A new species of *Carapa* (Meliaceae) from Central Guyana

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Abstract. **Carapa akuri**, a new species endemic to central Guyana, is described and illustrated. It is compared to the two other species (*C. guianensis* and *C. surinamensis*) occurring in the Guianas.

Key Words: *Carapa*, crabwood, Guyana, Meliaceae, non-timber forest product.

The genus *Carapa* Aubl. (crabwood) comprises species of small to large trees of economic importance distributed throughout tropical forests in Africa and America. Crabwood trees are a very important source of timber throughout its distribution range (Hammond et al., 1996; van Andel, 2000). The oil extracted from seeds commonly known as karapa or andiroba oil is used traditionally as repellent and for massage, as well as in the fabrication of candles and various cosmetic products such as soap, shampoos, and other personal care products (Martinborough, 2002; Forte et al., 2002; http://www.nerc-wallingford.ac.uk/research/winners/literature.html).

So far, only three species have been recognized in the Neotropics: *Carapa guianensis* Aubl., widespread in Central and northern South America and the Caribbean, *C. megistocarpa* Styles & Gentry, endemic to Ecuador and *C. procera* DC. (sensu lato) with a trans-Atlantic distribution (Styles, 1981; Gentry, 1988). Two of these species have been reported in Guyana: the 4-merous *C. guianensis* (Mennega et al., 1988; Polak, 1992) and the 5-merous *C. procera* (Ek, 1997; Payne, 2001). However, a recent systematic study of the genus by one of us (Kenfack, 2008) showed that these two species are actually complexes including over 20 distinct morphological entities. Here, following Noamesi (1958) and Kenfack (2008), we use the name *C. surinamensis* Miq. instead of *C. procera*, to refer to the American 5-merous species.

While attending a workshop in November 2002 on the sustainable use and fair trade of crabwood oil, organized by Iwokrama International Centre in Guyana (Forte et al., 2002), one of us (PMF) questioned the identity of *Carapa* trees from Central Guyana that were locally considered to belong to *C. guianensis* (Polak, 1992; Gerard et al., 1996; ter Steege, 2000). He noted subtle, but consistent differences in the bark, seeds, and seedlings of these plants compared to the 5-merous species in French Guiana. Field observations and herbarium studies suggested that they may belong to an undescribed species. Results from a global taxonomic re-assessment of the genus by one of us (DK), based on phylogenetic studies and a comprehensive morphometric

analysis showed further evidence that lead us to describe here a new species.

Material and methods

The new species was detected during field work in the Iwokrama Rainforest Reserve. It is morphologically very close to *C. surinamensis* especially, as both have 5-and 4-merous flowers. Nonetheless, one of us (PMF, 28–29 November 2005) observed important variation in the occurrence of 5-merous flowers on individual *C. akuri* trees, all located within short distances (i.e., tens of meters from each other). In addition to field studies, herbarium specimens from the following herbaria were examined: BRG, CAY, GU, P, and US.

In order to assess seed morphological differences, a Principal Coordinate Analysis (PCA) of 69 seeds of the two species (31 and 38 for *C. surinamensis* and *C. akuri*, respectively; see Appendix) was performed using the eight following characters: seed length (SL), seed width (SW), seed thickness (ST), hilum length (HL), hilum width (HW), and the three ratios HL/HW, HL/SL, HL/SW. Principal Coordinate Analysis (PCA) was carried out using the program NTSYSpc version 2.02f (Rohlf, 1998).

To evaluate the extent of occurrence and to assess conservation status of *C. akuri,* we used a Geographic Information System and script developed by Willis et al. (2003). We used collection localities of specimens known for Central Guyana (Fig. 3).

Additional specimens of *Carapa surinamensis* examined. FRENCH GUIANA. Commune de Sinnamary, CIRAD-Forêt concession, Paracou field station, South Block, Plot 9, tree 988, 40 m, 31 May 2007 (28 seeds), *Forget 586* (P). **SURINAM**. Sipaliwini, Vicinity of Blanche Marie Waterfall on the Nickerie River, 50 m, 26 november 1995 (3 seeds), *Evans* et al. *2479* (MO).

