Palms

Journal of the International Palm Society
Vol. 58(3) Sep. 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 on the website.

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.

Editors: John Dransfield, Herbarium, Royal Botanic Gardens, Kew, Richmond, Surrey, TW9 3AE, United Kingdom, e-mail j.dransfield@kew.org, tel. 44-20-8332-5225, Fax 44-20-8332-5278.
Scott Zona, Dept. of Biological Sciences (OE 167), Florida International University, 11200 SW 8 Street, Miami, Florida 33199 USA, e-mail zonas@fiu.edu, tel. 1-305-348-1247, Fax 1-305-348-1986.

Associate Editor: Natalie Uhl, 228 Plant Science, Cornell University, Ithaca, New York 14853 USA, e-mail nwu1@cornell.edu, tel. 1-607-257-0885.

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 Sep. 2014

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

This publication is printed on acid-free paper.

CONTENTS

Features

An undescribed species of Ptychospermatinae showing crown, leaves and inflorescences. Photo by Charlie D. Heatubun. See article by C. Heatubun et al., p. 115.

FRONT COVER

Fruits of *Hydriastele* sp. 2. See article by Heatubun et al., p. 115. Photo by Charlie D. Heatubun.

BACK COVER

Stand of *Mauritia flexuosa* at Maracá Ecological Station, Roraima, Brazil. See article by Khorsand Rosa, p. 109. Photo by R. Khorsand Rosa.

PALM NEWS


S. Zona

The **IPS 2014 Biennial meeting in Miami and the Florida Keys was an overall success**, and attendees enjoyed seeing palms in their natural habitat and fantastic public and private gardens. Additionally, they enjoyed fascinating evening lectures from palm specialists and the camaraderie of fellow palm enthusiasts representing six continents. The Dent Smith Memorial Award was presented to Libby Besse, who was on hand to receive her award, and posthumously to Jim Cain. In addition, the IPS was awarded the "La Palma Dorada" by the Asociación Venezolana de Palmas (Avepalmas), the Venezuelan Palm Society. At the Board of Directors meeting, **the venue for the 2016 Biennial was announced: Singapore and Sarawak**. The next Biennial promises to be the trip of a lifetime, not to be missed, so watch for updates and announcements on the IPS website and PalmTalk.

An interesting **application of molecular methods used in the name of conservation** was recently published by A.G. Nazareno and M.S. Reis, who examined cultivated individuals of *Butia eriospatha* in an attempt to determine their place(s) of origin (Conserv. Genet. 15:441–452. 2014). The authors claimed that all large individuals of *B. eriospatha*, sold in Brazil and overseas, were removed from wild populations, and that since Brazilian plants are protected by law, trade in such plants is illegal and threatens the long-term survival of the species. Using microsatellite markers, they found that cultivated individuals were more genetically diverse than the wild palms and that they were obtained from different populations (many not sampled by the authors). In terms of conservation, the authors conceded that, rather than levying criminal penalties against the owners of cultivated *B. eriospatha*, authorities might be advised to consider "compensatory mitigation" (i.e., seed collection from cultivated palms for genetic enhancement of wild stands).


S. Zona


M. Hoddle

Dr. Mark Hoddle has posted information about the **farming of weevil larvae for food in southern Thailand** (http://cisr.ucr.edu/blog/red-palm-weevil/entomophagy-farming-palm-weevils-food/). A study was made in September 2013 in the Trang area of southern Thailand. Weevil larvae were shown to be very easy to farm, with low production costs and potentially high profits. The weevils can be reared in plastic bins containing palm material (coconut or sago) or in sections of palm trunk. To innoculate the culture, three adult weevil pairs are placed in each plastic bin, and the resulting larvae are ready for harvest in about 4 weeks. A 30-liter bin can yield as much as 2 kg of grubs. For cooking, the larvae are given a pre-treatment of soaking in brine for ten minutes, heads are removed and then they can be cooked directly – stir-fried, coated in batter and deep fried or cooked in Thai curry. The blog is illustrated with pictures of the production of weevil grubs and with mouthwatering pictures of finished weevil larvae dishes.

A Review of the Pollination Biology of *Mauritia flexuosa*

Roxaneh Khorsand Rosa
Department of Biological Sciences, Florida International University, Modesto Maidique Campus, 11200 SW 8 St., Miami, Florida, 33199 USA
rkhor001@fiu.edu

1. Habit of *Mauritia flexuosa*.

In a recent study (Khorsand Rosa & Koptur 2013), I demonstrated that the Amazonian palm, *Mauritia flexuosa*, a species previously thought to be beetle-pollinated, is actually wind-pollinated. This paper briefly reviews the study on *M. flexuosa* and discusses the academic and practical implications of these novel findings.

The dominant pollination system in the palm family has been a subject of debate for the past 150 years. Delpino (1870) was among the first to associate anemophily (wind-pollination) with palms. Drude (1889) and Kerner von Marilaun (1895) also assumed palms to be anemophilous. Cook (1943) considered anemophily in palms to be the rule. Meeuse (1972) considered the primitive pollination mode of palms to be anemophily, especially in dioecious groups (see Henderson [1986] for a complete historical review).

The wind-pollination paradigm held by many 19th century European botanists was likely fostered by knowledge of wind-pollination in the date palm (*Phoenix dactylifera*) (Johnson 1915). Early botanists believed that the large inflorescences with small flowers and copious amounts of pollen were "primitive" and that wind-pollination was consistent with evidence that the earliest seed plants (conifers) were pollinated "passively" (Raven et al. 1999). Certain floral traits characterize anemophilous flowering plants including small, unisexual flowers with reduced perianth parts and an absence of nectar (Faegri & van der Pijl 1979). Anemophily has perplexed botanists since the time of Darwin, as it was thought to be inefficient and wasteful because of high pollen:ovule ratios and unpredictable wind aerodynamics (Niklas1985, Ackerman 2000).

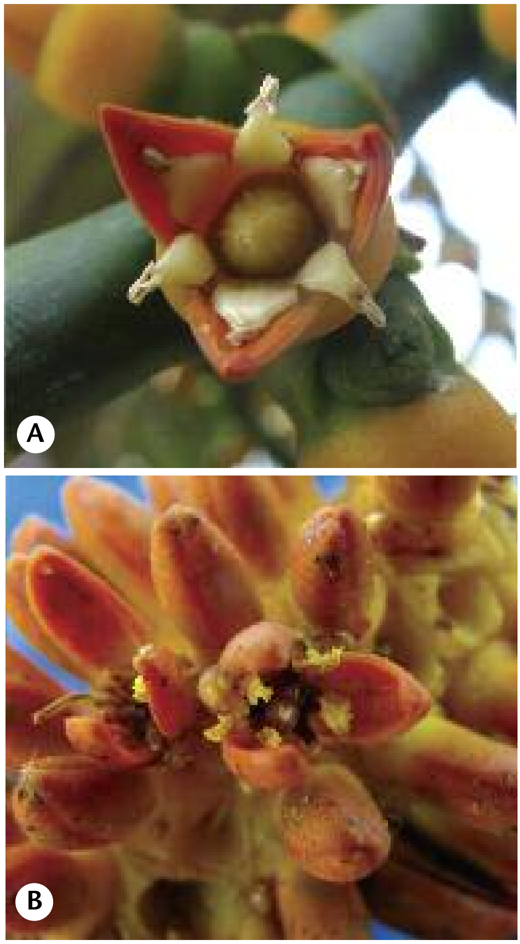
Although anemophily was the prevailing view of palms in the 19th and even into the 20th century, some observations from fieldwork in the Neotropics indicated entomophily (insect-pollination) (Wallace 1853, van der Pijl 1978) or a combination of both systems (Kerchove 1878, Coulter & Chamberlain 1915, Wettstein 1935). However, Henderson (1986) was responsible for shifting the predominant view away from anemophily and showing that insects are responsible for pollination in many palm species. Since his seminal paper, much progress has been made to understand pollination of palms. Barfod et al. (2011) conducted a thorough review of 60 studies focusing on palm pollination since 1986. The authors found the overwhelming majority of species to be animal-pollinated, with cantharophily, or beetle-pollination, as the most common mode. Ambophily, a combined system of wind- and animal-pollination, accounted for nine percent of the 77 species, while anemophily accounted for only seven percent.

2. *Buriti* fruits. Note scaly exocarp and beta-carotene-rich mesocarp.

The dioecious palm *Mauritia flexuosa* L. f. (Arecaceae: Calamoideae) is the most widespread palm in South America (Goulding & Smith 2007) and plays a pivotal role in Amazonian ecology, economy and culture (Fig. 1). In Roraima, Brazil, where the study was conducted, *M. flexuosa* grows in seasonally flooded habitats including lowland forest and savannas. This species provides critical food and nesting habitat for wildlife (Henry et al. 2000, Brightsmith 2005). The fruits, referred to as *buriti* in Brazil, constitute an important part of the Amazonian diet (Delgado et al. 2007) and have industrial and pharmaceutical applications (Schlemmer et al. 2007, Zanatta et al. 2008). *Buriti* fruits are typically one-seeded, globose to ellipsoid, and have a thin, scaly exocarp with bright yellow-orange fleshy mesocarp boasting the highest known levels of beta-carotene (Santos 2005) (Fig. 2).

Previously, *M. flexuosa* was associated with cantharophily. Storti (1993) observed curculionid, cucujid, and nitidulid beetles visiting pistillate and staminate inflorescences and found no pollen on Vaseline-covered microscope slides (a standard method of trapping wind-borne pollen) hung from pistillate inflorescences. Ervik (1993) also pointed to beetles as the primary pollinator of *M. flexuosa* and suggested that the wind may play a secondary role in pollination. However, recent work by Khorsand Rosa and Koptur (2013) provided strong evidence that the wind is the primary pollination vector of *M. flexuosa* and that beetles do not effectively pollinate the flowers.

I characterized floral morphology by conducting monthly phenological observations, testing for the presence of nectar and heat production (a characteristic of many beetle-pollinated plants) and recording flower opening time. To determine the pollination system, I conducted diurnal and nocturnal visitor observations in which visitor behavior and the number of landings were recorded. Floral visitors were collected from male and female inflorescences and analyzed for pollen content. Vaseline-covered microscope slides were hung from pistillate inflorescences and the number of pollen grains was counted 3–15 days later to understand if wind transports pollen between males and females. An exclusion experiment was also performed to determine the role of floral visitors and the wind in fruit set. In this type of experiment, closed, pistillate floral buds are covered in a mesh bag (excluding floral visitors but permeable to wind-borne pollen) or a paper bag (excluding floral visitors and wind-borne pollen). The proportion of fruit set in each treatment is compared with the control (pistillate inflorescences that were exposed to floral visitors and wind-borne pollen). Field observations and experiments were repeated in three habitats: undisturbed savanna-forest interface, undisturbed semideciduous forest and disturbed savanna. Disturbed savanna sites comprise native savanna converted into large-scale plantations of the exotic tree *Acacia mangium*.



3. *Mauritia flexuosa* flowers. A. Pistillate flower. Note scaly gynoecium and six staminodes. B. Staminate flower in cluster of flower buds. Note flexed stamens and beetle foraging for pollen inside of flower.

I counted over 100,000 flowers on a single staminate inflorescence and up to 6000 flowers on a pistillate inflorescence. Female flowers (Fig. 3A) have six staminodes and are larger than male flowers (Fig. 3B), which have minute pistillodes. Stigmas are dry. Both sexes produce floral fragrance, although the fragrance is stronger in males. Staminate flowers offer pollen as a reward; pistillate flowers offer no reward. No nectar was found in flowers of either sex. I found no evidence of thermogenesis.

Although a total of 20 insect taxa (belonging to seven families) was found visiting flowers, a large difference was found in the importance of family visitation rates to each sex, measured as the proportion of landings by that family relative to the total number of landings by all families. Nitidulid and cucujid beetles comprised 53% of all landings on female flowers but only 12% of all landings on male flowers. I also observed chrysomelid beetles in female flowers at night, but they were absent in male flowers. Although bees (Africanized honey bees and native bees) and wasps collected pollen from male flowers, they rarely contacted the stigmas of female flowers. Weevils (Curculionidae) were frequently observed in male inflorescences but were not found in female counterparts. Finally, no pollen was found on visitors collected from female flowers. I concluded that insect-pollination was very unlikely.

The majority of slides (63%) suspended from female inflorescences contained *M. flexuosa* pollen. An individual slide had up to 117 pollen grains. In the exclusion experiment, fruit set differed significantly among treatments. Fruit set was highest in the control, followed by the visitor exclusion treatment; fruit set was lowest in the visitor + wind exclusion treatment. The results of this experiment pointed to wind-pollination.

Mauritia flexuosa demonstrates a suite of features conducive to anemophily: many unisexual flowers with a reduced perianth, lack of nectaries and thermogenesis, few ovules per flower, prodigious pollen production, synchronous flowering between sexes and high conspecific density. However, strong floral scent contradicts what we would expect for a wind-pollinated species, prompting me to ask the obvious question: why would an anemophilous species invest in floral fragrance? Given the presence of staminodes and pistillodes in the flowers of modern *M. flexuosa*, we may conclude that the ancestors were hermaphroditic. The hermaphroditic ancestor of *M. flexuosa* was presumably entomophilous, which is now considered to be the ancestral pollination mode in palms (Silberbauer-Gottsberger 1989). Unisexual flowers and sexual dimorphism are believed to be a derived trait in palms (Tomlinson 1990). Khorsand Rosa and Koptur (2013) also raised the possibility that entomophilous ancestors used mimicry to attract floral visitors to unrewarding female flowers, as has been observed in the relatives of *M. flexuosa*, *Calamus castaneus* (McKey 2012) and *Mauritiella aculeata* (Listabarth 1999). The most parsimonious explanation, therefore, seems to be that floral fragrance in *M. flexuosa* has been carried over from an entomophilous ancestor and has not yet been lost.

