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TAXONOMY, ECOLOGY AND CONSERVATION OF *RAFFLESIA KERRII* MEIJER IN SOUTHERN THAILAND

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ABSTRACT

Rafflesia kerrii Meijer, Thailand's largest flower, is described from buds examined at Khao Sok National Park, Surat Thani Province, southern Thailand, in greater detail than previously reported. Current knowledge of the distribution, status and ecology of the species is reviewed. Threats to the survival of *R. kerrii* include habitat destruction and overcollection by local villagers for medicinal purposes and other reasons. *R. kerrii's* status is vulnerable, according to IUCN Red Data Book criteria. We suggest that *R. kerrii* should be promoted as a tourist attraction, in conjunction with a well planned education program, to provide an economic incentive for local people to protect the species. We also suggest that the government enact legislation to protect Thailand's botanical treasures, including *R. kerrii*, from commercial exploitation.

INTRODUCTION

The flowers of *Rafflesia kerrii* Meijer (Rafflesiaceae) (in Thai *"bua poot"* or *"bua toom"*) are undoubtedly the largest, most magnificent and most bizarre in Thailand, reaching a diameter of 70 cm or more (Fig. 1). Yet, despite its obvious attractions, very little is known of this extraordinary plant. It was not even included in the revision of the Rafflesiaceae in Flora of Thailand (HANSEN, 1972). This is surprising as the species may be endemic to Thailand and could become a major tourist attraction, if adequate steps are taken to conserve both the species itself and the habitat where it grows.

Like all members of the Rafflesiaceae, *R. kerrii* is a parasite, possessing no roots or green leaves of its own. For most of the year it exists as microscopic filaments and plates of tissue growing inside the roots of a host plant, usually a liana in evergreen forest. From time to time however, it develops buds which burst through the bark of the host's roots, grow to about the size of a football and eventually open to become one of the largest flowers in the world. For a short time, the foul smelling flowers attract insects, which are thought to carry out pollination, but within a few days of opening, the flowers shrivel and turn into a black, putrescent mass. The seeds of this species have not yet been found.

R. kerrii was first collected by Dr. A.F.G. Kerr, Thailand's first government botanist, in 1927 and 1929 from 4 locations in Southern Thailand (Fig. 17) (JACOBS, 1962).

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The most recent published report of the species was provided by NIYOMDHAM & KUBAT (1987) who photographed an open flower at Khlong Nakha Wildlife Sanctuary, Ranong Province, in March 1987.

In an earlier paper (MEIJER, 1984), the senior author identified *R. kerrii* as closely related to, but distinct from, *R. cantleyi* Solms-Laubach which occurs in the Malay Peninsula. This assertion was based on examination of herbarium specimens and a photograph of an open flower made by Kerr held at the Kew herbarium. However, because the specimens were cut into thin slices and not preserved as whole flowers in alcohol, some features could not be determined with complete accuracy. The observations presented here come from examination of fresh buds at Khao Sok National Park and they help to complete the description of the species. We reaffirm the view that *R. kerrii* is a distinct species, but now suggest that it is not as closely related to *R. cantleyi* as previously thought. We also discuss conservation measures which may be necessary to save the species from extinction.

DESCRIPTION

In March 1989, the junior author visited Khao Sok National Park (8° 54'–9° 08' N, 98° 28'–98° 46'E) Surat Thani Province, southern Thailand, to search for *R. kerrii*. No living specimens were found in the vicinity of the national park headquarters, but the species was commonly collected by local people for medicinal purposes. The photographs and description below therefore come from several large buds (Table 1) obtained from local villagers, who unfortunately had recently cut them from the host. *R. kerrii* flowers are unisexual. One female bud grew on the same host root as several males, but it is not known whether this indicates a single monoecious *R. kerrii* individual or several dioecious

Table 1. Details of *Rafflesia kerrii* Meijer buds examined at Khao Sok National Park.

Sex	Bud diameter (cm)	Cupula diameter (cm)	No. of Processes	No. of Anthers
M	25	14	36	28
M	21	11	41	30
F	18	11	42	-
M	16	8	27	26
M	-	-	44*	31*

*From the dried central disk of a male flower kept as a curio by a local villager.