Carapa akuri Poncy, Forget & Kenfack, **sp. nov.** Type: Guyana. Upper Demerara-Berbice Region, Mabura Hill, black water creek, 5°13'N, 58° 48' W, 29 Nov 2003, *P.-M. Forget 501* (holotype: P; isotypes: GU, MO, US). (Figs. 1, 2)

Arbor magna *C. surinamensisis* affinis, sed statura majore et habitu ramosissimo, cortice exfoliato, inflorescentia ampliore, atque apice conico robustoque, fructu ovoideo verrucis prominentiis, pariete suberoso praecipue differt.

Large canopy tree to 35 m tall, 80(−100) cm diam., glabrous. *Bole* cylindrical, branching high up to 20 m, base swollen, often with straight, robust and rounded buttresses up to 0.5 m high. *Bark* greyish and smooth on young individuals, flaking in rectangular to irregular patches in adult trees, reddish in slash, exudating a whitish-translucent sap; branches spreading into a dense crown. *Leaves* paripinnate, crowded at the end of branches, yellowish when young, (40–)60–115 cm long; petiole 12–28 cm long, base swollen, generally with 2 nectaries; rachis (30–)43–90 cm long, glabrous; leaflets opposite, 6–13 pairs, petiolules 1–2 cm long, lamina of basal pairs of leaflets 9–20×5–10 cm, apical pairs up to 16–56×4.5–13 cm, oblong, discolorous, apex rounded to broadly acute, mucronate, the mucro flattened laterally, thick and spatulate, glandular, base cuneate to rounded, slightly asymmetrical, midrib prominent beneath, with 8–20 secondary veins on each side, tertiary venation loose and flat. *Inflorescences* pendulous thyrses, in groups of 6–10 at the end of branches, in axils of undeveloped leaves up to 3 cm long, (35)60–100(120) cm long, very much ramified, lower branches up to 15 cm long, transversely scurfy; peduncle 8–14 cm long. *Flowers* 1–3, born in axil of a 1 mm long, scaly bract; (4)5-merous, pedicel (1.5–)2–3.5 mm long, often angular in section and transversely scurfy; calyx green, lobes narrowly triangular to broadly ovate, 1–1.5 mm long, margins ciliolate; petals whitish to yellow-green, free to the base, oblong or obovate, 4–6×2-3.5 mm; staminal tube white, urceolate, 3.5–5 mm long, ca. 4 mm diam., with 10 truncate or more or less emarginate lobes; anthers or antherodes 10, oblong, sessile, alternating with lobes, included within the tube, ca. 0.7×0.4 mm in carpellate flowers, 0.7–0.9×0.4–0.6 mm in staminate flowers; nectary cushion-shaped, white, 0.7–1.3×2–3 mm; ovary 5-locular, ovoid to globose in carpellate flowers, 1–1.7×1.5–1.8 mm, conical in staminate flowers, 0.6–1.5×0.5-1.3 mm; ovules 4 per loculus; style less than 0.7 mm long in carpellate flowers, 1–1.5 mm long in staminate flowers; stigma