Our knowledge of the evolution of anemophily in palms from presumed animal-pollinated ancestors is limited. Virtually nothing is known about the pollination systems of the one other species of *Mauritia, M. carana*. The only study of another species of the tribe Lepidocaryeae is Listabarth's (1999) study of *Mauritiella aculeata*, which he found to be pollinated primarily (but not exclusively) by meliponine bees. Both male and female flowers are fragrant in *Mauritiella aculeata*. The species is dioecious, although Listabarth (1999) occasionally found perfect flowers in staminate inflorescences. *Raphia taedigera*, a distant relative of *M. flexuosa*, is both wind and insect-pollinated (Myers 1984) and is monoecious.

Chamaedorea spp. (Listabarth 1993, Berry & Gorchov 2004), *Howea* spp. (Savolainen et al. 2006), *Juania australis* (Bernardello et al. 2001), *Mauritia flexuosa* (Khorsand Rosa & Koptur 2013), *Thrinax parviflora* (Read 1975), *Phoenix dactylifera* (Popenoe 1922) and other *Phoenix* spp. are wind-pollinated. They are a taxonomically heterogeneous assemblage of palms from diverse habitats, distributed around the world. Are they the only wind-pollinated palms? Is anemophily truly rare in the palm family, or does this generalization simply reflect the lack of field studies? Further research in the tropics is urgently needed to assess the frequency of anemophily in tropical palms.

Acknowledgments

I thank the International Palm Society, National Science Foundation, Fulbright Commission, Florida International University, National Institute for Research in Amazonia (INPA), and the Montgomery Botanical Center for funding. The Brazilian Ministry of the Environment (MMA) allowed me to access field sites. I thank R.I. Barbosa for logistical support; L. Noblick and N. Rosa for assistance with tree climbing and equipment; F. Guedes, I.S. Firmino, and R.P. de Souza for collecting data; S.J.R. da Silva, M.L. Barbosa, and C. Ruy for identification of visitors; and S. Zona for insight while writing the manuscript. This is contribution number 275 to the Florida International University Program in Tropical Biology.

LITERATURE CITED

ACKERMAN, J.D. 2000. Abiotic pollen and pollination: ecological, functional, and evolutionary perspectives. Plant Systematics and Evolution 222: 167–185.

BARFOD, A.S., M. HAGEN, AND F. BORCHSENIUS. 2011. Twenty-five years of progress in understanding pollination mechanisms in palms (Arecaceae). Annals of Botany 108: 1503–1516.

BERNARDELLO, G., G.J. ANDERSON, T.F. STUESSY AND D.J. CRAWFORD. 2001. A survey of floral traits, breeding systems, floral visitors and pollination systems of the Angiosperms of the Juan Fernández Islands (Chile). The Botanical Review 67: 255–308.

BERRY, E.J. AND D.L. GORCHOV. 2004. Reproductive biology of the dioecious understorey palm *Chamaedorea radicalis* in a Mexican cloud forest: pollination vector, flowering phenology and female fecundity. Journal of Tropical Ecology 20: 369–376.

BRIGHTSMITH, D.J. 2005. Parrot nesting in southeastern Peru: seasonal patterns and keystone trees. Wilson Bulletin 117: 296–305.

COOK, O.F. 1943. Household palms and related genera. National Horticultural Magazine 22: 83–102.

COULTER, J.M. AND C.J. CHAMBERLAIN. 1915. Morphology of the Angiosperms. D. Appleton & Co., New York.

DELGADO, C., G. COUTURIER, AND K. MEJIA. 2007. *Mauritia flexuosa* (Arecaceae: Calamoideae), an Amazonian palm with cultivation purposes in Peru. Fruits 62: 157–169.

DELPINO, F. 1870. Ulteriori asservazioni e considerazioni sulla dicogamia nel regno vegetale. Atti della Società Italiana di Scienze Naturali Milano 13: 167–205.

DRUDE, O. 1889. Palmae. In A. ENGLER AND K. PRANTL, Die naturlichen Pflanzenfamilien. II 3: 1–93. Verlag von Wilhelm Engleman, Leipzig.

ERVIK, F. 1993. Notes on the phenology and pollination of the dioecious palm *Mauritia flexuosa* (Calamoideae) and *Aphandra natalia* (Phytelephantoideae). In W. BARTHLOTT, C.M. NAUMANN, K. SCHMIDT-LOSKE AND K.L. SCHUCHMANN (eds.), Animal–Plant Interactions in Tropical Environments, 7–12. Zoologisches Forschunginstitut und Museum Alexander Koenig, Bonn.

FAEGRI, K. AND L. VAN DER PIJL. 1979. The Principles of Pollination Ecology. Third edition. Pergamon, Oxford.

GOULDING, M. AND N. SMITH. 2007. Palms, Sentinels for Amazon Conservation. Amazon Conservation Association, Missouri Botanical Garden Press, St. Louis.

HENDERSON, A. 1986. A review of pollination studies in the Palmae. The Botanical Review 52: 221–259.

HENRY, O., F. FEER, AND D. SABATIER. 2000. Diet of the lowland tapir (*Tapirus terrestris* L.) in French Guiana. Biotropica 32: 364–368.

JOHNSON, D.S. 1915. The history of the discovery of sexuality in plants. In Smithsonian Annual Report 1914, 383–406. Smithsonian, Washington D.C.

KERCHOVE, O. 1878. Les Palmiers. Rothschild, Paris.

KERNER VON MARILAUN, A. 1895. The Natural History of Plants. F.W. OLIVER (transl. & ed.). 2 vols. Blackie & Son, London.

KHORSAND ROSA, R. AND S. KOPTUR. 2013. New findings on the pollination biology of *Mauritia flexuosa* (Arecaceae) in Roraima, Brazil: linking dioecy, wind, and habitat. American Journal of Botany 100(3): 613–621.

LISTABARTH, C. 1993. Insect-induced wind pollination of the palm *Chamaedorea pinnatifrons* and pollination in the related *Wendlandiella* sp. Biodiversity and Conservation 1: 39–50.

LISTABARTH, C. 1999. The palms of the Surumoni area (Amazonas, Venezuela). II. Phenology and pollination of two flooded forest palms, *Mauritiella aculeata* and *Leopoldinia pulchra*. Acta Botanica Venezuelica 22: 153–165.

MCKEY, D. 2012. Flowering phenology and mimicry of the rattan *Calamus castaneus* (Arecaceae) in southern Thailand. Botany 90: 856–865.

MEEUSE, A.D.J. 1972. Palm and pandan pollination: primary anemophily or primary entomophily. Botanique 3: 1–6.

MYERS, R.L. 1984. Growth form, growth characteristics, and phenology of *Raphia taedigera* in Costa Rican palm swamps. Principes 28: 64–72.

NIKLAS, K.J. 1985. The aerodynamics of wind pollination. Botanical Review 51: 328–386.

POPENOE, P. 1922. The pollination of the date palm. Journal of the American Oriental Society 42: 343–354.

RAVEN, P.H., R.F. EVERT, AND S.E. EICHHORN. 1999. Biology of Plants, sixth edition. W.H. Freeman and Company, New York.

READ, R.W. 1975. The genus *Thrinax* (Palmae: Coryphoideae). Smithsonian Contributions to Botany 19: 1–98.

SAVOLAINEN, V., M.C. ANSTETT, C. LEXER, I. HUTTON, J. J. CLARKSON, M.V. NORUP, M.P., D. SPRINGATE, N. SALAMIN, AND W.J. BAKER. 2006. Sympatric speciation in palms on an oceanic island. Nature Letters 441: 210–213.

SANTOS, L.M.P. 2005. Nutritional and ecological aspects of buriti or aguaje (*Mauritia flexuosa* Linnaeus filius): A carotene-rich palm fruit from Latin America. Ecology and Food Nutrition 44: 345–358.

SCHLEMMER, D., E.R. DE OLIVEIRA, AND M.K. ARAÚJO SALES. 2007. Polystyrene/ thermoplastic starch blends with different plasticizers. Journal of Thermal Analysis and Calorimetry 87: 635–638.

SILBERBAUER-GOTTSBERGER, I. 1989. Pollination and evolution in palms. Phyton 30: 213–233.

STORTI, E.F. 1993 . Biologia floral de *Mauritia flexuosa* Lin. Fil. na região de Manaus, AM, Brasil. Acta Amazonica 23: 371–381.

TOMLINSON, P.B. 1990. The Structural Biology of Palms. Clarendon Press, Oxford.

VAN DER PIJL, L. 1978. Reproductive integration and sexual disharmony in floral functions. In A.J. RICHARDS (ed.), The Pollination of Flowers by Insects. Academic Press, London.

WALLACE, A.R. 1853. Palm Trees of the Amazon. John Van Voorst, London.

WETTSTEIN, R. 1935. Handbuch der systematischen Botanik. Franz Deuticke, Leipzig und Wien.

ZANATTA, C.F., V. UGARTONDO, M. MITJANS, P.A. ROCHA-FILHO, AND M.P. VINARDELL. 2008. Low cytotoxicity of creams and lotions formulated with Buriti oil (*Mauritia flexuosa*) assessed by the neutral red release test. Food and Chemical Toxicology 46: 2776–2781.

Palms on the Nickel Island: An Expedition to Gag Island, Western New Guinea

CHARLIE D. HEATUBUN
Fakultas Kehutanan dan Pusat Penelitian Lingkungan Hidup, Universitas Papua, Jl. Gunung Salju, Amban 98314, Manokwari, Papua Barat, Indonesia
charlie_deheatboen@yahoo.com

KRISMA LEKITOO
Herbarium Papuense, Balai Penelitian Kehutanan Manokwari, Jl. Inamberi – Pasir Putih, Manokwari 98312, Papua Barat, Indonesia

AND

ONASIUS PIETER MATANI
Badan Pengendalian Dampak Lingkungan Daerah Provinsi Papua Barat, Jl. Reremi Puncak, Manokwari 98312, Papua Barat, Indonesia

This is an account of an exciting expedition to an off-shore island in northwestern New Guinea. The relatively isolated position, small size, unusual geological formation, including limestone and nickel-rich mineral deposits, and the peculiarities of its palms make Gag Island one of the most threatened palm habitats in New Guinea.

Gag Island is a small island about 11.5 × 8 km, lying at 0°25’00”S and 129°53’00”E and belonging to the Raja Ampat Archipelago. Administratively, Gag is part of Kabupaten (regency) Raja Ampat, in the Indonesian province of Papua Barat (West Papua). The island is about 160 km NW of Sorong on the New Guinea mainland, and it can be reached in 12–18 hours by using a traditional *pinisi* boat, or about 5 hours by speedboat, or 35 minutes in a small aircraft. Sea travel to this area is totally dependent on the “wind-season” or monsoon, so at particular times of the year, usually during *musim angin selatan* (the south-wind season) there is almost no sea transport serving the island.

Gag Island has been famous since 1969, when a large deposit of nickel was discovered by the Pacific Nickel Co., and according to their estimate, deposits were sufficient for at least 30 years mining. However, mining activity has been postponed for several years due to environmental and biodiversity issues, especially after the forest on Gag was declared a protected area by the Indonesian Ministry of Forestry. The mining concession overlaps the protected forest on the island, but a special regulation was issued recently by the central government to accommodate "mining in protected areas," and the status of the forests on Gag Island changed into a mining concession. As a result, the concession holder has started to build the mining infrastructure, even though many conservationists and environmentalists still disagree with the plan to exploit the minerals on Gag.

The position of Gag and other islands of Raja Ampat is biogeographically significant, especially the roles these islands play as a connection between the main island of New Guinea and areas farther west. Recent biodiversity studies conducted by Conservation International (McKenna et al. 2002) and the Nature Conservancy (Takeuchi 2003, Webb 2005) demonstrate that the Raja Ampat Islands are unique and have high biodiversity. The conservation agencies together with the Government of Indonesia have recommended the Raja Ampat Islands (including Gag) to be designated by UNESCO as a World Heritage Site (McKenna et al. 2002, Takeuchi 2003).

Raja Ampat Archipelago is the one of several areas in western New Guinea that are under-collected according to Conn (1996) and Johns (1997). However, several collecting trips have now been conducted to the area, such as trips to Salawati and Batanta (1996), Waigeo (1997) and Misool (2002) by Herbarium Manokwariense (Universitas Papua, Manokwari), by The Nature Conservancy (Takeuchi 2003, Webb 2005), and most recently by the Indonesian Institute of Sciences (LIPI) to Waigeo in 2007. However, none of these trips visited Gag, and thus the flora of this island (including palms) was poorly known. During our expeditions, we were really privileged to explore, collect and make an account of Gag's palms for the first time and also to make important discoveries, such as a new record of *Heterospathe elata* for New Guinea (Heatubun et al. 2012), a new record of *Calamus zollingeri* and *Calyptrocalyx spicatus* for New Guinea and extended range of *Saribus brevifolius* (in this paper) and a new taxon of Ptychospermatinae (Heatubun et al., in press).

The expeditions

Two palm expedition have been carried out to Gag Island. The first expedition was conducted in 2006, as part of Palms of New Guinea project (Baker 2000, 2002) and to support CDH's PhD research project on the genus *Areca*

1. The *pinisi* boat KLM Febry Jaya, the wooden vessel which used in the expedition to Gag Island. (Photo by Charlie D. Heatubun).

L. (Heatubun 2009, Heatubun et al. 2012b), and also together with colleagues from the Balai Penelitian Kehutanan (Forestry Research Institute), aiming to get information about existing terrestrial biota of the island. The second expedition was in 2011, as part of a project on the taxonomy, ecology and conservation of palms on Gag Island with funding from the International Palm Society (IPS Endowment Fund 2010 to CDH and William J. Baker). This paper tells the story of our unforgettable experiences in reaching and escaping Gag Island, mostly from the first expedition, and about its unique palms and their recent taxonomic status.