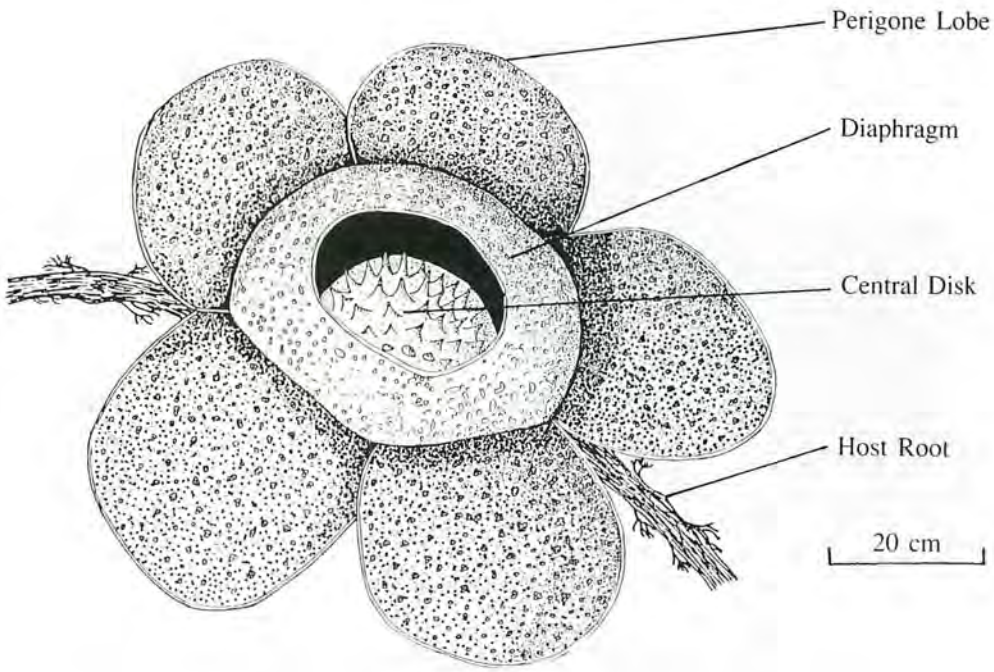

Figure 1. An open flower of *Rafflesia kerrii* Meijer.

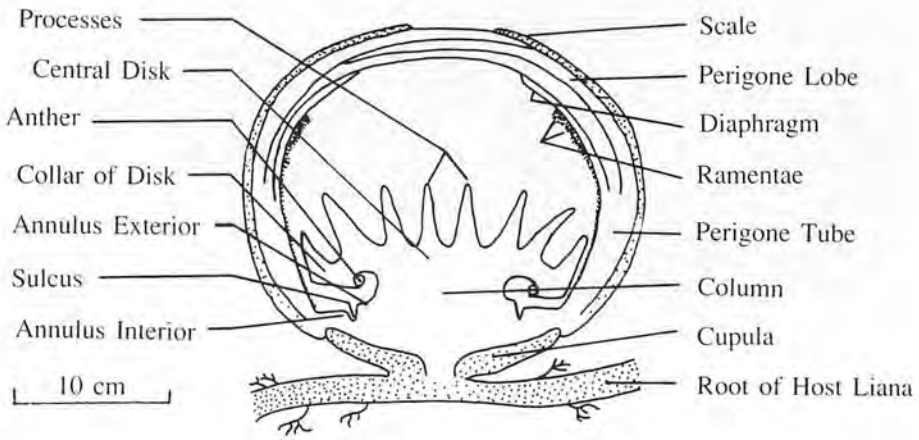

Figure 2. Longtitudinal section through a male bud of *R. kerrii*.

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Figure 3. A young *R. kerrii* bud, just emerging through the root bark of the host liana.

Figure 4. Two *R. kerrii* buds. The left one is still enclosed by scales, but the scales of the right one have parted slightly, exposing the pink under surface of the perogone lobes. The white ruler in this and subsequent figures is 15 cm long.

