

Assessing the *Rafflesia kerrii* population status and their threats in Lojing Highlands, Kelantan, Peninsular Malaysia

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ABSTRACT

Malaysia, recognized as one of the world's mega-diverse hotspots, is currently facing a decline of many endangered and rare species due to natural and anthropogenic factors. Amid these species, *Rafflesia kerrii*, the largest iconic parasitic flower, is facing threats from ecological changes, habitat disturbance, and human activity. Despite being threatened, the population of *Rafflesia kerrii* in Lojing Highlands is still present, but in smaller numbers compared to a decade ago. Therefore, a four-month intensive survey from October 2023 to February 2024 was conducted in the *Rafflesia* Conservation Park, Lojing Highlands, covering three main sites (Beirus-Dawai; Cebur; Cebur-1Malaysia) to assess the current status (distribution and populations) and threats of the species. A Global Positioning System (GPS) was used to tag the information on location and elevation, whereas the distribution map was generated by using QGIS 3.44.2 version. A standard criterion status was employed to classify the population of the species into four categories, namely: (i) Active; (ii) Poorly Active; (iii) Dormant; and (iv) Extinct. Results show that *R. kerrii* populations in the study areas are still promising, with a total of 20 populations and 52 clusters recorded. Of these, 92.31% were classified as Active, 5.77% as Poorly Active, and 1.92% as Dormant, found at elevations ranging from 930 to 1,054 meters above sea level (asl.). Despite the positive population indicators, the survey revealed the area is facing habitat disturbance and anthropogenic threats, particularly the cutting of *Rafflesia* host plants, crucial for the parasite's existence. This factor causes threats to the long-term viability of *Rafflesia* populations and potentially to extinction in the future. Therefore, an immediate and effective management action for *Rafflesia*, including habitat protection, community awareness, and ecological monitoring, should be implemented to ensure sustainable protection and regeneration of *R. kerrii* in this area.

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1.0 INTRODUCTION

Malaysia, recognized as one of the world's mega-diverse countries, is home to many rare and unique species (Latiff, 2019). However, many of these species are now facing threats due to both natural changes and anthropogenic activities (Darwati et al., 2025; Ramadhani et al., 2017). One such genus is *Rafflesia* spp., a rare and endemic parasitic flowering plant from the Rafflesiaceae family that grows in the tropical rainforests of Southeast Asia countries – including Malaysia (14 species), Thailand (1 species), Indonesia, with the latest discovery, *Rafflesia harjatii* (18 species), Brunei (1 species), and the Philippines (16 species) (Mahyuni et al., 2026; Malabrigo et al., 2023; Adam et al., 2022; Norhazlini et al., 2022). *Rafflesia* is notable for its gigantic blooms, with diameters of up to one meter, and its putrid scent attracts flies

for pollination (Hor et al., 2021). As an obligate holoparasitic plant lacking leaves, stem, or true root, *Rafflesia* depends totally on host plant, *Tetrastigma* spp., to obtain nutrients, minerals, and a water supply for sustenance (Nais, 2001). Not only that, Xi et al. (2013) reported on horizontal gene transfer (HGT) and reveals *Rafflesia* 'steal' the gene from the host plant.

In Malaysia, 14 species of *Rafflesia* spp. have been recorded. *Rafflesia kerrii* is one of the most distinctive species due to its large diameter, red-orange flower, perigone lobes covered with small warts, and wide diaphragm opening. *R. kerrii* is endemic to Peninsular Malaysia (Kelantan and Perak) and southern Thailand (Asfarina et al., 2022). Zulhazman et al. (2010) reported that the Lojing Highlands are a hotspot for the discovery of new species. A total of 26 *R. kerrii* populations

were mapped in Kg. Jedip, Kg. Cedau, and Kg. Kuala Renggil during a scientific expedition. Consequently, 404 hectares have been gazetted as the *Rafflesia* Conservation Park (RCP).

According to Malabrigo et al. (2023), *Rafflesia*'s conservation status varies across regions. In Malaysia, the *Rafflesia* is more protected in Sabah and Sarawak. In contrast, Peninsular Malaysia pays less attention to it. The status of *R. kerrii* (Malaysia Plant Red List) is Not evaluated (NE) (MyBIS, retrieved in August 2015). Brunei has one species of *Rafflesia*, *R. pricei*, which is found in Ulu Temburong National Park. Here, rigorous conservation measures are enforced under national legislation. In the Philippines, the lack of a comprehensive conservation strategy for *Rafflesia* threatens the 16 species listed as Critically Endangered, Endangered, and Vulnerable. Indonesia has taken a significant conservation step. All *Rafflesia* species are protected under national laws, and the *Rafflesia* Strategic Action Plan (RSAP) guides conservation efforts. The *Komunitas Peduli Puspa Langka* (KPPL) community also participates actively in *Rafflesia* conservation. In Indonesia, most *Rafflesia* species are classified as Critically Endangered, using national criteria. This situation shows the urgent need for conservation actions to prevent extinction in their natural habitats (Malabrigo et al., 2023).