The first expedition began on 18 July 2006, when two of us (KL and OPM) and other expedition members travelled to Sorong from Manokwari by regular ferry boat, arriving in Sorong on the following day. In the meantime, CDH undertook the long journey from Bogor in West Java, staying overnight in Manado in North Sulawesi before joining the expedition team in Sorong. In Sorong, we spent three days prior to departure to Gag. We needed time to prepare all the permits and logistics and, most importantly, to find a sea-worthy boat to ferry us safely over the ocean to Gag. At the same time, we paid attention to the weather forecast and tried to decide when exactly would be the best time for us to travel. Although the authorities suggested we should postpone our expedition until the sea condition was more favorable to travel, we had to do our fieldtrip as soon as possible because we had tight schedules, with other commitments planned for the time after the trip. After we had a short discussion and made some observations, we finally decided that we should use a big boat to cross the ocean, and our choice was a 45-ton wooden vessel, the *KLM Febry Jaya* – a *pinisi* boat (Fig. 1). The *pinisi* is a type of traditional sailing boat of the Makassar Bugis people of South Sulawesi. *Pinisi* have served the traditional trading routes among the islands for centuries and are famous for crossing the Indian Ocean to Madagascar and Africa in medieval times. Our boat was 20 m long and 8 m wide and equipped with an 8 × 4 m main sail and one supporting engine, and it had the potential to reach seven knots in normal conditions.

Just after midnight on 22 July 2006, we started to load the vessel with all our gear and personal belongings, and finally the boat departed at three o'clock in the morning. The *pinisi* moved out slowly from the pier and sailed, following the bay in front of the town of Sorong. In minutes, we were already headed north to Waigeo Island. In our first six hours, it was relatively windless and our vessel sailed normally. We reached the town of Waisai (the capital of Kabupaten Kepulauan Raja Ampat) in the south of Waigeo Island at mid-day. Because there was no pier at the time, we just dropped anchor and landed on the beach using a small canoe. We tried to meet the authorities in the town; unfortunately, we had arrived on a Saturday when the main office of the local government was closed, so all we could do was to drop off our information and return to the boat.

The trip continued, and we sailed straight to the west to Gag. After passing Saunek Island, we entered the Dampier Strait, which separates Waigeo in the north from Batanta to the south. The strait is named for Captain William Dampier (1651–1715), the author and seaman who visited the area and collected algae along the north coast of New Guinea's Kepala Burung (Bird's Head Peninsula) in 1700 on the *HMS Roebuck*. The Dampier Strait is famous for having been visited by the great British naturalist and co-discoverer of the mechanism of evolution, Sir Alfred Russell Wallace, in 1859 (Wallace 1874).

We all had a great time on this crossing; we saw spectacular scenery on several small islands along the Dampier Strait: the bluish crystal-clear sea water with magnificent coral reefs, the white sand beaches clinging to the islands and the coconut trees pointing to the sky, the perpendicular limestone-cliffs just bursting out from the sea and an unexpectedly beautiful sunset over Merpati Island. We really enjoyed our journey and were astonished by what we saw. Our *pinisi* moved slowly and reached Merpati Island in the late afternoon, and soon we cast anchor off the island. Although the island was suitable for landing, we decided to sleep on the boat.

Early morning on the next day, we continued our expedition to our destination, Gag Island. It was about four o'clock in the morning, when our vessel left Merpati Island. The captain said that we had to rush to cross the ocean and reach Gag Island before mid-day, because strong winds usually blow at noon and the resulting big waves could be really dangerous. There was no land between Merpati and Gag, and the distant open-sea water was waiting to be crossed. However, the ocean was very friendly, the breeze blew from behind and

2. An ultramafic hill on Gag Island with palms emerging from the forest canopy. (Photo by C.D. Heatubun).

small waves helped to push us on. Finally, Gag Island appeared, a small dot in the distance rising up from the horizon, and becoming clearer and clearer. In just a few hours, we were approaching the shore.

The scenery was unusual; ultramafic rocks and brown clay soil was exposed, contrasting with the sea water and blue skies in the background (Fig. 2). Shrubs and dwarf trees were dominant in the grayish heath forest vegetation. The different colors of vegetation were scattered in the lowlands to the limestone hills on the other side of the island, while coconut groves camouflaged the heavily disturbed lowland forest just behind the village. We were close to shore, and the village stretched along the coastline of a small bay, Gambir Bay. On the other side of the bay, just opposite the village, were the facilities of the base camp of the mining company, PTGN, with a small pier, the only one on the island. We had arrived at mid-day. The boat was tied up at the pier, and a few people were waiting to see us; they were the camp manager of PTGN and the local authorities of Gag Island. Then we discussed our collecting plan, including collecting sites inside the mining concession area. Soon after the meeting, we unloaded our personal belongings from the boat and stayed overnight at base camp.

We started our collecting activity on the morning of 24 July 2006, when a few members of the expedition team went to the northern part of the island and set up our camp. After a quick exit from PTGN's base camp, all the members of the expedition team met together in our camp in the north of the island. Actually, our camp was set up close to a small spring and also very close to the beach (about 20 m from the water's edge) under coconut trees, at a place called Kapatpapo. This area was dominated by heavily disturbed old garden vegetation, coconut plantation and fragments of lowland forest along a small creek and forest on the limestone hill. The lowland rainforest and limestone hill forest were top priority for exploration.

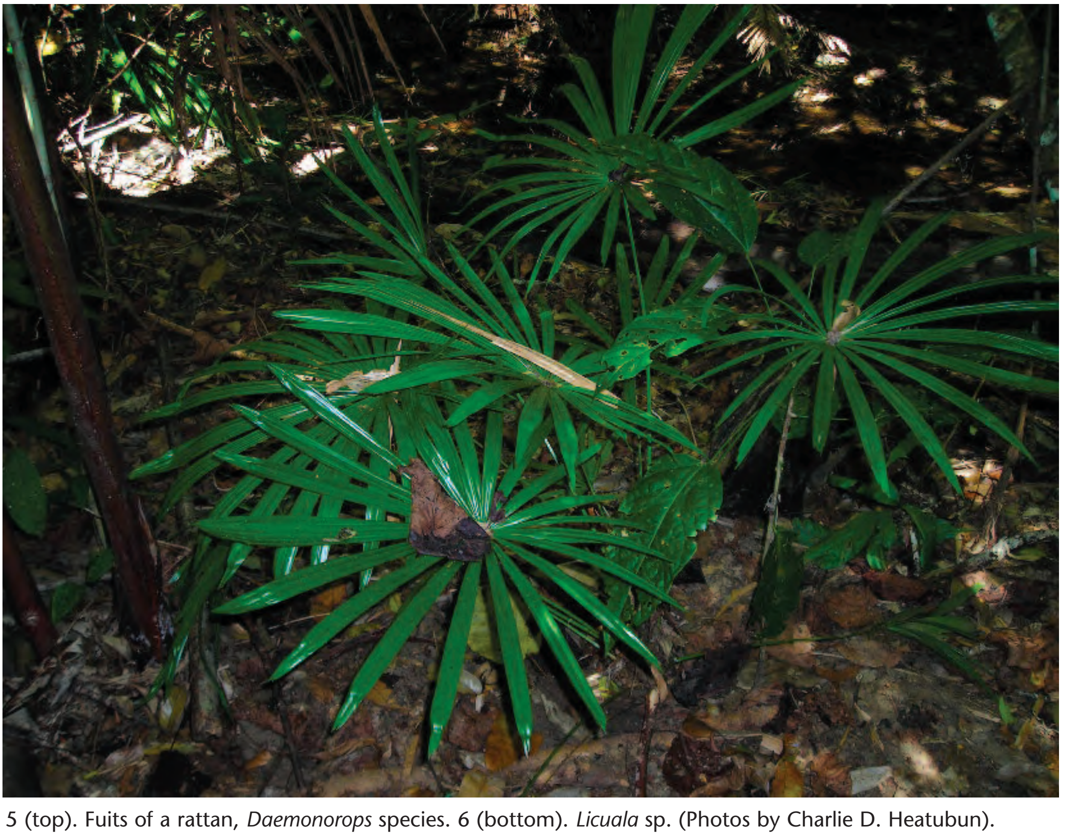
We divided into two small groups; one was led by KL with the main task of making a forest inventory and vegetation analysis of the island. The other group, led by CDH and OPM, aimed to collect any interesting plants found during the fieldtrip, including palms and gingers. We walked out from our camp, passed the coconut trees and straight to the west, crossing contours, and tried to reach the other side of the island. That forest was lowland rainforest on the small limestone hill, but the condition was heavily disturbed by local mixed-cultivation gardens, expansion of coconut plantation and firewood extraction by local people. After a half day of walking, we realized there was no forest left on the other (western) side of the island, so we went no farther. The forest had been converted to mixed-garden and coconut plantation. We decided to go back to camp and did some collecting on the way. On this occasion, we made collections of several palms such as *Calamus zollingeri*, *Calamus* sp. 1, *Daemonorops* sp., *Heterospathe elata, Licuala* sp. and a few individuals of very unusual young palms (and seedlings) with the appearance of *Hydriastele* or *Ptychococcus* but we failed to find the mature palm. We also made collections of a giant ginger (possibly a species of *Alpinia*) with leafy stems shooting out to 10 m high from the ground, as well as collections of interesting bamboos and other grasses and several trees.

Calamus zollingeri Becc. is a Sulawesi rattan species, which is solitary in Gag (but often clustering in Sulawesi). It is a rattan climbing to 20 m high, with a cane diameter of about 6 cm with sheaths and 4 cm without sheaths. The leaves are about 475 cm long with cirrus and bearing about 100 pairs of regular leaflets, white powdery and waxy underneath and the petiole about 40 cm long. The inflorescence can reach 200 cm long with several partial inflorescences, the first branch of the partial inflorescence 65 cm long. This is the largest rattan on the island and is usually found in lowland rainforest and/or limestone forest. Cane from this species is used as rope or binding material for traditional construction and is called *wala dou* in Gebe dialect. This represented an important new record of this species for New Guinea (Fig. 3).

Calamus sp. 1 is a small clustering rattan with very distinctive dense white velvet-like hairy sheaths and almost erect stems to 3 m high. This rattan is found mainly in forest gaps or in old secondary forest on alluvium or limestone areas and is locally called *wala molo* in Gebe dialect. It is also used as rope and binding material.

Daemonorops sp., or *sane* in Gebe dialect, is a clustering moderate rattan, climbing to 30 m high in alluvial forest and/or limestone hill forest. Diameter of the canes with sheaths is

3 (below left). Leaf sheath of rattan *Calamus zollingeri*. 4 (below right). Cane with sheath of rattan *Daemonorops* sp. (Photos by Charlie D. Heatubun).



5 (top). Fuits of a rattan, *Daemonorops* species. 6 (bottom). *Licuala* sp. (Photos by Charlie D. Heatubun).


7 (left). Undescribed species of Ptychospermatinae. 8 (right). Triads in bud of the undescribed species of Ptychospermatinae. (Photos by Charlie D. Heatubun).

3–5 cm, and without sheaths about 2 cm, the sheath covered with dense brown powder on top of blackish bristly hairs (Fig. 4). Leaves with cirrus are about 450 cm long and bearing 69 pairs of regularly-arranged leaflets. The inflorescence is the main character to distinguish it from *Calamus*; in *Daemonorops* it is pendulous and enclosed by many persistent very spiny bracts. The inflorescence hangs down to about 1 m long and bears globose fruits about 2 cm in diameter and covered with milky brown, shiny scales (Fig. 5). The cane of this rattan is also used as weaving material for making baskets.

Licuala sp. (*pesem* in Gebe dialect) is a solitary moderate tree palm to 10 m tall with numerous fan leaves (Fig. 6). The leaf is 220–235 cm long and bears about 39 segments. The segments split deeply to the hastula and all segments have a similar dimension. The interfoliar inflorescence is borne among the leaves about 230 cm long with a peduncle around 55 cm long and prophyll 33 cm long. The flowers are small, cream in color and the fruits are small, green, and ripening orange. This *Licuala* occupied lowland areas up to the forest on limestone hill and locally the stem or wood from this palm is used as piles and/or planks for traditional construction.

In the following days, we spent our time searching for and finding a few patches of lowland forest; they were close to the airstrip and Kablebet River. It was amazing that we found a few mature stands of *Heterospathe elata* in secondary forest (see Heatubun et al. 2012). We also found an emergent tree species of undescribed Ptychospermatinae palm (Figs. 7–11). The palm was also present in secondary forest and old, abandoned gardens, where it persists as a relict from the original forest. This new taxon, or *gul botom* in Gebe dialect, is a large solitary tree palm to 25 m tall with a conspicuous crownshaft and about 12 leaves with strikingly pendulous leaflets, forming the hemispherical crown. The leaf is about 275 cm long and bears 55 pairs of regular praemorse leaflets. The inflorescence is infrafoliar and about 75 cm long with third order branches, and the peduncle is shorter than the rachis. The fruit is mid to light green, orange and red when ripe, and the seed ellipsoid with ruminate endosperm. Another population of this mysterious palm (*CH 746*) was also found in patchy lowland forest near Kablebet River

9 (top). Detail of pistillate flowers after anthesis of the undescribed species of Ptychospermatinae.
10 (bottom). Ripe fruits of the undescribed species of Ptychospermatinae. (Photos by Charlie D. Heatubun).

where the population was healthy with several mature trees in full fruit. From this area, we also collected two species of *Areca*, One is the native *Areca macrocalyx*, a small to medium solitary palm with stem to 5 m tall, internodes 4–15 cm long and about 5 cm in diameter, 7 leaves in the crown and bearing about 19 pairs of leaflets, the crownshaft 90 cm long and leaf sheath 70 cm long. Inflorescence is colorful, hanging down about 53 cm long and 14 cm width, with a caducous bract and congested rachillae (Fig. 12). This *Areca* is native to Gag

Island and mainly grows on stream banks in lowland forest in limestone areas and is quite distinct from typical *A. macrocalyx* in its colorful inflorescence and rachillae of the second and third order. Sometimes, the fruits are used by local people as a substitute for betel nut (*A. catechu*). It is also locally known as *pinang hutan* or *kasimya* in Gebe dialect.