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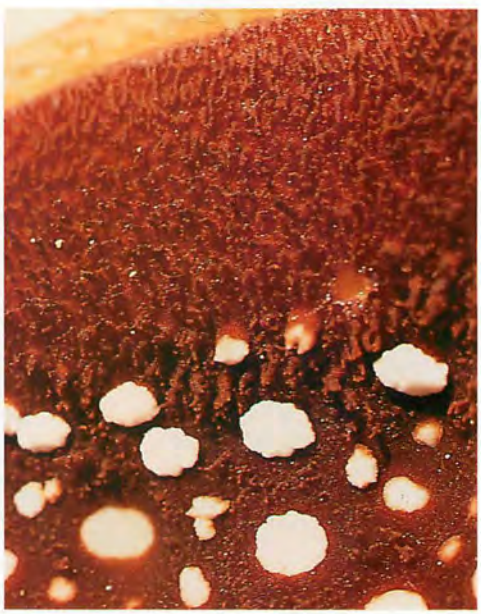

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Figure 5. Under surface of diaphragm. Through the central opening of the diaphragm, the upper surface of the perigone lobes can be seen.

Figure 6. Close-up of upper surface of perigone lobes showing white margin, small warts and shallow depressions.

Figure 7. Close-up of under surface of diaphragm showing transition from white dots to ramentae.

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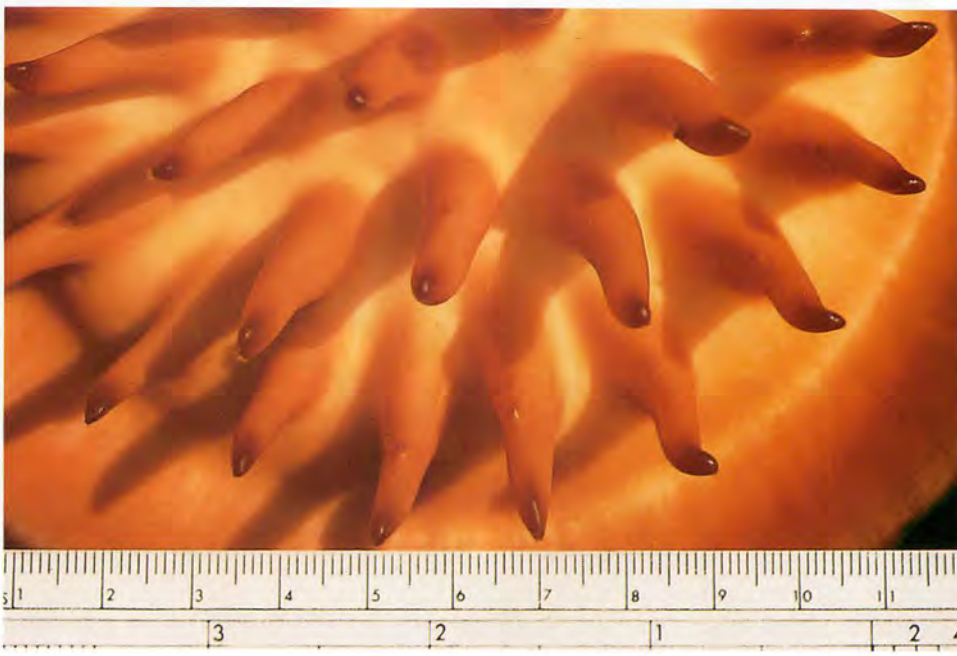

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Figure 8. Bottom half of male *R. kerrii* bud showing central disk and processes.

Figure 9. Close-up of processes, showing slightly darkened tips.

ones. Except when stated otherwise, measurements are for the largest bud examined (a male, 25 cm in diameter). Technical terms for bud and flower parts are indicated in Figures 1 and 2.

Initially, buds develop beneath the bark of the roots of the host liana. The root bark appears to expand and thicken as the bud grows (Fig. 3), perhaps stimulated in some way by the parasite. However, once the bud attains a circumference of 14 – 15 cm, the root bark ruptures to reveal the *R. kerrii* bud, completely enclosed by 15 scales arranged in 5 whorls of 3. The ruptured host bark tissue continues to grow to form a woody cupula which supports the developing bud at its base (Fig. 15). The diameter of the cupula is about half to two - thirds that of the whole bud. In older buds, the outer scales are dark red - brown, dry and apparently dead, easily flaking away from the bud (Fig. 4). Each scale has between 10 and 20 longtitudinal veins, the number of which increases with scale size and age. Scales around the largest bud examined measured up to 18 cm long and 14 cm wide, larger than reported earlier for open flowers (MEIJER, 1984). Buds are completely enclosed by scales up to a circumference of about 16 cm. As the buds grow larger, the scales are pushed apart to reveal what will become, in the open flower, the lower surface of the perigone lobes, pink coloured or dark red where injured.