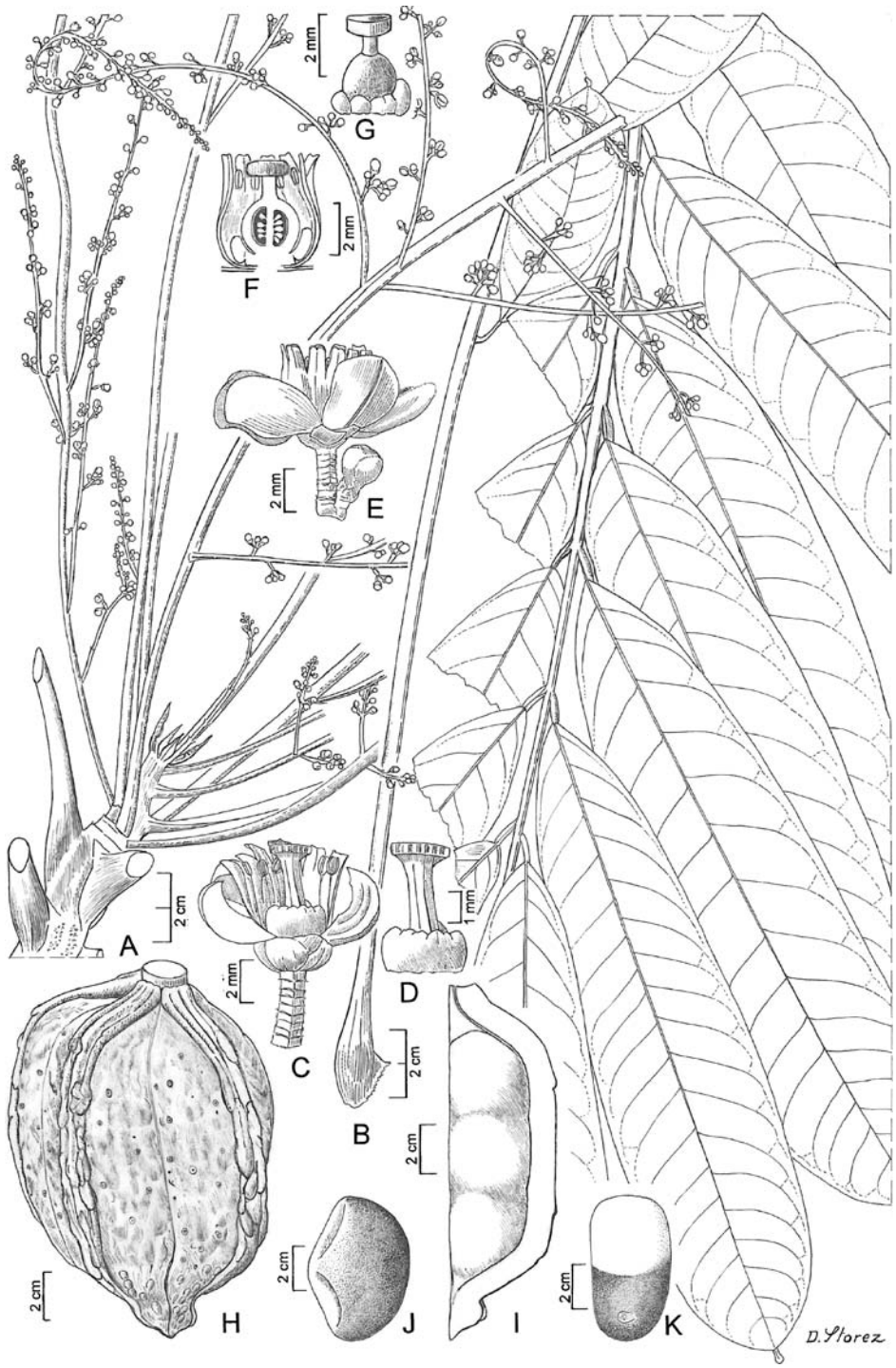

Fig. 1. *Carapa akuri*. **A.** Branch with inflorescence. **B.** Leaf. **C, D.** Male flower. **D.** Gynoecium. **E-G.** Female flower. **E.** Side view. **F.** Medial section. **G.** Gynoecium showing lobed nectary at the base. **H-K.** Fruit. **H.** Surface view. **I.** Internal view of one valve. **J-K.** Seeds. **J.** View from above. **K.** Lateral view with hilum. (A, B drawn from the holotype; P; C, D from *Mutchnik 383*; CAY; E-G from *Forget 502*; P; H-K from *Forget 576*, P).