The other species of *Areca* was *Areca* sp.; this solitary moderate palm with stem reaching up to 15 m high was planted by local people in their gardens together with common betel nut (*A. catechu*). This species of *Areca* is easily distinguished from the true *A. catechu* by its short internodes and distinctive recurved leaves in the crown, and also the inflorescence is robust with staminate flowers arranged on one side of rachillae (unilateral), and has three conspicuous scars on the egg-shaped fruit caused by woody sepals scratching the epicarp during the development fruit from the gynoecium. However, this species is treated as *A. catechu*, in the recent monograph of the genus *Areca* from East Malesia (see Heatubun et al. 2012b for explanation). This palm is not native to Gag Island. Local people said that they had brought seeds and seedlings from Gebe Island in North Moluccas and planted them on Gag Island. The same species has been recorded and collected from cultivation on the North Coast of Yapen Island in Cenderawasih Bay (Geelvink Bay), Papua Province by the CDH. Usually on Gag, local people called this palm *pinang gebe* or *mala lolef* in Gebe dialect.

Another interesting palm also found during this occasion was *Calyptrocalyx spicatus* (Lam.) Blume (Figs. 13 & 14). This solitary moderate palm grows along stream banks on alluvial soils in the limestone forest and it can reach up to 15 m tall. There is no crownshaft and the leaves are about 400 cm long and bear about 50 pairs of leaflets. The 3-spiked inflorescence is about 250 cm long and has persistent bracts borne between the leaves. Although this is a new record of *C. spicatus* for New Guinea, this taxon needs further investigation because it can be distinguished from typical Moluccan *C. spicatus* in inflorescence and fruit characters. The inflorescence of this taxon is always 3-spiked, and the fruit has thick brown indumentum on the surface of epicarp, and also whitish cream color when ripe, while, the Moluccan *C. spicatus* has 1- or 2-spiked inflorescences, and fruits that are smooth and red when ripe according to Dowe & Ferrero (2001) in their revision of the genus *Calyptrocalyx*.

11. Endocarp, seed and endosperm of undescribed species of Ptychospermatinae. (Photo by C.D. Heatubun).

12. Inflorescence of *Areca macrocalyx* showing rachillae with staminate flowers at anthesis and pistillate flowers after anthesis. (Photo by Charlie D. Heatubun).

Before moving to another part of the island, we listed without collecting the common and/or cultivated palms that we found, such as *Areca catechu*, *Caryota rumphiana*, *Metroxylon sagu*, *Nypa fruticans* and *Salacca zalacca*. Besides the palms, we also collected other plants from coastal vegetation, mangroves and swampy areas including a beautiful terrestrial orchid, *Arachnis beccarii* – this species grew on the karst limestone on the beach, its beautiful flowers dominated by yellow and red leopard-spotting on the adaxial (upper) surface of its tepals while being purple-colored on the abaxial (lower) surface.

13 (top). Staminate flowers at anthesis of *Calyptrocalyx spicatus*. 14 (bottom). Ripe fruits of *Calyptrocalyx spicatus*. (Photos by Charlie D. Heatubun).

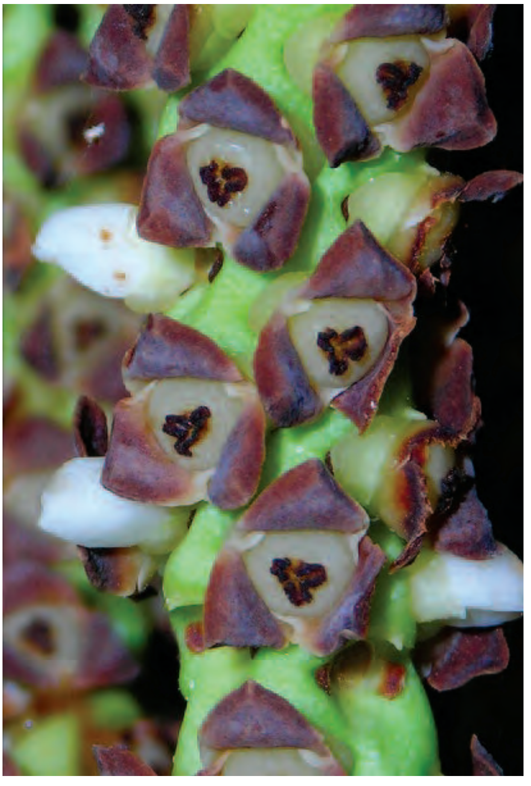
After spending five days in Kapatpapo, we moved to the heath forest on ultramafic and volcanic formations inside the mining concession of PT. Gag Nikel. Due to strict regulations from the company, we had to stay in a village with local people and walk to the concession area for collecting. We started collecting on the ultramafic area by walking along the main mining road, from base camp uphill. The road was in good condition, with gravel and limestone construction, but sometimes with laterite soils. The area was fantastic! The demarcation of each type of vegetation was so clear from a distance. From the highest point, the summit of Mt. Susu (275 m elevation), we saw the entire island as a huge puzzle of vegetation types, and each piece of the puzzle represented one specific plant community. The heath forest comprises small trees and woody shrubs, such as *Alstonia beatricis* and *A. rubiginosa* (Apocynaceae), *Calophyllum* sp. (Calophyllaceae) with tiny yellowish foliage and fruits, the tree *Gnetum gnemon* and the liana *Gnetum gnemonoides* (Gnetaceae), *Pouteria* sp. (Sapotaceae) and others; they all had an unusual appearance, being small and short in all dimensions or of a dwarf habit.

From this habitat, we collected two species of *Hydriastele*. The first one was *Hydriastele* sp. 1 (Figs. 15–17) from swampy and water-logged areas behind the main camp of PT. Gag Nickel. This palm is distributed from swamp forest to the slopes on heath forest and it resembles *Hydriastele brassii* (Burret) W.J.Baker & Loo from the mainland of New Guinea.

The second species, *Hydriastele* sp. 2 (Figs. 18 & 19), occurred in the heath forest along the main road from base camp up to the mining area on the slope and up to the hill of the heath forest on ultrabasalt soil. This handsome palm is a large solitary tree palm tall to 25 m tall with conspicuous crownshaft and about eleven recurved leaves that form a beautiful crown, spherical in outline. The leaf is about 200 cm long and bears 34–44 pairs of regularly arranged leaflets. The horsetail-like inflorescence is pendulous, as is typical of *Hydriastele,* hanging down to 50 cm below the crownshaft. The fruits are colorful, yellowish metallic green and orange near the tip (see Front Cover). The seedling of this species has an entire bifid leaf and becomes pinnate after the rosette phase. We also found this taxon later in heath forest on ultramafic areas in Halmahera, North Moluccas (Heatubun 2011).

After we spent a whole day searching this area, we went back down to Gambir village, collecting *Saribus brevifolius* (Figs. 20 & 21) on the way. This fan palm has relatively small

15. *Hydriastele* sp. 1. in the swampy habitat. (Photo by Charlie D. Heatubun).



16 (left). Pistillate flowers at late anthesis of *Hydriastele* sp. 1. 17 (right). Ripe fruits of *Hydriastele* sp. 1. (Photos by Charlie D. Heatubun).

leaves and dominates slopes and ridges on the ultramafic rocks. The seedling of *Saribus brevifolius* shares the same habitat with *Hydriastele* sp. 1 and *Hydriastele* sp. 2, as shown in Fig. 22.

After ten days on the island, we had sampled all the palms we had encountered, including all introduced palms (see Table 1 for the entire list). Before we went back to Sorong, the villagers of Gambir gave us a special farewell party. We had dinner together; they served us with enormous local dishes and several traditional cakes and, of course, palm wine. The palm wine was made from the sap of the coconut and nipah palm (*Nypa fruticans*), naturally fermented. When three of us (CDH, KL and OPM) finished our supper and went back to our accommodation to pack our belongings, some of expedition team members stayed on partying, dancing till midnight. Before 2 a.m. the party was over and all expedition members headed off to our *pinisi* at the pier. It took almost one hour to embark and set sail to leave Gag.

Soon, after leaving Gag, we were in the middle of a heavy storm. The wind blew strongly and the waves reached about 3 m high. Our vessel was struck by huge waves, and we rocked about in the dark. We were terrified because we had never experienced anything like this; within just a few minutes, the *pinisi* boat was hit by big waves again and again, from the front, left side and right side. All passengers had been ordered to wear life jackets and to stay calm; some were terribly sea-sick. We were all silent; the only sounds were the boat's engine, the wind and the waves. Although it was early morning it was still dark, and we waited anxiously for sunrise, constantly checking our watches. We were reminded of the old Christian hymn "Above the Hills of Time" by Thomas Tiplady (1886) "*As ship-wrecked seamen yearn for morning light....*" That summed up almost exactly what we felt!

The sun finally rose together with the ending of the storm and clearing the morning mists. The captain had taken the wheel himself, and together with his crew, they sailed the boat safely through the stormy sea. We were all relieved and happy to see the *pinisi* had already entered the Dampier Strait and the weather became friendly. After we passed Kri Island, the *pinisi* turned right following the tip of the East Cape of Batanta Island, and we then sailed

18. *Hydriastele* sp. 2. in heath forest at ultramafic. (Photo by Charlie D. Heatubun).

straight to the south to Sorong. Thus ended our first expedition to Gag Island.

Palm diversity, ecology and biogeography

In general, the palm flora in the Gag Island is not very rich – 19 species of palm have been encountered during the expedition, and 14 species (74%) are native (see Table 1). Of the native palms, seven species (50%) are particularly interesting and need further investigation, especially taxa in the genera of *Calamus*, *Calyptrocalyx*, *Daemonorops*, *Hydriastele* and *Licuala*. One taxon (*CH 741, 742*) has already been confirmed as a new genus of subtribe Ptychospermatinae from molecular evidence and a manuscript is in the works (Heatubun et al. in press) – this taxon was also found and collected by CDH from a limestone hill in southwest Waigeo Island. There is no palm species endemic to Gag. However, Gag shares several species with islands nearby, and these species have restricted areas of distribution. For example, *Saribus brevifolius* was known before only from the small island of Kawe in the north of Batanta Island (Dowe & Mogea 2004) and is now confirmed from Gag Island; this species is thus endemic to Raja Ampat Islands. Similarly, *Hydriastele* sp. 2 is found on Gag Island and also in East Halmahera (Heatubun 2011), while *Hydriastele* sp. 1 resembles *H. brassii* from mainland New Guinea (Baker & Loo 2004) – the identity of these palms will be determined in a forthcoming monograph of *Hydriastele* (Heatubun & Baker in prep.). The palm's occurrence on Gag is correlated with the soils and geological formation. There is a clear separation between palm species growing on ultramafic/ultrabasalt and limestone substrates. Only three species of palms are adapted to ultramafic/ultrabasalt, and the rest grow on limestone and/or are cultivated near the village (see Table 1).

Gag Island is actually located between two different palm floristic regions, namely Moluccas to the west and New Guinea (and Bismarck Archipelago) to the east. At the generic level, all native palms on Gag have affinities to both floristic regions as listed in Dransfield et al. (2008: 649), except for the new taxon of Ptychospermatinae, which is distributed only in the Raja Ampat Islands (Gag and Waigeo Islands), never found on mainland New Guinea. The discovery of this new palm also supports an explanation of phylogeography for the subtribe Ptycho-

19. Young palm of *Hydriastele* sp. 2. (Photo by Charlie D. Heatubun).

spermatinae with special reference to Raja Ampat Islands as a connecting bridge for species dispersal from the east to the west (Zona et al. 2011), as evidenced by *Adonidia* (Baker & Heatubun 2012) with a disjunct distribution pattern (Baker & Couvreur 2012, Zona et al. 2011). However, the generic placement of the Biak *Adonidia* will have to be

20 (top). *Saribus brevifolius*. 21 (bottom). Seedliings of *Saribus brevifolius.* (Photos by Permenas Dimonmou).

22. Seedlings of *Saribus brevifolius* and two species of *Hydriastele* on ultramafic soil. (Photo by C.D. Heatubun).

changed in response to recent findings from molecular phylogenetic studies in Ptychospermatinae (Alapetite et al. 2014, Heatubun et al. in press). At the species level, the occurrence of *Calamus zollingeri*, *Calyptrocalyx spicatus*, *Daemonorops* sp., *Heterospathe elata* and *Hydriastele* sp. 2 define the Moluccan element rather than the New Guinean in the palm flora of Gag. The replacement of the New Guinean emergent tree palm species, such as *Cyrtostachys* spp., *Hydriastele costata* and *Rhopaloblaste* spp., by *Heterospathe elata*, *Hydriastele* sp. 2 and *Saribus brevifolius* and a new taxon of Ptychospermatinae makes more clear the oceanic connection to Gag Island. However, these all support palm distribution patterns in general in the Malesian region (Baker & Couvreur 2012) and show the important role played by Raja Ampat Islands in connecting mainland New Guinea to the islands farther west and north, including the Philippines (Webb 2005).

Uses and folk taxonomy

In general, palms are of major economic importance on Gag Island. For example, the sago palm (*Metroxylon sagu*) has provided a staple food for the people on the island. The coconut palm (*Cocos nucifera*) and the betel nut palm (*Areca* spp.) are "cash crops" and they give direct income to local people who sell the copra (dried coconut) and betel nut outside the island, usually to Menado in North Sulawesi. Rattan and wild tree palms have provided weaving and construction materials for daily needs.

Most people who live on Gag originally migrated from Gebe Island in North Moluccas, so all the local or vernacular names are in the Gebe dialect. Often local names comprise a single-word or basic name and the basic name plus prefixes. The prefixes usually relate to habit or typical taxon. For example *wala* (= rope) is a prefix to the rattan genus *Calamus* referring to the climber or liana habit. Similarly

Table 1. List of palm species in Gag Island.