Figure 5 shows the inside of the top half of the largest bud with the under surface of the diaphragm and the upper surface (considering an open flower) of the perigone lobes. In open flowers the perigone lobes are about 20 cm long and 24 cm wide (MEIJER, 1984). The perigone lobes have a white edge and fairly regularly spaced, oval depressions about 7x10 mm spaced 1–4 cm apart (Fig. 6). These depressions have not been reported before and may disappear when the flower opens and the perigone lobes expand. The perigone lobes are also covered with light red warts each possessing 2–4 lobes, 2–4 mm across, spaced 5–10 mm apart. Other species of *Rafflesia* also have warts on the perigone lobes, but in *R. kerrii* the warts are the smallest, relative to red background, of any *Rafflesia* species, a feature which clearly distinguishes *R. kerrii* from the Malaysian *R. cantleyi*, which has large warts covering more area than the red parts of the perigone lobes.

In the largest bud examined, the central opening of the diaphragm was 10–12 cm in diameter, about half that of open flowers. The upper surface of the diaphragm could not be examined because it was impossible to separate it from the perigone lobes. However, Kerr noted in his diary (22/1/29) (supplied by Kew Gardens, London) that the upper surface is yellowish with lighter small spots. On the under surface of the diaphragm Figure 5 shows 7–9 concentric rings of white dots (compared with 3–4 in *R. cantleyi)*, more than in any other species of *Rafflesia* and more than previously reported (MEIJER, 1984). Near the central opening of the diaphragm the white dots are smallest, 1–2 mm in diameter, spaced about 2–6 mm apart. Towards the outer edge of the diaphragm (i.e. near the edge of the photograph) the dots are largest, 3–6 mm in diameter and spaced 3-7 mm apart. Here the white dots become raised slightly on red stalks (Fig. 7) and they are replaced fairly abruptly by a dense mat of branched ramentae, up to 5 mm long and 1.5 mm wide. Both the ramentae and the white dots appear to be derived from the same structures and

to be extreme variations of them. Towards where the diaphragm joins the inner wall of the perigone tube, the ramentae become more reduced in size and unbranched, until on the inner wall of the perigone tube itself, there are only small densely-packed warts which occur right down to the base.

Figure 8 shows a top view of the central disk of a male bud. The disk is supported beneath by a column. Both disk and column are covered in a thick layer of wax. In open flowers the disk is partly obscured by the diaphragm. In the largest bud, the central disk was 17–18 cm in diameter, slightly larger than previously reported for open flowers (MEIJER, 1984). The number of processes on the upper surface of the central disk varied from 27 to 44 (Table 1). The processes are slightly darker in colour at their tips than at their bases, slightly flattened and up to 3.5 cm long (Fig. 9). The disk has a collar 2.5–3.5 cm wide encircling its rim (Fig. 10). The under surface of the collar and the column of males are covered with fine bristles 3–4 mm long.

The anthers are positioned in cavities 1 cm wide and 1.2 cm long inside the lower lip of the collar (Fig. 11). In each anther cavity there are weak, longtitudinal ridges up to 7 mm long. The number of anthers varied from 26 to 31 (Table 1). Each anther is white, oval-shaped, 9 mm long by 6 mm wide with a single, central pore. Cross sections through the anthers show that they contain numerous small cavities (Fig. 12). Beneath the central disk, the dark orange column is deeply grooved (Fig. 13), with the number of grooves equal to the number of anthers ± 1. Grooves are about 1 cm wide. In the largest bud examined, the column was 5.5 cm from its base to the top of the collar around the rim of the central disk, and 11 cm in diameter at its neck, immediately beneath the central disk, larger than previously reported for open flowers (MEIJER, 1984). The base of the column is widened, forming the annulus interior and is separated from the annulus exterior by a sulcus, 3 mm wide. The annulus exterior was 3 cm wide.