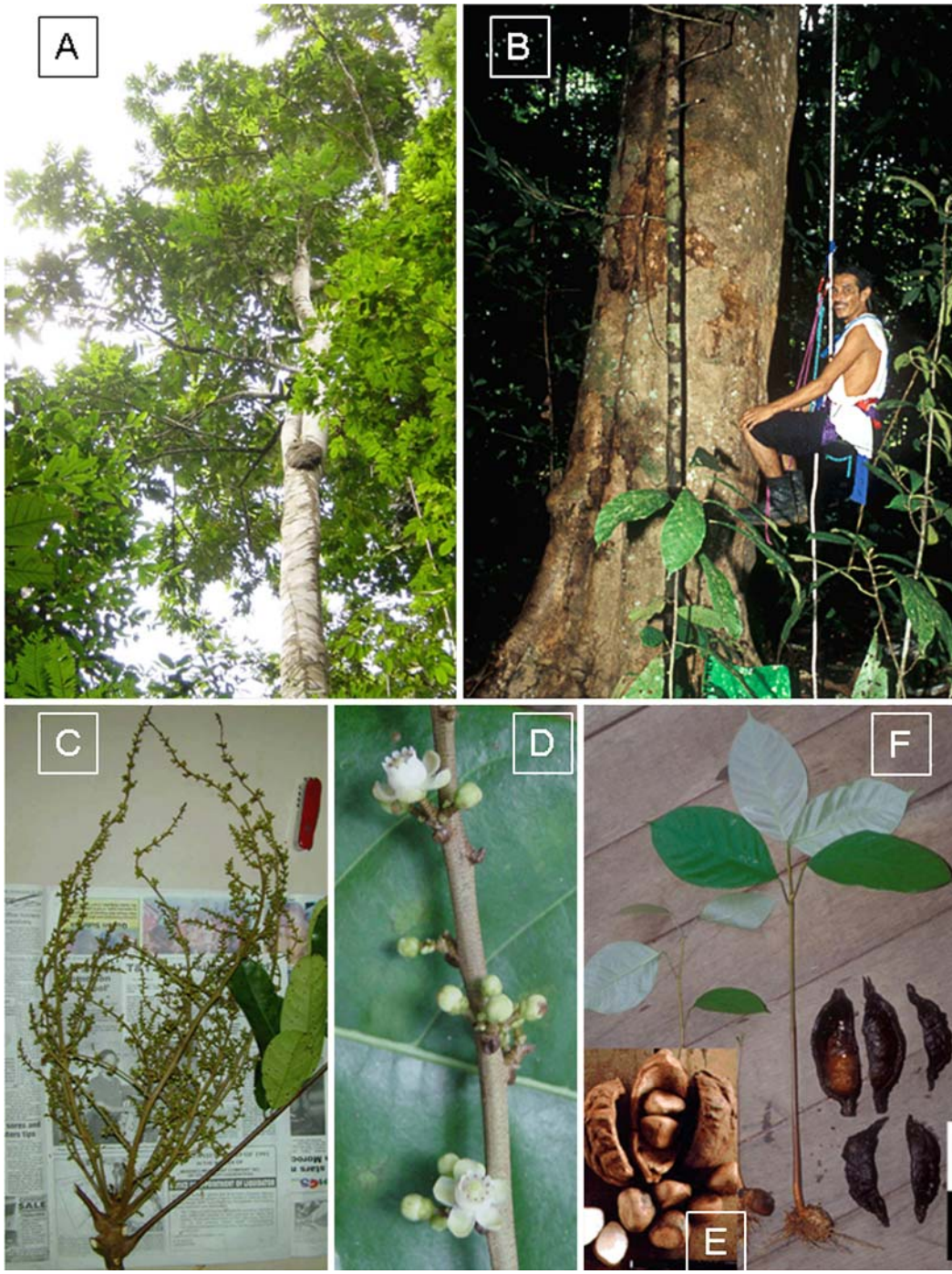

FIG. 2. *Carapa akuri*. **A.** Tree crown and trunk. **B.** Base. **C.** Inflorescence. **D.** Flower. **E.** Mature fruit. **F.** Fruit valves and seedlings. (A-D from the holotype; E, F from *Thomas s.n.*, GU.) Photographs by P.-M. Forget (A-D and F) and D. S. Hammond (E).