No.	Species	Collections or Records	Local name (Gebe dialect)	Geological substrate
1.	*Areca catechu* L.	Sight records (cultivated)	*mala chu'* (*pinang*)	Cultivated (Limestone)
2.	*Areca catechu* cv. Gebe	*Heatubun et. al. CH 751, CH 752* (cultivated; said originally from Gebe Isl.)	*mala lolef* (*pinang gebe*)	Cultivated (Limestone)
3.	*Areca macrocalyx* Zipp. ex Blume	*Heatubun et. al. CH 747, CH 748*	*kasimnya*	Limestone
4.	*Calamus zollingeri* Becc.	*Heatubun et. al. CH 733, CH 734*	*wala douw*	Limestone
5.	*Calamus* sp. 1	*Heatubun et. al. CH 736*	*wala molo'*	Limestone
6.	*Calyptrocalyx spicatus* Blume	*Heatubun et. al. CH 749, CH 750*	— (unknown)	Limestone
7.	*Caryota rumphiana* Mart.	Sight records	*bali'*	Limestone
8.	*Cocos nucifera* L.	Sight records (large-scale plantations)	— (not recorded)	Cultivated (Limestone)
9.	*Daemonorops* sp.	*Heatubun et. al. CH 738*	*sane'*	Limestone
10.	*Heterospathe elata* Scheff.	*Heatubun et. al. CH 735, CH 739, CH 740*	*gul ways*	Limestone
11.	*Hydriastele* sp. 1	*Heatubun et. al. CH 759, CH 764, CH 765*	*gul botom*	Ultramafic (Ultrabasalt)
12.	*Hydriastele* sp. 2	*Heatubun et. al. CH 760, CH 761*	*gul botom*	Ultramafic (Ultrabasalt)
13.	*Licuala* sp.	*Heatubun et al. CH 737, CH 745*	*pesem'*	Limestone
14.	*Saribus brevifolius* (Dowe & Mogea) C.D. Bacon & W.J. Baker	*Heatubun et. al. CH 762, CH 763*	*ngawan'* (unarmed petiole)	Ultramafic (Ultrabasalt)
15.	*Saribus rotundifolius* (Lam.) Blume	Sight record (cultivated; said to be originally from Gebe Isl.)	*matmet'* (armed petiole)	Cultivated (Limestone)
16.	*Metroxylon sagu* Roetb.	Sight records	*yof*	Swamp (Limestone)
17.	*Nypa fruticans* Wurmb	Sight records	— (not recorded)	Mangrove (Limestone)
18.	*Salacca zalacca* (Gaertn) Voss	Sight records (cultivated; seeds originally from the market in Menado, North Sulawesi).	— (not recorded)	Cultivated (Limestone)
19.	Ptychospermatinae gen. nov.	*Heatubun et. al. CH 741, CH 742, CH 746*	*gul botom*	Limestone

mala is the prefix for typical *pinang* (= source of the betel nut) and *gul* is applied to a slender tree palm. However, the cosmology of the local people, their knowledge about plants and their classification of plants need to be studied further.

Conservation

A conservation assessment of palms on Gag is urgently needed in relation to land conversion and mining activities. Based on our field observations, almost all native palms were highly threatened in both the limestone and the ultramafic (ultrabasalt) habitats. Almost 20 percent of land in the limestone area in Gag Island has been converted to coconut plantations. A few varieties of *C. nucifera* were planted to produce copra as raw material for the cooking oil industry. Coconut plantations and traditional mixed-cultivation gardens are a serious threat to the forest or vegetation on the limestone formations. *Calyptrocalyx spicatus* and a new taxon of Ptychospermatinae are high priority species in our list from this area. The total number of individuals of adult *C. spicatus* is fewer than five, and there is no sign of seedlings, while its habitat is being cleared for mixed-cultivation gardens. The new taxon of Ptychospermatinae has fewer than 50 adult palms.

However, the real threat is mining activity not only for the palms but also to the entire ecosystem on the island and in the region of Raja Ampat, if the central government approves the permit to allow PT. Gag Nikel to exploit nickel ore on Gag. Land clearance and top soil removal will be required to extract the nickel ore on Limonite and Saprolite soils, so the whole ecosystem on the ultramafic / ultrabasalt areas will disappear. The initiative to propose Raja Ampat Islands as a World Heritage Site to UNESCO (McKenna et al. 2002, Takeuchi 2003) is encouraging and if it happens would make Gag Island (and Raja Ampat Islands) a field laboratory to study evolution and natural history – another Galapagos Islands on the other side of the world.

The process of establishing the conservation status of the palms of Gag with IUCN red list categories and criteria (IUCN 2012) will need to wait until the taxonomic status of each taxon becomes clear.

Acknowledgments

We thank the authorities in Sorong, Waisai and Gag Island, the *Kepala Kampung* of Gag, the *Forum Komunikasi Masyarakat Gag*, the management of PT. Gag Nickel (PTGN) of Sorong branch office and the camp Gag Island, and all people of Gag Island for their support and help during the expedition. The head of *Balai Penelitian Kehutanan* (BPK) in Manokwari allowed CDH and OPM to join the first expedition. We thank our colleagues on the first expedition for their patience and good humor on the trip. The *Kapten* and his mighty crew of the *KLM Febry Jaya*, our *pinisi* boat, sailed safely through the storm and brought us to Gag, so we could tell the story of the nickel island and its incredible palms. The authors thank John Dransfield from the Royal Botanic Gardens, Kew and Campbell Webb from Harvard University, Mr. Daud Leppe and Herman Remetwa of BPK Manokwari, and Tobias Paiki and his family in Sorong. The expeditions were partially funded by Royal Botanic Gardens Kew and BPK Manokwari to CDH, and International Palm Society (IPS) Endowment Fund 2010 to CDH (and William J. Baker) for the second expedition.

Literature Cited

Allen, G.R. 2002. Reef fishes of the Raja Ampat Islands, Papua Province, Indonesia. In: McKenna, S. G. R. Allen and S. Suryadi (eds.), A marine rapid assessment of the Raja Ampat Islands, Papua Province, Indonesia. Conservation International, Washington, USA. Pp. 46–57.

Allen, G.R. 2003. Coral fishes of the Raja Ampat Islands. In: Donnelly, R., D. Neville and P. J. Mous (eds.), Report on Rapid Ecological Assessment of the Raja Ampat Islands, Papua, Eastern Indonesia. The Nature Conservancy – Southeast Asia Center for Marine Protected Areas, Bali, Indonesia. Pp. 42–58.

Alapetite, E., W.J. Baker and S. Nadot. 2014. Evolution of stamen number in Ptychospermatinae (Arecaceae): insights from a new molecular phylogeny of the subtribe. Molecular Phylogenetics and Evolution) 76: 227–240.

Baker, W.J. 2000. The Palms of New Guinea project. Palms 44: 160, 165.

Baker, W.J. 2002. The Palms of New Guinea project. Flora Malesiana Bulletin 13: 35–37.

Baker, W. and A.H.B. Loo. 2004. A synopsis of the genus *Hydriastele* (*Arecaceae*). Kew Bulletin 59: 61–68.

Baker, W.J. and J. Dransfield. 2006. Field Guide to Palms of New Guinea. Royal Botanic Gardens, Kew.

Baker, W. and C.D. Heatubun. 2012. New palms from Biak and Supiori, Western New Guinea. Palms 56: 131–150.

Baker, W.J. and T.L.P. Couvreur. 2012. Biogeography and distribution patterns of South-East Asian palms. In: Gower D., K. Johnson, J.E. Richardson, B. Rosen, L. Ruber and S. Williams (eds.), Biotic evolution and environmental change in Southeast Asia,. Cambridge University Press, Cambridge. Pp. 164–190.

Conn, B.J. 1994. Documentation of the flora of New Guinea. In: C.I. Peng and C.H. Chou (eds), Biodiversity and terrestrial ecosystem. Academica Sinica Monograph 14: 123–156.

Dowe, J.L. and M.D. Ferrero. 2001. Revision of *Calyptrocalyx* and the New Guinea species of *Linospadix* (Linospadicinae: Arecoideae: Arecaceae). Blumea 46: 207–251.

Dowe, J.L. and J.P. Mogea. 2004. A new species of *Livistona* (Arecaceae) from New Guinea. Palms 48: 197–203.

Dransfield J., N.W. Uhl, C.B. Asmussen, W.J.Baker, M.M.Harley and C.E. Lewis. 2008. Genera Palmarum: the Evolution and Classification of Palms. Royal Botanic Gardens, Kew.

Heatubun, C.D. 2009. Systematics and evolution of the palm genus *Areca*. Ph.D Thesis, Bogor Agricultural University, Bogor and Royal Botanic Gardens, Kew.

Heatubun, C.D. 2011. A new species of *Ptychosperma* from Halmahera, North Moluccas. Palms 55: 183–189.

Heatubun, C.D., L.M. Gardiner and W.J. Baker. 2012a. *Heterosphate elata,* a new records for New Guinea Island. Palms 56: 61–64.

Heatubun, C.D., J. Dransfield, T. Flynn, S.S. Tjitrosoedirdjo, J.P. Mogea and W.J. Baker. 2012b. A monograph of Betel Nut Palms (*Areca*: Arecaceae) of East Malesia. Botanical Journal of the Linnean Society 168: 147–173.

Heatubun, C.D., S. Zona and W.J. Baker. in press. Three new genera of arecoid palm (Ptychospermatinae: Arecoideae: Arecaceae) from eastern Malesia. Kew Bull.

IUCN. 2012. IUCN Red List Categories and Criteria. Version 3.1. IUCN, Gland and Cambridge.

Johns, R. J. 1997. Background papers for the study of the flora and vegetation of the N. E. Kepala Burung, Irian Jaya, Indonesia. Royal Botanic Gardens, Kew.

McKenna, S., G.R. Allen and S. Suryadi. 2002. A marine rapid assessment of the Raja Ampat Islands, Papua Province, Indonesia. Conservation International, Washington, USA.

Ministry of Coordinator Economics Sectors of the Republic Indonesia. 2011. The Master Plan of Acceleration, Extension and Development of Indonesian Economy 2011–2025. The Republic of Indonesia, Jakarta. 210 pp.

Takeuchi, W. 2003. A community-level floristic reconnaissance of the Raja Ampat Islands in New Guinea. Sida 20: 1091–1136.

Tiplady, T. 1886. Above the hills of time. http://www.cyberhymnal.org/bio/t/i/tiplady_t.htm.

Wallace, A.R. 1874. The Malay Archipelago. Harper and Brothers, New York.

Webb, C.O. 2005. Vegetation of the Raja Ampat Islands, Papua, Indonesia. A report to The Nature Conservancy (unpublished). 33 pp.

Zona, S., J. Francisco-Ortega, B. Jestrow, W.J. Baker and C.E. Lewis. 2011. Molecular phylogenetics of the palm subtribe Ptychospermatinae (Arecaceae). American Journal of Botany 98: 1716–1726.

In Search of Madagascar's Elusive River Palm, *Ravenea musicalis*

FORREST HOGG
Imperial College London, Silwood Park, Buckhurst Rd, Ascot, SL5 7PY, UK
forrest.hogg13@imperial.ac.uk

AND

JOHNNY HENSHALL
Kingsmead Road, London, SW2 3HY, UK
jhenshall87@gmail.com

1. *Ravenea musicalis* in its natural habitat, the Vatomirindry River.

A record of two new populations of Madagascar's Critically Endangered water palm, *Ravenea musicalis*, augments the species population size and distribution range, and updates the palm's conservation status.

Ravenea musicalis is a Critically Endangered aquatic palm, endemic to the southeast of Madagascar (Fig. 1; Beentje 1993, Rakotoarinivo & Dransfield 2012). Since its discovery (to science) some 20 years ago (Beentje 1993), *R. musicalis* has only ever been recorded from one location, the Belavenoka River, situated about 30 km north of Taolagnaro (Fort

Dauphin). Rakotoarinivo and Dransfield (2012) estimated the population size at 450 mature individuals and declining from ongoing habitat loss and over-harvesting.

As expected, *R. musicalis* shares many morphological characteristics with other *Ravenea* species – solitary, unarmed, dioecious and pleonanthic – but it also possesses some unique features worth highlighting. *Ravenea musicalis* is the only true water palm in Madagascar (*Dypsis aquatilis* is its nearest rheophytic rival), and some remarkable adaptations have evolved in relation to its aquatic habitat. *Ravenea musicalis* seeds germinate within the enclosed fruit (pericarp), an adaptation deployed by many mangrove trees (Beentje 1993). The strong curvature of the seedling leaves and growth of the secondary rootlets (upwards and towards light) aids the plant's establishment in strong currents. Juvenile leaves developing underwater remain flaccid, trailing downstream in the river's current, presumably to reduce the risk of being uprooted. As the individual emerges above the water surface, the leaves become rigid and the distinctive, soft bottle-shaped (ventricose) trunk slowly takes form (Beentje 1993).

The major conservation concern for *Ravenea musicalis* is its highly restricted distribution, limited to a single unprotected site (the upper reaches of the Belavenoka River). In addition, adult palms are felled by local people for building temporary canoes and by foreign horticulturalists for seed collection (Rakotoarinivo & Dransfield 2012). Farmers from Farafara-Vatambe and Belavenoka rely on the fertile riparian soils, converting much of natural riverside vegetation for manioc, sugar cane and rice cultivation. Furthermore, pronounced climate change is expected for Madagascar over the next century: predictive models strongly suggest that the south of the Madagascar will be most affected (Hewitson & Crane 2006), experiencing significantly less rain in the dry season (June–September) (Tadross et al. 2008). If the Belavenoka River were to dry up, *Ravenea musicalis* habitat would be lost.

Although there has been an increase in palm research effort in the Anosy region over recent years (e.g. Rabenatoandro et al. 2007, Dransfield & Rakotoarinivo 2012, Hogg et al. 2013), *Ravenea musicalis* has been not been recorded elsewhere. As researchers based in the southeast of the island, we seized the opportunity to explore some of the more remote river systems in Anosy for the elusive water palm. Encouragingly, reports from people in the Mahatalaky commune indicated that *torendriky* (the Antanosy name for *R. musicalis)* could be present on other rivers besides the Belavenoka. We mapped (using a handheld GPS unit) the known Belavenoka population and, aided by local knowledge, explored two other large river systems (Ebakika and Vatomirindry) within the Mahatalaky commune area (Fig. 2) for *Ravenea musicalis*.