A female bud, examined at Khao Sok, was similar to males except that there were no anthers or anther cavities and the grooves and ridges on the column were very much reduced. On the underside of the central disk very short, soft, white hairs replaced the bristles found in males. The ovary was positioned at the base of the column. The diameter of the ovary was approximately one-third that of the whole bud (Fig. 14). The white ovary tissue consisted of irregularly-shaped small cavities and thick septa, to which numerous ovules were attached.

After a flower has opened and decayed, the cupula shrinks to become a circular woody scar 3–3.5 cm in diameter, with a central depression and radial grooves, which persists on the host root (Fig. 16).

ECOLOGY

The hosts of *R. kerrii* are lianas of the genus Tetrastigma (Vitaceae), as is typical of other *Rafflesia* spp. However, only two positive identifications of host plants to the species level have been made so far. The senior author identified the host of a *R. kerrii*

bud, growing near Khao Sok, as *T. leucostaphylum* (Dennst.) Alston ex Mabberley, and NIYOMDHAM & KUBAT (1987) reported that the host of an open flower at Khlong Nakha Wildlife Sanctuary was *T. papillosum* (Bl.) Planch. (Niyomdham *et al.* 1455 (BKF)).

Information about the habitat requirements of *R. kerrii* is also sketchy. Both *T. leucostaphylum* and *T. papillosum* are found along margins of hill and lowland dipterocarp forest and on limestone hills (LATIFF, 1984). Within Khao Sok National Park and the adjoining Khlong Saeng Wildlife Sanctuary most lowland forest has already been flooded beneath the Chiew Larn Reservoir, but large areas of evergreen forest with *Dipterocarpus* spp. remain at higher altitudes and a spectacular outcrop of limestone runs approximately north-south through the area. The altitudes at which *R. kerrii* has been collected or observed range from 200 m to 1,600 m above sea level.

Flowering appears to be seasonal, coinciding with the hottest and driest time of year. The junior author observed small buds, 4–8 cm in diameter collected by Royal Forest Department staff at Khlong Nakha as early as December. Open flowers have been reported from January to March. However, the senior author's observation of a bud, 6 cm in diameter, at the end of May suggests that flowering may extend into June. There have been no reports of visible buds or flowers between July and November.

As with most other members of the Rafflesiaceae, the mechanisms of pollination and seed dispersal of *R. kerrii* are not known with certainty. Flowers are unisexual and pollination is probably carried out by insects. Flies are attracted to the flowers by a strong odor, similar to that of rotting meat (MEIJER, 1985). In his diary (22/1/29) (supplied by Kew Herbarium, London) Kerr noted that an open flower of *R. kerrii* had a "faint offensive smell" and that the bases of old flowers were "swarming with maggots". He suggested that flies which visit the newly opened flowers deposit their eggs inside. JUSTESSEN (1923) observed traffic of flies between male and female flowers of *R. arnoldii* in Sumatra. *R. kerrii* buds examined at Khao Sok, when cut open, all emitted a very strong but sweet smell. However, chemical changes may occur to produce a noxious smell when the buds are fully mature and ready to open.

The fruit and seeds of *R. kerrii* have never been scientifically described and how the seeds are dispersed to infect a new host *Tetrastigma* is a mystery. It has been suggested for other *Rafflesia* spp. that deer, pigs or even elephants may trample on the fruit and carry the seeds on their feet. Alternatively, ants or termites, which commonly enter decaying flowers, have been proposed as seed dispersal agents. Ground squirrels have been observed to eat *R. arnoldii* fruits and they may transfer the seeds to a host *Tetrastigma* by their claws (MEIJER, 1985; EMMONS & NAIS, pers. comm.).

DISTRIBUTION AND STATUS

Current evidence suggests that *R. kerrii* is largely confined to the southern Tenasserim Hills in Thailand in the Provinces of Chumphon, Ranong and Surat Thani (Fig.

17). The Tenasserim Hills continue into Burma and if suitable evergreen forest remains, *R. kerrii* might also occur there. A male *Rafflesia* bud, with about 30 anthers and very small warts on the perigone lobes, collected by Witkamp in 1935 at Bukit Tepoh is probably also *R. kerrii*. The summit of Bukit Tepoh lies exactly on the Thai-Malaysian border and it is not known on which side of the mountain Witkamp collected the specimen. MAXWELL (pers. comm. 1990) also found a *Rafflesia* in the same area (Sukirin District, Narathiwat Province) in 1987 but, due to its advanced state of decay, he was unable to collect a specimen and determine the species.