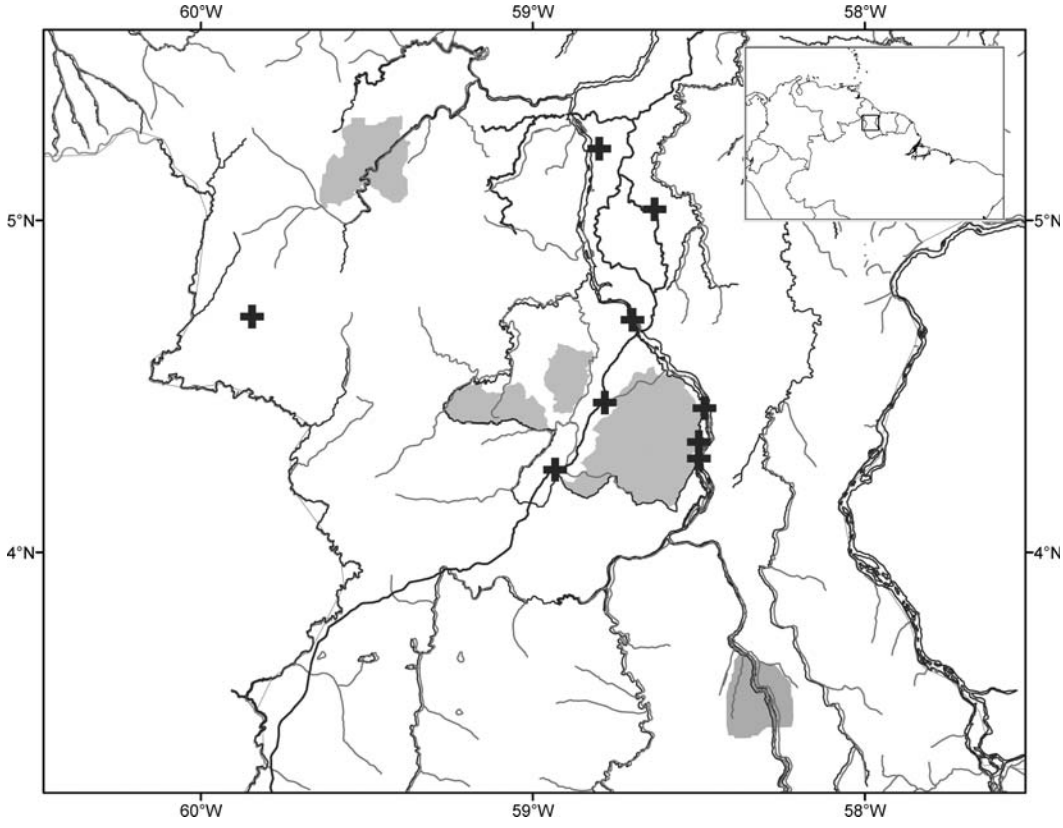

Fig. 3. Map of Central Guyana with collection localities of *Carapa akuri* (cross). Shaded areas are Kaieteur National Park (North), Iwokrama Rainforest Reserve (Central) and Conservational International Concession (South).

discoid, yellow, 1.4–2 mm diameter. *Fruit* a capsule, green when immature, becoming brown at maturity, globose to ovoid 7–11 × 6–17 cm, apex often conspicuously acuminate; valves with more or less developped warty excrescences and numerous extrafloral nectaries; seeds 2.5–4.8 × 3–5.5 cm, up to 4 per valve; hilum oval, 4.5–12 × 1.5–6 mm; testa brown and smooth. *Seedlings*: epicotyl 30–50 cm tall, the first leaves simple, blades discolorous, the adaxial surface pale greyish green, bright.

