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

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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)

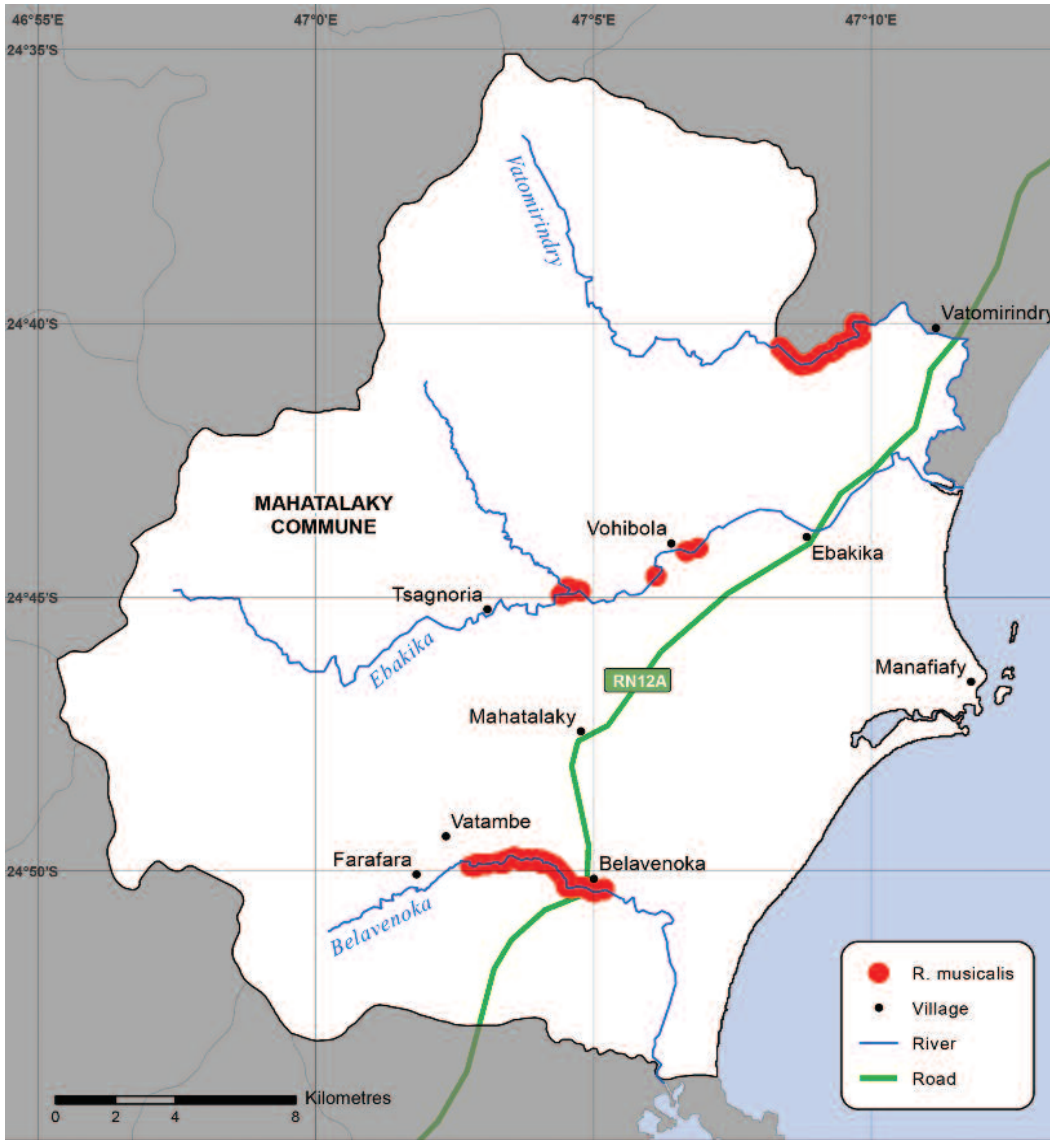
7. Ravenea musicalis in the Vatomirindry River.

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.

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