However, it is clear that *R. kerrii* has a narrow and rapidly shrinking distribution. Two of Kerr's four original collection sites are not within national parks or wildlife sanctuaries and have largely been converted to rubber plantations. Survival of the species at these sites must therefore be in doubt. Most recent reports of the species are from Khao Sok National Park and the adjoining Khlong Nakha Wildlife Sanctuary. These two protected areas are contiguous with Khlong Saeng Wildlife Sanctuary which also contains suitable habitat for *R. kerrii*. The total area protected amounts to 2,281 km^2 (IUCN, 1987). However, even though these areas are officially protected, large areas of habitat suitable for *R. kerrii* have been destroyed within them. The Chiew Larn Dam, completed in 1986, created a reservoir which flooded 165 km^2 of lowland evergreen forest within Khao Sok National Park and Khlong Saeng Wildlife Sanctuary. The reservoir has made the remaining forest much more accessible than before. By February 1987 about 300 villagers had settled on the reservoir in floating houses and they have caused considerable damage by cutting trees and killing wildlife (NAKHASATHIEN, 1989). WANGHONGSA (1989) reported that around the Chiew Larn Dam all forest up to an altitude of 98.5 m had been cut and burnt. Around the middle of the reservoir about 44% of the forest had been destroyed, but around the upper, northern end of the reservoir forest remained relatively unharmed.

Not only is the habitat of *R. kerrii* bing destroyed, but so are the individual plants. The buds and flowers of the species are so conspicuous, the cannot help but attract attention. Local people often cut them out of curiosity, at the same time severing the roots of the host. Several people living near Khao Sok kept dried parts of buds as curios in their houses. In addition, the plant is believed to have medicinal properties. All parts of the buds or open flowers are boiled in water and the resulting decoction taken as a general tonic, cure for fever or back ache or as a sexual stimulant for old men. Buds are sometimes sold at traditional medicine stalls at local markets for 80–120 baht depending on size. The buds are also edible. The vascular tissue at the base of the column is sweet and is relished by local people as a delicacy. Male buds are more highly prized than females because they are said to be sweeter. Most, if not all, colonies of *R. kerrii* easily accessible from Khao Sok National Park headquarters have already been destroyed. A site visited by the senior author in 1983, where he saw local people cutting the buds of *R. kerrii*, had no signs of buds or flowers when visited by the junior author in March 1989. Several sites near the national park headquarters visited by the junior author, where local guides claimed to have collected the plant in previous years, were also devoid of buds and open flowers. Villagers

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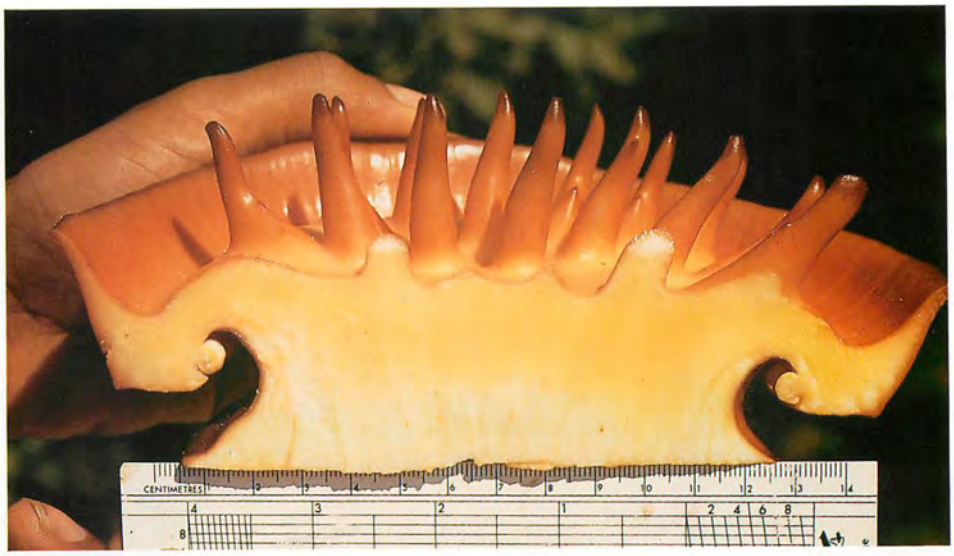

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Figure 10. Longitudinal section through central disk and column of male *R. kerrii* bud showing processes, collar and anthers inside the lower lip of the collar.