Distribution and endemism.—Based on herbarium specimens, *Carapa akuri* is restricted to central Guyana, in an area already recognized as rich in narrowly endemic species (Kelloff & Funk, 2004; Funk et al., 2007) such as *Dicymbe alstonii* Sandwith, *Chlorocardium rodiei* (R. H. Schomb.) Rohwer, H. G. Richt. & van der Werff, *Vouacapoua macropetala* Sandwith, *Eschweilera potaroensis* Sandwith, and *Swartzia leiocalycina* Benth. (ter Steege, 2000). Within this known distribution range, *C. akuri* is not an abundant species and the extent of its occurrence is estimated to 4143.18 km^2. Reports of the occurrence of *Carapa guianensis* in Guyana must now be considered with caution because of the possibility of misidentification. Two of us (PMF and RST) surveyed crabwood populations in forests at the Iwokrama Rainforest Reserve, Forest Ecological Reserve Mabura Hill, and Tropenbos Pibiri Reserve. Only *C. akuri* has been identified in all three forests. Inventory data from the Pibiri forest (5°01'652"N; 58°37'696"W; unpublished report, Tropenbos Guyana Programme, Guyana; van der Hout, 1996) and the Upper Essequibo Conservation Concession (UECC) (approximately 3°41'N; 58°20'W; Welch, 2002) showed densities of 6 to 13 trees (DBH>10 cm) per hectare.

Ecology.—Carapa akuri grows on various types of soils such as clay, loam, and brown sands, along large streams and in seasonally inundated forests, as well as on upland lateritic hills. At the Forest Ecological Reserve Mabura Hill and the Tropenbos Pibiri Reserve, which are both species-rich forests, only *C. akuri* was observed, occurring in all types of habitats, from banks of permanently wet creeks to uphill forest. In the Iwokrama forest, *C. akuri* is present in species-rich, non-flooded forest, several hundred meters from the river banks as well as in the periodically flooded mono-dominant *Mora excelsa*-rich forests near the Essequibo River. There, *C. akuri* occurs in habitats occupied elsewhere by *C. guianensis* (Styles, 1981), such as swampy areas, permanently wet forests, edges of large rivers, and *C. surinamensis,* such as non-flooded areas like hill slopes in Surinam and French Guiana (PMF, pers. obs.). The seeds are an important food source for some terrestrial vertebrates such as the red-rumped agouti (*Dasyprocta leporina*), the collared and white-lipped peccary (*Pecari tajacu* and *Tayassu pecari*, respectively), brocket deer (*Mazama spp.*); some birds, such as macaws (*Ara* spp.), feed on the immature fruits. Scatter-hoarding rodents such as agouti and acouchy (*Myoprocta exilis*) are likely the main seed dispersal agents of *C. akuri* as observed in *C. surinamensis* (Forget, 1996; Jansen et al., 2004; Jansen & Ouden, 2005).

Phenology.—Carapa akuri as well as *C. surinamensis* flower annually during the dry season between November and February (Thomas, 1999, 2002; Forget, 1996). Fruiting occurs in the rainy season, between February and July at the community-level fruiting peak, and toward its end (Forget, 1996; RST and PMF, pers. obs.). Casual fruiting may occur in November suggesting that a second peak of flowering, though weaker in intensity, may be observed during the wet season. The documented minimum tree size to set fruits is 16 cm dbh at Iwokrama forest (Payne, 2001). Seeds of *C. akuri* are among the largest found in Guianan rainforests (identified as *C. procera* in Hammond & Brown, 1995).