The Belavenoka Population

The Belavenoka River flows for 9 km down from the foothills of the Vohimena Mountains, a mountain range cloaked by the Tsitongambarika rainforest, into a series of large lakes near to Lokaro Village before meeting the Indian Ocean.

On 28 February 2013, we began the survey at the river's source, following the riverbank on foot. Farmers from Farafara-Vatambe have converted nearly all the riverside land for cassava (manioc), sugar cane and rice cultivation. Several people from Farafara reported that the palm is used for food (palm heart) in the lean season and for building temporary canoes (trunk) in the wet season (Fig. 3). As Beentje (1993) found at this time of the year, nearly all the female trees were laden with fruit (Fig. 4).

2. Area for exploration – the Mahatalaky Rural Commune.

3 (top). A temporary canoe carved from the trunk of *R. musicalis*. 4 (bottom). Fruits.

The upstream riverine vegetation was dominated by *Typhonodorum lindleyanum* (Araceae), *Mascarenhasia arborescens* (Apocynaceae), *Harungana madagascariensis* (Hypericaceae) *Pandanus platyphyllus* (Pandanaceae), *Bambusa* sp. (Poaceae), *Cynometra* sp. (Fabaceae) and *Syzygium sp*. (Myrtaceae). Large, iridescent aquatic skinks (*Zonorsaurus maximus*) were found basking on the banks of the river. As we descended downstream, *R. musicalis* became more abundant – adults clustering in large groups, interspersed with numerous juveniles. Downstream from the village of Belavenoka only four adults were found, indicating the population's eastern limit. In total, we mapped 1036 adult *Ravenea musicalis*.

5. Searching the Ebakika River by *lakana.*

The Ebakika Population

The large (300km²) catchment zone of the Ebakika River neighbors the Belavenoka catchment zone directly to the north (Vincelette et al. 2007). The river runs for approximately 25 km in a northeasterly direction from the Vohimena Mountains, joining with Vatomirindry River close to the Indian Ocean.

Setting out from the *baque* (river crossing) at Ebakika Village, we headed upstream in a *lakana* (a traditional canoe) in search of the palm (Fig. 5). As we paddled past the small rural village of Vohibola we spotted the first palm, standing alone in the middle of a 100-m wide stretch of river (Fig. 6). Eventually, we found a swampy tributary, known locally as a *saha*, which marked the entrance into a grove of *R. musicalis*. Several of the palms there had been felled towards the crown, presumably for the edible palm cabbage.

We mapped 32 adults in the *saha* and another three isolated individuals further downstream, giving a total of 35 adult palms for the Ebakika River. Recruitment was only evident within the *saha* grove, where we estimated 70 juveniles. No individuals were either flowering (including immature inflorescence) or in fruit (25 April 2013). Rapids close to the Tsagnoria market crossing marked the western (upstream) extent of the population. Plantations of sugar cane and manioc dominated large parts of the river margins surveyed.

The Vatomirindry Population

Bordering the Iabakoho Commune, the Vatomirindry River is the hardest to access and least populated of the three river systems (Fig. 7). Unlike Ebakika and Belavenoka, an impressive gallery forest bounded the riverbanks, hosting other palm species, including *Ravenea sambiranensis* and *Dypsis nodifera*. Our guide, Francis, was convinced that the river was inhabited by *voay* (crocodiles – *Crocodilus nilus*), which ruled out surveying from shallows. So we rather tentatively skirted the edge of the river, mapping adult individuals as we advanced downstream. Neither fruit nor flowers (including immature inflorescence) were visible (26 April 2013). Levels of regeneration, however, were remarkably high – numerous juveniles and subadults at all stages of development. As we approached the Vatomirindry village, *R. musicalis* numbers decreased and cassava fields replaced the gallery forest. In total, we mapped 726 adult individuals – a healthy population with no observations of harvesting.

6. A lone *R. musicalis* adult near Vohibola village on the Ebakika.

Conservation Status

Ravenea musicalis has a total population size of 1,797 mature individuals located in three discrete river systems (Fig. 8). The Belavanoka and Vatomirindry Rivers represent the largest of the subpopulations, with 1036 and 726 individuals respectively. Harvesting of mature palms was evident in the Belavenoka and Ebakika populations for both canoe and palm heart use. Situated near to several village clusters, over-exploitation of the Ebakika population is a likely explanation for the low numbers (35), as several recently cut stumps were surveyed. Conversion of riparian habitats for agriculture is also a potential factor behind the decline in Ebakika. In contrast, the thriving Vatomirindry population is more isolated from human disturbance, representing an important discovery for the conservation status of the species.

Upstream occupancy appears to be limited by either rocky cascades (e.g. Ebakika) or narrow upriver waters (e.g. Belavenoka). Downstream, tidal salinity influences (Vincelette et al. 2007)

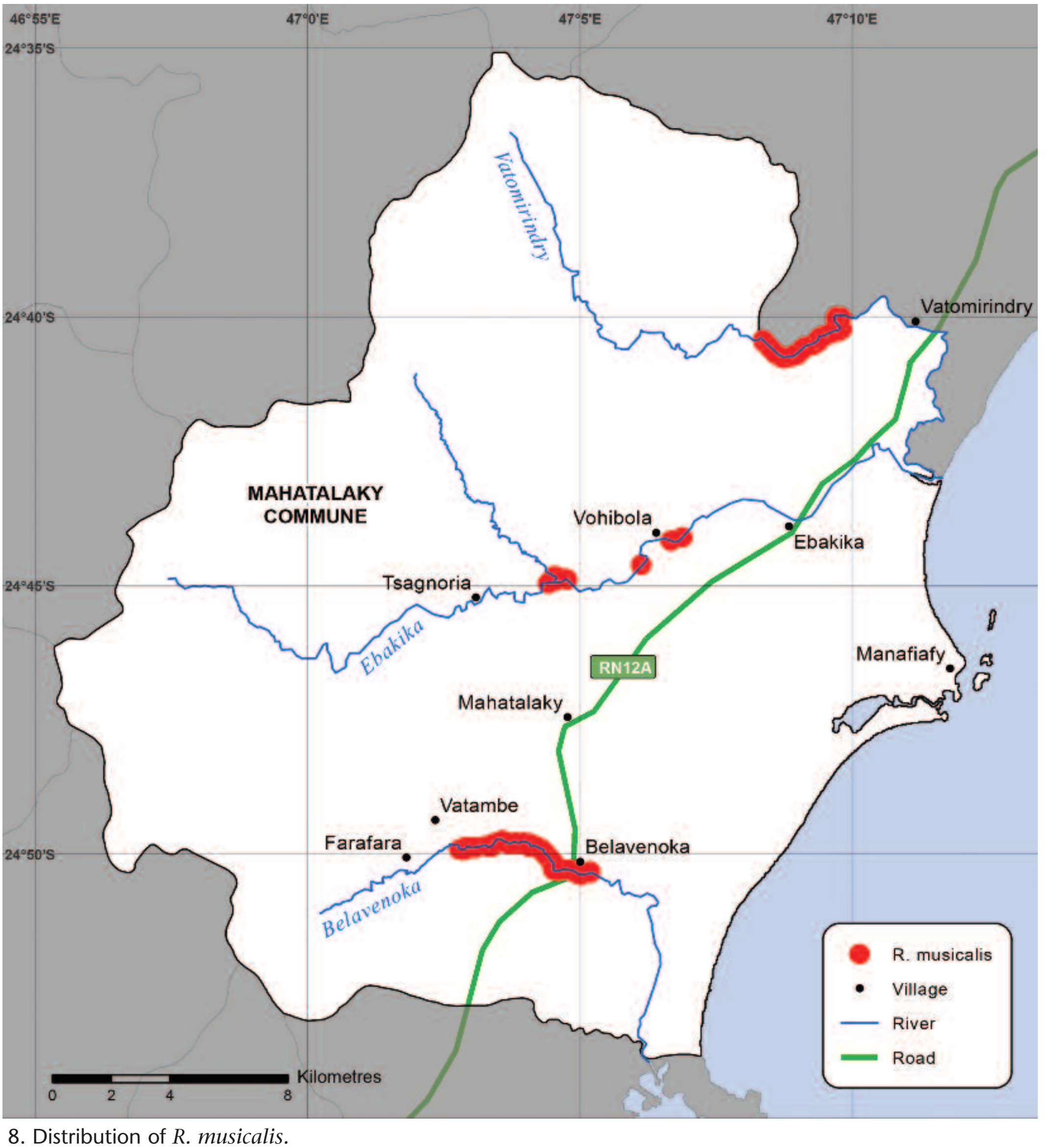
7. *Ravenea musicalis* in the Vatomirindry River.

and/or increased siltation from land conversion to agriculture could be inhibiting the establishment of young plants. In line with Beentje (1993), we believe that *R. musicalis* appears to require sandy riverbeds to flourish; individuals sprouting on submerged rocky pavements (or on fluvial deposits) fail to attain maturity. Over the next decade, land conversion for food production is likely to accelerate with projected increases in human population within Anosy (Vincelette et al. 2007).

Ravenea musicalis exists in three discrete locations separated by a mosaic of terrestrial habitat types, representing a significant barrier for pollination and seed dispersal. Poor dispersal ability places small populations, such as in the Ebakika River, at greater risk of extinction. Both phenology (fruit maturation in the wet season) and seed morphology (pre-abscission germination), strongly supports hydrochory as the primary seed dispersal mechanism. However, under current climatic conditions, hydrochory is unable to facilitate inter-catchment colonization events (Devey et al. 2013).

In order to assess a species according to IUCN Red List criteria (IUCN 2013), Area of Occupancy (AOO) is a key parameter used to determine geographic range and degree of fragmentation. AOO is calculated by totaling the area of grid cells occupied by the target species, which in this case was calculated using GIS software GeoCAT (Bachman et al. 2011). Whilst the IUCN (2013) recommend setting the standard cell width at 2 km, *Ravenea musicalis* arguably requires a smaller cell size to reflect the discrete and constricted limits of the river habitat it occupies. Therefore, the minimum cell width for each individual waypoint was reduced to 500 m, resulting in an AOO of 7.25 km^2 for the species.

When the low number of subpopulations (3), highly restricted range (AOO = 7.25 km^2), inferred decline of habitat quality and ongoing harvesting at Ebakika and Belavenoka sites are considered *Ravenea musicalis* remains a threatened species. However, the inclusion of



8. Distribution of *R. musicalis*.

the Vatomirindry and Ebakika populations significantly improves the conservation status of the species from Critically Endangered [B1ab(ii,iii,v)+2b(ii,iii,v) ver. 3.1] to Vulnerable [D2 ver. 3.1] according to IUCN guidelines for Red Listing species (IUCN 2013). Criterion Vulnerable [D2] is applicable to a species restricted to fewer than five fragmented locations or typically occupying less than 20 km^2, but where plausible threats could cause rapid declines in the extant populations.

The increasing Anosy human population, estimated at 2.9% per year (Vincelette et al. 2007), will place added pressure on riparian habitats for manioc, rice and sugar cane cultivation. As communities aggregated along the three rivers expand, palm exploitation could equally rise. Rapid increases in habitat loss and exploitation could result in a need to reassess the palm's status to Endangered or Critically Endangered. Moreover, predicted effects of global climate change will likely further impact habitat quality; whilst this is unlikely to represent an imminent threat, in the longer term it may become a determinant factor.

Acknowledgments

We thank Azafady for supporting this project, especially our colleagues Lisa Bass, Samm Short, Mark Jacobs, Tsina Endor, Emahalala "Lala" Ellis and the Pioneer and ACP volunteers. Accessing these remote areas would have been impossible without our intrepid guides, Francis and Jean-Luc. *Misaotra betseka ra*! Finally, thanks go to Mijoro Rakotoarinivo and John Dransfield for inspiring the research and offering advice throughout the study.

LITERATURE CITED

BACHMAN S., J. MOAT, A.W. HILL, J. DE LA TORRE AND B. SCOTT. 2011. Supporting Red List threat assessments with GeoCAT: geospatial conservation assessment tool. In: Smith V, Penev L (Eds) e-Infrastructures for data publishing in biodiversity science. ZooKeys 150: 117–126.

BEENTJE, H. 1993. A new aquatic palm from Madagascar. Principes 37: 197–202.

DEVEY, D.S., F. FOREST, F. RAKOTONASOLO, P. MA, B.T.M. DENTINGER AND S. BUERKI. 2013. A snapshot of extinction in action: The decline and imminent demise of the endemic *Eligmocarpus* Capuron (Caesalpinioideae, Leguminosae) serves as an example of the fragility of Madagascan ecosystems. South African Journal of Botany 89: 273–280.

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

DRANSFIELD, J. AND M. RAKOTOARINIVO. 2012. The palms of Tsitongambarika, southeast Madagascar. Palms 56: 162–179.

HEWITSON, B.C. AND R.G. CRANE. 2006 Consensus between GCM climate change projections with empirical downscaling: precipitation downscaling over South Africa. Int. J. Climatol. 26: 1315–1337.

HOGG, F., S. FUNNELL, M. SHRUM, E.R. ELLIS AND L.H. TSIMIJALY. 2013. The useful palms of Sainte Luce: implications for local resource availability and conservation. Palms 57: 133–144.

IUCN. 2013. Guidelines for Using the IUCN Red List Categories and Criteria. Version 10.1. Prepared by the Standards and Petitions Subcommittee.

RABENANTOANDRO, J., F. RANDRIATAFIKA AND P.P. LOWRY II. 2007. Floristic and Structural Characteristics of Remnant Littoral Forest Sites in the Tolagnaro Area. Pp. 65–93, in: GANZHORN, J.U., S.M. GOODMAN AND M. VINCELETTE (EDS.). Biodiversity, Ecology and Conservation of Littoral Ecosystems in Southeaastern Madagascar, Tolagnaro (Fort Dauphin). SI/MAB Series #11. Smithsonian Institution, Washington DC, USA.