Figure 11. Close-up of anthers.

Figure 12. Cross section through anthers after preservation in alcohol, showing multi-cavitied interior.

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Figure 13. Central disk and column, showing annulus interior, annulus exterior and sulcus.

Figure 14. Cross-section through ovary of female *R. kerrii* bud.

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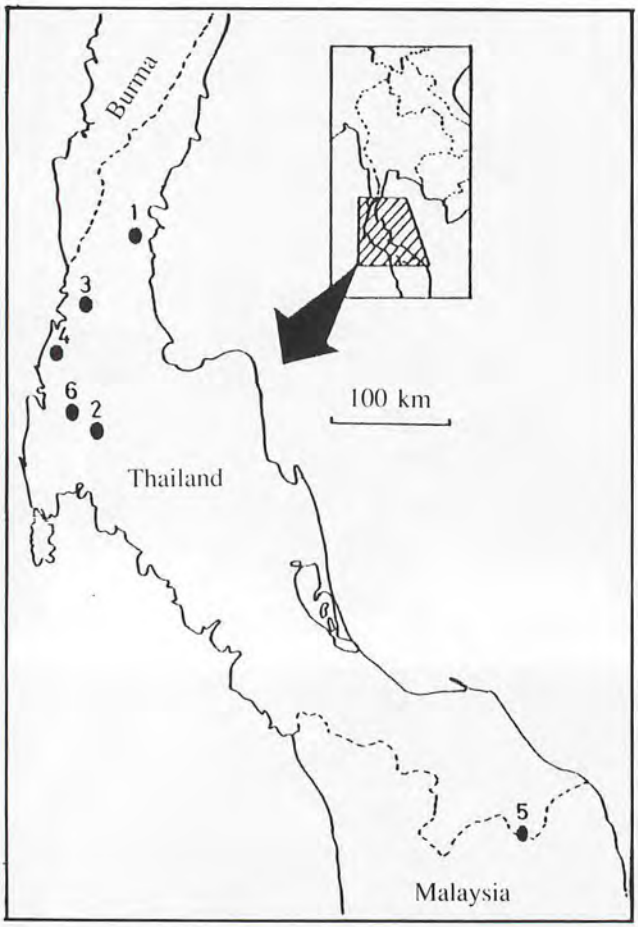
Figure 15. A large *R. kerrii* bud viewed from beneath, showing the woody cupula and root of host liana.

Figure 16. A scar remaining on the root of the host liana after a *R. kerrii* flower has decomposed.



1) Ranong Province, Ban Lam Lieng, 200 m, Kerr 11781 (BM, K, BK) 2/2/27 ; Khlong Phlao National Park, (OOTIN, pers. comm., 1988).

2) Surat Thani Province, Song Phi Nong, 300 m, Kerr 12390 (BM, K) 20/3/27.

3) Ranong Province, Khao Pho Ta Chong Dong, 300 m, Kerr 16805 (BM, K, BK) 22/1/29.

4) Ranong Province, Khao Pho Ta Luang Kaeo 600 m, Kerr 16980 (BM, K, BK) 3/2/29 ; Khlong Nakha Wildlife Sanctuary, 800–1000 m, Niyomdham 1434, 17/3/87 (see NIYOMDHAM & KUBAT, 1987).

5) Thai-Malaysian border, Bukit Tepoh, Witkamp s.n. 1935 (in alcohol collection at Herbarium Bogoriense).

6) Surat Thani Province, Khao Sok National Park, 500 m, Smitinand 12139 (C) 6/3/76 ; 1100 m, Somthop s.n. (BKF) Jan 1978 ; Meijer s.n. 27/5/83 and Elliott 14/3/88 (photographs in this paper).

Figure 17. Records of *Rafflesia kerrii* Meijer.

claimed to have collected the buds photographed for this paper a great distance from the national park headquarters.

On the basis of its narrow distribution, continuing loss of habitat and over-collection by local people we propose that *R. kerrii* satisfies the criteria of a vulnerable species, according to the Red Data Book categories of the International Union for the Conservation of Nature (IUCN, 1980).

