this article. Alan Tan and Dr. Chin See Chung, both SBG, supported the effort to provide pollen from SBG to the HBG and made the resources available to do so.

Literature Cited

Blackmore, S., S.C. Chin, L.C. Seng, F. Christie, F. Inches, W.U. Putri, N. Watherston and A.H. Wortley. 2012. Observations on the morphology, pollination and cultivation of Coco-de-mer (*Lodoicea maldivica* (J.F. Gmel.) Pers., Palmae). Journal of Botany 2012, Article ID 687832, doi: 10.1155/2012/687832.

Gollner, A.L. 2008. The Fruit Hunters. Scribner, New York. 279 pp.

Read, R.W. 1979. Live storage of palm pollen. Principes 23: 33–35.

Singeo, W. 2011. Honolulu Botanical Garden's double coconut. Public Garden 27: 19–20.

Staples, G. and Aung Thame. 2012. Match-making palms – double coconuts find love across the seas. Gardenwise 38: 33–35.