RAKOTOARINIVO, M. AND J. DRANSFIELD. 2012. *Ravenea musicalis*. In: IUCN 2013. IUCN Red List of Threatened Species. Version 2013.2. <www.iucnredlist.org>. Downloaded on 25 April 2013.

TADROSS, M., L. RANDRIAMAROLAZA, Z. RABEFITIA AND K.Y. ZHENG. 2008. Climate Change in Madagascar; Recent Past and Future. pp. 18. Washington, DC: World Bank.

VINCELETTE, M., L. DEAN AND J.U. GANZHORN. 2007. The QMM/Rio Tinto Project History in Tolagnaro and its Social and Environmental Concepts. Pp 1–8, in: GANZHORN, J.U., S.M. GOODMAN AND M. VINCELETTE (EDS.). Biodiversity, Ecology and Conservation of Littoral Ecosystems in Southeaastern Madagascar, Tolagnaro (Fort Dauphin). SI/MAB Series #11. Smithsonian Institution, Washington DC, USA.

VINCELETTE, M., J. DUMOUCHEL , J. GIROUXAND AND R. HERIARIVO. 2007. The Tolagnaro (Fort Dauphin) Region: A Brief Overview of the Geology,Hydrology,and Climatology. Pp 9–24, in: GANZHORN, J.U., S.M. GOODMAN AND M. VINCELETTE (EDS.). Biodiversity, Ecology and Conservation of Littoral Ecosystems in Southeaastern Madagascar, Tolagnaro (Fort Dauphin). SI/MAB Series #11. Smithsonian Institution, Washington DC, USA.

VIRAH-SAWMY, M., K.J. WILLIS AND L. GILLSON. 2009. Threshold response of Madagascar's littoral forest to sea-level rise. Global Ecology and Biogeography 18: 98–110.

The *Ceroxylon* Trip in Northern Peru

MICHAEL L. MERRITT
P.O. Box 492463
Kea'au, Hawai'i 96749
USA

1. The forest of *Ceroxylon quindiuense* at Ocol.

When IPS board members and other guests dispersed following the 2013 interim board meeting at the Inkaterra Ecolodge near Puerto Maldonado in southeastern Peru, most boarded planes for Lima. But for a small subgroup including myself, Lima was just a stop on the way to the trailhead for another palm adventure, this one to see the famous wax palms of northern Peru.

Our journey was to see the Ocol Forest, a forest of *Ceroxylon* palms (Fig. 1) on the upper slopes of the Andes Mountains. The leader of the tour was IPS Board member Fernando ("Pacho") Roca Alcazar, who has worked in the region for many years, but now resides in Lima, where he is an administrator at the Catholic University in that city. The plane landed at the airport in Tarapoto, a city of over 100,000 persons in the Department of San Martin, at an elevation of

2. Our tranportation across Huallaga River.

about 350 m (1200 ft.) in the western foothills of the Andes. Located 6.5° of latitude below the Equator, Tarapoto is also known as the "City of Palms" after a native palm species (*taraputus*) found in abundance in the nearby lagoon (now replaced by city streets) by the early Spanish settlers in the 1780s. Pacho thought the *taraputus* was either *Mauritia flexuosa* or *Dictyocaryum lamarckianum*.

From the airport, we were transported to Puerto Palmeras, a resort and staging ground for ecotourism in the area, although the many buildings of the resort seemed to be centered about the huge swimming pool with an outside bar, hardly suggesting the rigors of ecotourism. In contrast to the lowland heat of Inkaterra (12.5° of latitude below the Equator), the prevailing temperature of the Andean

3. Participants in the *Ceroxylon* adventure, left to right: Soejatmi Dransfield, Kathleen Grant and Tom Jackson, John Dransfield, David Tanswell, Jeffry and Christine Brusseau, Alexander, Lauri and Toby Spanner and Pacho.

foothills was relatively comfortable. However, our evening arrival did not permit palm exploration, and early in the morning we left for our next destination, Lago Lindo, a resort near the town of Sauce.

We traveled south of Tarapoto on a well-paved highway, then traveled east on a minor road to the bank of the Huallaga River. Here a ferry – actually a raft propelled by several big outboard motors – carried cars and passengers across the broad and fast-flowing river (Fig. 2). After waiting an hour or so, it was our turn. As we were propelled across the river, we gathered for a group picture (Fig. 3) in the front of the ferry (the missing member of the group, yours truly, is behind the camera). The apparently primitive character of the transportation was deceptive, however. Government agencies have offered to fund construction of a bridge, but the local population has blocked it, fearing that development would spoil the character of their region and bring in too many visitors.

Once across the Huallaga, we resumed our bus journey, climbing in elevation. We began to see many specimens of a robust *Syagrus* species (Fig. 4). Toby Spanner later identified the species as *S. sancona* on the basis of the number of rachillae. We disembarked from the bus at the top of a hill overlooking the Lago Lindo resort, which, at an elevation of 700 meters (2300 feet), also serves as headquarters for an ecological reserve. The walk down the hillside to the resort is well known and is featured in much of the online advertising for local resort facilities. Figure 5 from along the trail shows a palm typical of the area, *Oenocarpus mapora*. At one point, we came across some artisans sculpting statues of men of importance in Peruvian history from the underlying soft sandstone, including José de San Martín, the nation's founder. We just beat the rain to the main building. Soon, we were served lunch at the lakeside boathouse. Across the lake were large groups of *Attalea* palms, which I assumed were *A. butyracea*, though some local botanists referred to them as *A. phalerata*.

Each member or family of our group was assigned a cabin with a front deck, table and chairs and a hammock in a picturesque tropical hillside setting overlooking the lake. Outside my cabin, on very high ground, was a very nice-looking young specimen of *Mauritia flexuosa*. After settling in, we gathered in the main building to begin a guided tour of the lakeside gardens. We saw more *Attalea* sp., a tall spineless form of *Bactris gasipaes*, and several smaller *Bactris* spp. by the side of the

4 (left). *Syagrus* cf. *sancona*. 5 (right). *Oenocarpus mapora*.

6. *Mauritiella armata.*

path. One of the latter was most probably *B. brongniartii*. One spectacular flowering non-palm was a *tangarana* (*Triplaris sangarana*). Upon our return, we could participate in feeding the tropical birds, such as macaws. A pet toucan proved to be very aggressive in its pursuit of food. As it turned dark, we gathered in the lobby for what became the tour drink of choice, the pisco sour (like a whiskey sour, but made with the local *pisco* alcohol derived from fermented grapes). Our cabins had electricity from 6 to 10 p.m. only and no hot water, so we turned in early after dinner for an early morning cold shower and departure from this beautiful place, where I would have liked to stay for a while longer.

We were on our way to Pomacochas, the location of the Puerto Pumas resort, normally closed except for special groups. They opened for our visit with a staff of two employees. This would be our staging area for treks during the remainder of the tour. We stopped for lunch, still in the lowlands, at an open air restaurant next to a wetland with a forest of *Mauritia flexuosa*. The dead fronds hanging down had an intriguing appearance. Later, alongside the road, we saw several large palms typical of the region: *Mauritiella armata* (Fig. 6), *Oenocarpus mapora* and *Oenocarpus bataua* (Fig. 7). We were never close to the last species, nor to the *Dictyocaryum lamarckianum* that we could see in the distance on hillside ridges as we climbed steadily into the mountains. Finally, we saw our first *Ceroxylon*, tall palms with very straight, ringed trunks, often with a white waxy surface between the rings. The tree shown in Fig. 8 was either *C. echinulatum* or *C. quindiuense*. Both species have pendulous leaflets. *Ceroxylon quindiuense* is supposed to be a taller, more massive tree (in fact, it is the world's tallest palm, reaching 60 m [200 ft.] in height). Toby Spanner, who, with Pacho, was the most knowledgeable in our group about the genus *Ceroxylon*, noted that it was difficult to distinguish between the two species when viewing an isolated tree in the field.

Ceroxylon palms are dioecious. There are 12 species currently recognized, of which we saw four, or probably five, during our tour. Henderson et al. (1995) listed *C. vogelianum* as the only *Ceroxylon* species present in northern Peru, but they were probably working with incomplete information from a region that was then lawless and dangerous to enter. Vast


7 (left). The distinctive crown of *Oenocarpus bataua*. 8 (right). A species of *Ceroxylon*.

Ceroxylon forests once spread across the Andean foothills, but most have been lost to clearing for agriculture. Henderson et al. (1991) stated that 90 percent of the Andean forests had been eradicated.

Ceroxylon palms are subject to other threats as well. Collection of fronds from several varieties, including *C. quindiuense*, for Palm Sunday observances have substantially imperiled populations, and the governments

9. *Ceroxylon parvifrons*, a high-elevation species.

10. *Ceroxylon peruvianum.*

of several countries are now trying to suppress this practice. Frequently, some *Ceroxylon quindiuense* are left intact during clearing of land for pastures. However, removal of the plant cover around the palms and movement of cattle around them, compacts the soil about the roots, and the palms decline, the trunk becoming very thin at the top before death occurs. We observed this unfortunate result in the pastures on the edges of the Ocol forest.

Although the various *Ceroxylon* species are adapted to specific ranges of altitude in their natural environment, altitude is not an obstacle to the growing of *Ceroxylon*, as Pacho has been successful in growing four species (*C. alpinum*, *C. amazonicum*, *C. ventricosum* and *C. vogelianum*) in his garden at sea level in Lima for several years. But *Ceroxylon* does not grow quickly, and many years might be required to produce a trunked palm. *Ceroxylon* palms like humidity, but do not do well in extreme heat or cold. The mild, foggy climate of Lima would suit them well, as might the windward climate of various Hawaiian Islands.

The fruits are red-orange and 1.5–2.5 cm (0.6–1.0 in.) in diameter. Two species have a smooth skin, but most show a warty pattern that is highly characteristic of individual species and "is a useful taxonomic character to recognize species," according to a recently published monograph on the genus (Sanin & Galeano 2011). The seeds are round, brown or black, smooth, and 1.0–2.0 cm (0.4–0.8 in.) in diameter. Germination is adjacent-ligular and the eophyll is entire. After our visit to the Ocol forest, Toby initiated discussions with local conservationists about supplying *Ceroxylon* seeds for his palm seed business and remained for several additional days of reconnaissance in the area, so palm hobbyists may find these seeds available in the near future.

Since it was late, we retired to Puerto Pumas for pisco sours, dinner and a night's rest. At over 2200 m (7200 ft.), the town was cold, and we pulled out our jackets to wear in the unheated hotel. In the chilly morning, breakfast was scrambled eggs, papaya, melons and delicious tamales. After several hours of travel, we stopped in Chachapoyas, the administrative seat of the Amazonas District, where we were asked to meet local political leaders.Then, it was on to see more *Ceroxylon*.

11. A ruined, pre-Incan fortress.

The next species was *C. parvifrons* (Fig. 9), reputed to grow at the highest elevations (up to 3500 m, or about 11,500 ft.) of any palm species. This species is quite distinctive in its appearance, having erect, arched leaves with stiff, regularly-arranged leaflets. Finally, we reached the main objective of our trip, the Ocol Forest, a massive stand of *C. quindiuense* (Fig. 1) within walking distance of the village of Molinopampa. This rare and unique view helped us visualize what the vast ancient stands of these forests on the Andean mountain slopes must have looked like. Our hike into the forest took us close to a specimen showing the typical shuttlecock form of juveniles of all *Ceroxylon* species. We saw trees with as much as 8 m (about 25 ft.) of trunk that still retained the juvenile shuttlecock form. The higher forest also contained many examples of *Prestoea acuminata* var. *acuminata*, a clumping form of this widely distributed species. Offshoots of the latter species often had rose-colored leaf bases.

The following morning, we became tourists and headed for the ruins of Kuelap, a pre-Incan mountain fortress similar to Machu Picchu and near the town of Tingo. Our road journey took us near a population of *Ceroxylon peruvianum*. In this species, only recently (2008) described, the wide, closely-spaced leaflets are in slightly different planes giving the leaves a somewhat plumose appearance (Fig. 10). From Tingo, we ascended a mountainside road that could be a candidate for the TV program "The World's Most Dangerous Roads."

Near the fortress was a new and well-appointed visitor center, but there was still a climb of a kilometer to reach the fortress ruins (Fig. 11) at 3100 m (about 10,000 ft.). Wandering around the ruins, we found many trees with large numbers of deep red bromeliads (probably a *Tillandsia* species) covering the branches. The rain was off and on again, and we could see storms approaching across the mountain valleys. From the ramparts of the fortress, we could see hillside farm plots, cultivated perhaps since before the time of the Incas.

The next morning, we made our final departure from Puerto Pumas. But we made several palm stops on the journey back, one to view *Ceroxylon vogelianum* (Fig. 12). This species is one of the smaller *Ceroxylon* species and has thin leaflets in many planes, giving it a plumose appearance. Then it was time for our

12. *Ceroxylon vogelianum.*

return to Puerto Palmas in Tarapoto to rest for a few hours before the evening flight back to Lima and points beyond. For me, it had been one of the more memorable trips of my experience.

LITERATURE CITED

HENDERSON, A., P. CHURCHILL AND J. LUTEYN. 1991. Neotropical plant diversity. Nature 229: 44–45.

HENDERSON, A., G. GALEANO AND R. BERNAL. 1995. A Field Guide to the Palms of the Americas. Princeton University Press, Princeton, New Jersey.

SANIN, M.J. AND G. GALEANO. 2011. A revision of the Andean wax palms, *Ceroxylon* (Arecaceae). Phytotaxa 34: 1–64.