CONSERVATION

As Thailand's largest and most spectacular flower, *R. kerrii* is truely a national treasure and worthy of the strictest conservation measures. If habitat destruction and over-collection is allowed to continue, Thailand will lose an important part of its national heritage.

There are also sound economic reasons to protect *R. kerrii*. In a recent survey carried out by students at the Department of Biology, Chiang Mai University, 558 tourists were asked how much they would pay for a guided day trip to see "Thailand's largest flower (70 cm in diameter)" growing in the wild. The average price suggested was 450 baht, similar to the sum tourists were prepared to pay to see a herd of elephants in the wild. Development of *R. kerrii* as a tourist attraction would not only help to bring in much needed funds for conservation work within the remaining areas of *R. kerrii*'s habitat, but might also persuade local villagers that the plant is more valuable left growing in the forest than cut as a curiosity or medicinal plant.

We therefore suggest that *R. kerrii* be promoted as a tourist attraction within Khao Sok National Park, where some tourist facilities already exist. Populations in Khlong Nakha and possibly Khlong Saeng Wildlife Sanctuaries which are not in immediate danger from over-collection due to their remoteness, should be left alone to serve as controls, so that any detrimental effects of tourism can be detected and remedial action taken if necessary. In order to develop *R. kerrii* as a tourist attraction the following measures would be needed. Colonies of *R. kerrii* within Khao Sok National Park should be mapped to determine the status of the plant. Colonies should be visited regularly by local people, employed by the national park as guides, to make measurements of bud growth rate in order to predict when open flowers will be available for tourists to see. When buds are about to open, the guides could inform tourists staying at guesthouses, which already exist near the park entrance (YEE, 1990), and negotiate a price for a day's trek to see and photograph the flower. In this way, local people would be given a considerable financial incentive not to cut the plant and even to protect colonies against vandals. Raised wooden walkways should be placed around colonies visited by tourists to prevent tourists from trampling the roots of the host plant or stepping on young *R. kerrii* buds growing unseen beneath leaf litter. In addition, Kerr's original collection sites of *R. kerrii* should be properly surveyed to determine whether or not the species still survives there. If found, such areas should be protected as wildlife sanctuaries.

In Malaysia and Indonesia, *Rafflesia* spp. have already been successfully promoted as tourist attractions. Income from tourists has encouraged authorities to increase protection for existing forest reserves and to designate new ones, thus benefitting many species, besides *Rafflesia* spp. In Indonesia, *Rafflesia* decorates the 200 Rp stamp. In Sabah, tourists are welcomed at airports with billboards decorated with *Rafflesia* and the Tourism Ministry of Malaysia is actively using *Rafflesia* as a symbol to attract visitors to Mt. Kinabalu National Park. In Thailand, the eco-tourist market has been largely ignored by the Tourism Authority and large tour companies. This is likely to change, however, as the tourism potential of Thailand's extensive protected areas system is realized. To be successful, eco-tourism needs "star attractions" and *R. kerrii,* if properly protected, could act as such an attraction. Protecting *R. kerrii* and the forests where it grows would therefore benefit not only the tourism industry, but also the rural poor, by providing them with an economic alternative to encroachment in national parks and wildlife sanctuaries.

Changes in legislation might also help to save *R. kerrii* and other rare wild plants from extinction. In Thailand, plants are treated very much as second class species. It is 30 years since the Wild Animals Reservation and Protection Act (WARPA) was enacted (1960) to prohibit killing and trade in rare wild animals but there is no similar law to protect plants. Such a situation means that Thailand is unable to carry out its international obligations under the Convention on the International Trade in Endangered Species of Wild Fauna and Flora (CITES), which Thailand joined in 1983. CITES covers both plants and animals, but with no national legislation to protect plants, Thailand's government is powerless to prevent commercial exploitation of wild plants in danger of extinction. A law prohibiting the uprooting, cutting and trade in endangered plant species may not solve the problem entirely, especially if poorly enforced (as is the case with WARPA) but at least it would demonstrate a national willingness to save some of Thailand's finest remaining botanical treasures, including *R. kerrii,* the finest of them all.

ACKNOWLEDGMENTS

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