Etymology and common names.—The specific epithet is used by the Makushi Amerindians living in the region to name the red-rumped agouti (*Dasyprocta leporina*, Engstrom et al., 1999), which is likely the main seed disperser of *Carapa* in Guyana (see Forget, 1996). Fanshawe (1947) distinguished three crabwood timber types in Guyana: red-or hill-crabwood, white-or swamp-crabwood and black-crabwood without giving any reference to scientific names. We suggest that hill-crabwood should refer to *C. akuri*.

Uses and conservation.—The straight bole of *C. akuri* produces good lumber that is used locally. The extraction of oil from seeds by the Makushi communities of Kurupukari is not as extensive as that for *C. guianensis* in the more northern Waini River area. A large logging concession currently overlaps the known geographic range of *C. akuri* and the Iwokrama Forest. Within this area, this species has been harvested heavily on the assumption that it is widespread *C. guianensis*. The identification of *C. akuri* as a new species with a much narrower geographic distribution argues for a reassessment of the land use. Given the current deforestation of Central Guyana, the risk of overexploitation of *C. akuri* for timber, and its reduced the extent of its occurrence, we evaluate the conservation status of this species as ENB1b (i,v) following the IUCN (2001) Red List Categories and Criteria version 3.1.

Additional specimens examined. GUYANA. Upper Takutu-Upper Essequibo Region: Rupununi area, new road from Lethem to 25 km past Surama village entrance, 28 Feb 1990, *Acevedo 3431* (CAY, GU, US). **Potaro-Siparuni Region:** Iwokrama Rainforest Reserve, Essequibo River at Kurupukari, North of Iwokrama base camp, Turtle Mountain transect, 28 Nov 1994, 100 m, *Mutchnik & Allicock 383* (CAY, GU, US); Lady Smith Creek transect, 21 Feb 1995, 50 m, *Mutchnik 843* (GU, US); Pisham Pisham transect, km 4.9, 6 Oct 1995, 80 m, *Clarke 365* (GU, US); Akromukru Transect at Akromukru Falls, km 2.4, 70–90 m, 17 Mar 1996, *Clarke 1304* (GU, US); Malali Hill, 20 Nov 2004, *Forget 576* (P); **Upper Demerara Berbice Region:** Tropenbos Pibiri Reserve, 1 Dec 2003, *Forget 502* (GU, P, US).

The ratio of 5-to 4-merous flowers ranged from (0--)70–100 % for a large sample (N= 50–100 per tree) collected from the ground under isolated trees (with no crown overlap) along trails. At the Turtle Mountain trail (4° 43'57"N, 58°42'45"W), north of the Iwokarama field station along the Essequibo river, for instance, trees might have only 4-or 5-merous, or both 4-and 5-merous forms. Alternatively, at the Malali Hill trail (4°

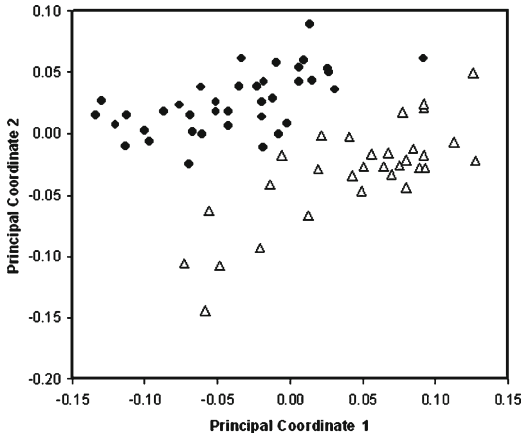

Fig. 4. Scatter plot of the two first axes of a Principal Coordinate Analysis of 69 seeds of *Carapa akuri* (●) and *C. surinamensis* (△) using eight quantitative characters.