Preliminary Observations on the Stem Enlargement of *Colpothrinax wrightii*, the Cuban Belly Palm

Katiuska Izquierdo Medero
*Estación de Monitoreo y Análisis Ambiental Sandino, ECOVIDA,
Km 4½ Carretera a La Fe, Sandino, Pinar del Río, Cuba
kizquierdomedero@gmail.com*

The results of an analysis of stem diameter and height in mature individuals of *Colpothrinax wrightii* are presented. The study was carried out in the localities of Sabanalamar, Santa Teresa and San Ubaldo, which are part of the San Ubaldo-Sabanalamar Floristic Management Reserve in Cuba. Reproductive adults were found to possess larger bellies than non-reproductive adults.

A characteristic of some palms is to form extensive colonies, which are well known in Latin America as *palmares* (Capote & Berazaín 1984). The Cuban Belly Palm, *Colpothrinax wrightii* Griseb. & H. Wendl. ex Voss., is an endemic species from Pinar del Río and Isla de la Juventud, Cuba, that grows on white sands and slates (Borhidi 1981).This species is classified as endangered (EN: B2abc) by IUCN, in light of the drastic decrease in population size as a result of over-exploitation and indiscriminate use (Peña et al. 1998).

A significant feature of this species is the conspicuous belly that characterizes the mature individuals. Controversy exists regarding the cause and function of the belly. Many botanists have tried to give an explanation to these questions and much speculation exists. This paper presents a hypothesis to explain the appearance of the belly in the life of this palm.

Materials and Methods

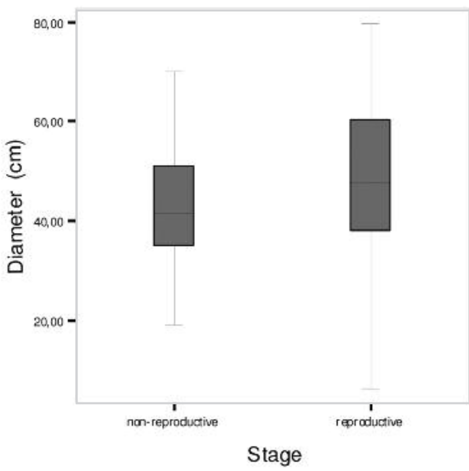
The study localities are Sabanalamar, Santa Teresa and San Ubaldo that are part of the San Ubaldo-Sabanalamar Floristic Management Reserve, Pinar del Río, Cuba. The vegetation forms three well-defined communities: sandy savanna with *Pinus*, herbaceous marsh and fresh water aquatic communities. The tree

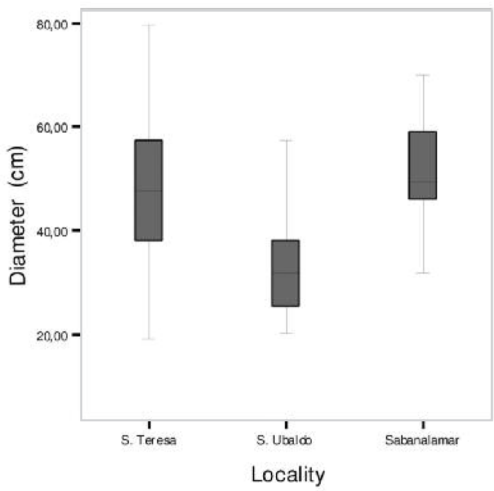

1 (left). *Colpothrinax wrightii*, reproductive adult. 2 (right). Non-reproductive adult.

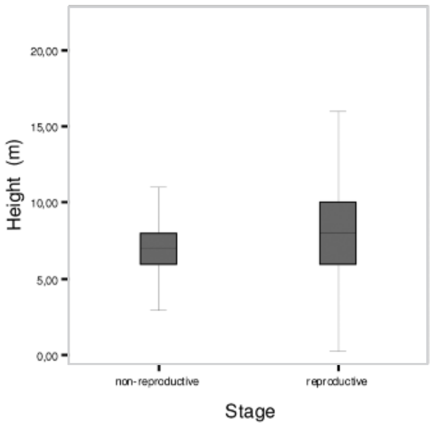
stratum is composed of pines and palms (*Pinus tropicalis* and *P. caribaea*), oak (*Quercus oleoides*) and *Colpothrinax wrightii*, among other species of palms. The shrub stratum is richer in species. Representative genera are: *Byrsonima*, *Lyonia*, *Ouratea* and *Hypericum*. The herbaceous understory is the richest, with numerous characteristic species and endemics. Typical families include Xyridaceae, Eriocaulaceae, Haemodoraceae, Cistaceae, as well as the insectivorous Lentibulariaceae and Droseraceae.

Within each area, palms were sampled along transects every 400 m. Each transect was traced starting from the border of each locality and extended until no more palms were present. Twenty linear transects were made (5 in Sabanalamar, 9 in Santa Teresa and 6 in San Ubaldo), and all palms within 5 m of each side

3 (left). Statistical analysis of the stem diameter and reproductive status. 4 (right). Statistical analysis of the stem diameter and locality. Means are statistically different to the 0.05 level in both diagrams.







5. Analysis of plant height by growth stages.

of the line were examined. The diameter of the stem of *Colpothrinax wrightii* was measured in adults, which were assigned to one of two classes – reproductive adults (belly stems, with inflorescences; Fig. 1), non-reproductive adults (belly stems, without inflorescences; Fig. 2). Juveniles (no belly stems, no inflorescences) were ignored. No palms were found having inflorescences but not bellies. The diameter was measured with a metric tape, at the level of the widest part of the belly. The height of the individuals was measured with a metric tape or with a 10 m graduated rod.

Statistical analysis: The analyses were carried out using SPSS vers. 15.0. Height and diameter data for both of the reproductive stages were tested for normality using a Kolmogorov-Smirnov test and a Lilliefors correction.

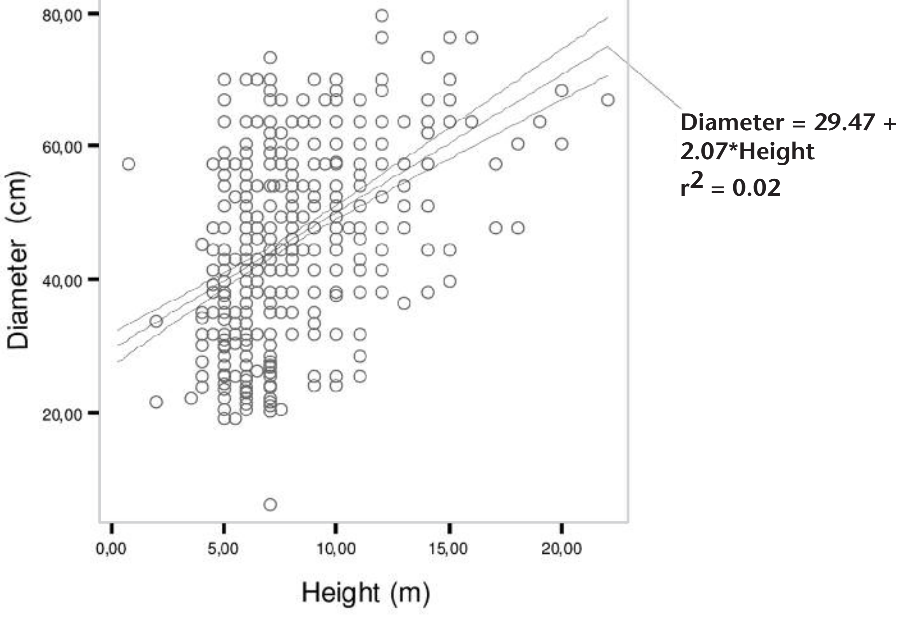
A Mann-Whitney was applied to determine if the median height differed significantly among growth stages in all localities and to determine if the diameter among growth stages differed too. To determine if a significant difference in mean diameter occurred among localities, I carried out an analysis of variance (ANOVA), followed by a Dunnett C post-hoc test because equal variances could not be assumed. The relationship between height and diameter of the stem was evaluated using a Spearman's Rank correlation.

Results

Stem diameter of non-reproductive adults ranged from 19.11 to 70.06 cm (n = 419; mean = 43.02; standard error = 0.57); that of reproductive adults ranged from 6.37 to 79.62 cm (n = 307; mean = 48.96; standard error = 0.75) (Fig. 3). Median stem diameter differed significantly among reproductive and non-reproductive adults (U = 47, 075.50; df = 1 and $p < 0.05$).

Stem diameter also varied among the three localities, Sabanalamar, Santa Teresa and San Ubaldo (Fig. 4). In the analysis of diameter by

6. Relationship between height and diameter in adults of *Colpothrinax wrightii*.



locality, the values can be ranked: San Ubaldo < Santa Teresa < Sabanalamar ($F = 56.476$; between groups df = 2, within-group df = 723 and $p < 0.05$). The post-hoc tests confirm that the differences are high among all the localities: San Ubaldo and Santa Teresa (differences in medians = 9.88 and p = 0), San Ubaldo and Sabanalamar (differences in medians = 13.99 and p = 0) and Santa Teresa and Sabanalamar (differences in medians = 4.12 and p = 0.008).

Reproductive individuals were taller than non-reproductive individuals ($U = 47, 202.5$, $p < 0.05$) (Fig. 5). A greater variation in height was found in reproductive adults (2.0–22.0 m) than in non-reproductive adults (1.5–15.0 m). Height and belly diameter were positively correlated ($R_S = 0.45$, $p< 0.05$) (Fig. 6).

Discussion

The analysis shows that reproductive adults tend to have trunks with bigger belly diameter than do non-reproductive adults. Moreover, the relationship between stem height and belly diameter suggests that larger (taller) palms have larger bellies, although the correlation is weak. These results suggest that a small-bellied, non-reproductive palm acquires a larger belly before reproducing and that the belly size continues to increase as the palm grows in height.

Because palms have no vascular cambium and produce no secondary xylem, palm stems do not usually increase in diameter with growth; however, increase in stem parenchyma tissue, cell enlargement and cell wall deposition can result in gains in stem diameter (Tomlinson et al. 2011). The belly of *Colpothrinax wrightii* has a higher proportion of parenchyma tissue than the unswollen parts of the stem. As a consequence, the capacity of the belly to enlarge over time may be much greater than that of an ordinary stem.

The function of the belly is still imperfectly known, although these results suggest that there is a relationship with reproduction. The reproductive process is very expensive for the plant from the energy point of view, and given that this species occurs on nutrient-poor soils, it is very probable that *Colpothrinax wrightii* develops the belly for the accumulation of starch prior to flowering and fruiting. Fisher et al. (1996), dissecting an individual of *Acrocomia crispa*, noted very little starch content in the belly and instead found structures that they believed might be lipid droplets. Lipids have higher energy content than starches. The stem of *C. wrightii* has not be studied at the anatomical level and its storage products are unknown.

Zona et al. (2000) concluded that the enlargement of the stem in *C. wrightii* was an adaptation for the storage of water, a conclusion based on cultivated individuals, in which the bellies were less conspicuous and for which water was available year around. They noted that the bellies of cultivated individuals were less conspicuous because the non-swollen parts of the stem were larger in diameter than in wild palms. In our areas of study, water is unlimited because the species grows near bodies of water, and yet individuals still produce conspicuous bellies. Although the belly may store water, it does not form in response to water stress or a surfeit of water.

Literature Cited

Capote, R. and R. Berazaín. 1984. Clasificación de las formaciones vegetales de Cuba. Revista Jard. Bot. Nac. Univ. Habana 5(2): 27–75.

Borhidi, A. 1991. Phytogeography and Vegetation Ecology of Cuba. Akademiai Kiado. Budapest.

Fisher, J.B., J.M. Burch and L.R. Noblick. Stem structure in the Cuban Belly Palm. Principes 40: 125–128.

Orozco-Segovia, A., A.I. Batis, M. Rojas-Arechiga and A. Mendoza. 2003. Seed biology of palms: A review. Palms 47: 79–94.

Peña, E., P.I. López, J. Lazcano, A.T. Leiva and U.S. Seal (eds.). 1998. Memorias del Primer Taller para la Conservación, Análisis y manejo Planificado de Plantas Silvestres Cubanas, CAMP I. 13–15 April. IUCN/SSC Conservation Breeding Specialist Group, Apple Valley, MN. 520 pp.

Tomlinson, P.B., J.W. Horn and J.B. Fisher. 2011. The Anatomy of Palms, *Arecaceae – Palmae*. Oxford University Press, Oxford.

Zona, S., D. Evans and K. Maidman. 2000. La palma barrigona. Palms 44: 85–87.

PALM LITERATURE

LAS PALMERAS HUICUNGO: THE HUICUNGO PALMS. Francis Kahn and Betty Millán. Universidad Nacional Mayor de San Marcos and Institut de Recherche pour le Développement, Lima, Peru. Pp. 173, numerous color photographs and maps.

This beautiful book, measuring 21.5 × 28.0 cm, is a photographic guide to the members of section *Huicungo* of the spiny cocosoid genus *Astrocaryum*, most of the species of which occur in Peru. The book has parallel Spanish and English text. There is a brief introduction to the genus *Astrocaryum*, which is treated in the narrow sense, excluding *A. mexicanum* and *A. alatum* that are referred to the segregate genus, *Hexopetion*. A synopsis of the infrageneric classification of *Astrocaryum* is provided before the authors go on to discuss section *Huicungo* with its subsections. Detailed keys to the fifteen species of the section follow and then each species is given expanded treatment, complete with distribution map and diagnostic details, superbly illustrated throughout. The photographs comprise habitat shots, pictures of the whole palm, crown, leaf with leaflet arrangement, inflorescence and many close-up details of staminate and pistillate flowers and fruit. These wonderful close-ups provide evidence for the distinctness of the species. The book is beautifully designed and altogether sumptuous, but I am left wondering how it will be used. It is too unwieldy to be taken in the field, so it will probably be consulted back at base. In a way, the book is a celebration of a group of spiny palms, not generally appreciated for their beauty; the authors, the recognized experts of the genus, provide abundant and fascinating evidence of the attraction of these important palms. Congratulations on the production of a most unusual palm book.

John Dransfield
Royal Botanic Gardens, Kew, UK