37'48.7"N, 58°39'43.9"W), several kilometres south of the above mentioned *C. akuri* population, we only observed trees with 5-merous flowers. Thus, an apparent trend was observed for *C. akuri* to occur as 4-merous flowered trees in aggregated populations in swampy, mono-dominant forest with a high density of *Mora excelsa* Benth., *Eperua falcata* Aubl. or *Pentaclethra macroloba* (Willd.) Kuntze. Alternatively, trees with 5-merous flowers were spaced apart on well-drained, hilly terrain, associated with *Dicorynia guianensis* Amshoff and other species in mixed species-rich forests. Additional molecular studies and repeated collection within the Iwokrama Reserve are therefore needed to clarify this spatial diversity, at both local and regional scales.

Two leaf characters distinguish the two 5-merous species in the Guiana region. When dried, the leaflets are conspicuously discolorous, tan above and brown beneath in *Carapa surinamensis*, including the type specimen, while they are dry green olive in *C. akuri*. The most constant vegetative character is the tertiary venation that is dense and raised in *C. surinamensis*, and loose and diffuse in *C. akuri*. Also, the seeds of *C. akuri* are generally larger than those of *C. surinamensis*.

Regarding seed morphological traits, the first axis of PCA (Fig. 4) accounted for 61% of the total variation and had highest positive loadings for SL and SW, and highest negative loadings for the three ratios. The second axis accounted for 24% of the variation, again with SL positively correlated and ST negatively correlated. In the plane of these two first axes (Fig. 4), the seeds of the two species form a continuum but are not intermixed.

Key for identification of 5-merous species of *Carapa* of Central Guyana

1. Leaflet blade not discolorous, network of tertiary venation dense and raised . . . . . *C. surinamensis*
1. Leaflet blade discolorous, network of tertiary venation loose and diffuse . . . . . *C. akuri*

Acknowledgments

We are thankful to the Guyana Forestry Commission, Georgetown, which granted permission for field expeditions to Mabura and Pibiri forests. Pierre-Michel Forget was granted by Plan Pluri-Formation "Ecologie fonctionnelle et développement durable" at Muséum National d'Histoire Naturelle and by UMR 7179 CNRS-MNHN. We thank Janet Forte and Sharon Ousman from the Iwokrama International Center for their invitation to participate in the Workshop in Guyana, and for facilitating PMF's first trip to Iwokrama forest in November 2002. We thank Harry Benedict who assisted our climbing for the voucher collections, and Waldyke Prince for his help at the Iwokrama Field Station. We are also indebted to Doorjohan Gopaul for his help while visiting the National Herbarium and Centre for the Study of Biological Diversity at University of Guyana, Georgetown. We thank the curators of the following herbaria for allowing access to their collections: BRG, CAY, GU, P, and US. Thanks to Douglas Daly and Scott Mori for comments and help at various stage of

the review process. We are also indebted to Patrice Mutchnick, Vicki Funk, and Sara Alexander for valuable information about locality data from vouchers at US. Finally, we are thankful to Jewel Liddell at The University of Guyana National Herbarium for help with the export procedure, and to Dr. Indarjit Ramdass at the Environmental Protection Agency of Guyana for giving us permissions to conduct biodiversity research on "Diversity of Crabvwood species in South America" (EPA permission No. 211105 BR042) and to export vouchers (EPA permission No. 011205 SP: 008) to France, and to Dominique. Storez who prepared Fig. 1.

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Appendix

Number of seeds examined and source voucher data.

Origin	Voucher	Seeds
Carapa surinamensis		
French Guiana. Commune de Sinnamary	*Forget 586* (P)	28
Surinam. Sipaliwini	*Evans et al. 2479* (MO)	3
Carapa akuri		
Guyana. Potaro-Siparuni, Iwokrama Rainforest Reserve, North Pakaraimas	*Mutchnick 1521* (BRG)	14
Guyana. Potaro-Siparuni, Iwokrama Rainforest Reserve, Upper tributary of Burro-Burro River	*Hoffman 4593* (BRG, GU, US)	8
Guyana. Potaro-Siparuni, Iwokrama Rainforest Reserve, Malali Hill	*Kenfack 2110* (BRG)	16