Ineffective conservation measures have left the species vulnerable to threats. The main threats are habitat loss from logging, agricultural clearing, high bud mortality, and unsustainable tourism. The *R. kerrii* in Lojing is promising but has declined over the last decade. Although 1,000 acres have been gazetted as *Rafflesia* Conservation Park (RCP), regulations are poorly enforced. Qayyum et al. (2023) reported that while tourism boosts local economies and awareness, it is a double-edged sword. In Sabah, a successful local grower of *Rafflesia* manages to derive income by promoting visits to the garden, resulting in sustainable ecotourism (Ng, 2012). However, an uncontrolled influx of visitors can cause damage to the buds and the delicate supporting vegetation. Land-use change and agricultural expansion are also critical threats (refer to Figure 1). These combined impacts demonstrate the urgent need for an ecological assessment of *R. kerrii* in Lojing Highlands and a conservation plan. Thus, this study aims to determine the population status and threats to *R. kerrii* in Lojing, Kelantan, Peninsular Malaysia. Protecting *Rafflesia* is vital for biodiversity, local communities, and national pride, as noted by Malabrigo et al. (2023).

2.0 METHODOLOGY

The study area is in the Lojing Highlands, Gua Musang, Kelantan (refer to Figure 2). It sits in the northern section of the Titiwangsa Mountain Range and has an altitude of 800 to 1,400 m a.s.l. The area is dominated by upper dipterocarp and lower montane forests (Zulhazman et al., 2021; Dony-Adriansyah et al., 2015). The main inhabitants are the *Temiar* ethnic community. Lojing is well-known for *R. kerrii*, which attracts both local and international visitors. The landscape features about 16,235 ha of Permanent Forest Reserve and 8,000 ha of private lands. Much of the private land has been converted to agricultural areas, particularly vegetable farms (refer to Figure 1). Most locals work as labourers or as *Rafflesia* tourist guide for extra income.

The method employed in this study was designed to meet the research objectives: to assess the population status and its threats. An intensive field survey was conducted at three sites (Beirus-Dawai, Cebur, and Cebur-1Malaysia) in RCP from October 2023 to February 2024 to document the distribution and population status of *R. kerrii*. Each identified population was subdivided into clusters. Within each cluster, the number of *Rafflesia* cycles, the stages of each cycle, and the condition of each stage were documented and photographed. The coordinates and elevations of each cluster and its associated host plants were obtained using a Global Positioning System (GPS), and all locations were physically tagged *in situ*. A systematic technique was used to create a detailed distribution map of *R. kerrii*, which involved integrating GPS locations with QGIS 3.44.2 version, an open-source GIS software (QGIS Development Team, 2025).

Data from field surveys were analyzed to comprehend the population dynamics and geographical range of *R. kerrii*. The information on landcover classes in RCP was obtained and generated from the JRC Tropical Moist Forest Transition (1990-2024) (Vancutsem et al., 2019) (refer to Figure 2), while the land use changes from 2012 to 2022 were generated from the ESA Land Cover CCI version 2.1.1 by using the Earth Map platform (Morales et al., 2023). Population status was evaluated and classified into four categories, referring to guidelines by Nais (2001); (i) Active – presence of several stages of *Rafflesia*, including cupule, bud, flower, decayed flower, fruit, and scar; (ii) Poorly Active – presence of unhealthy/dead bud; (iii) Dormant – state of rest or inactivity, presence of scar and the absence of any cupule or bud; and (iv) Extinct – decayed host plant/ destroyed habitat. The calculation for each stage is based on the percentage of cluster number over total number of cluster.

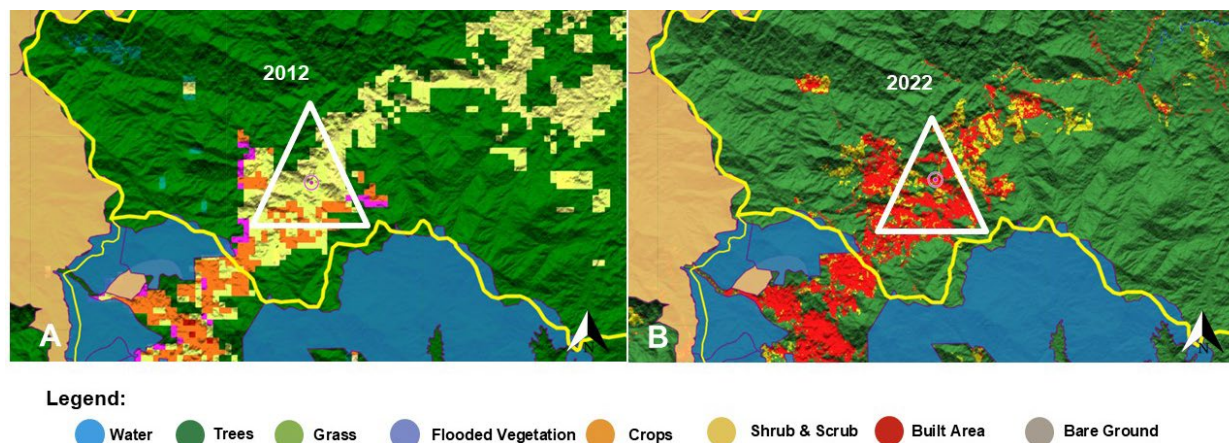


Figure 1: Land use maps of Lojing Highlands in (A) 2012 and (B) 2022 showing major landscape changes within the area of interest (triangle) and the surrounding boundary (yellow line). Land cover classes are represented as Water (blue), Trees (dark green), Grass (light green), Flooded vegetation (purple), Crops (orange), Shrub & scrub (yellow), Built area (red), and Bare ground (grey). The maps highlight notable expansion of built-up areas and reduction of tree cover over the decade. Source: <https://earthmap.org>.

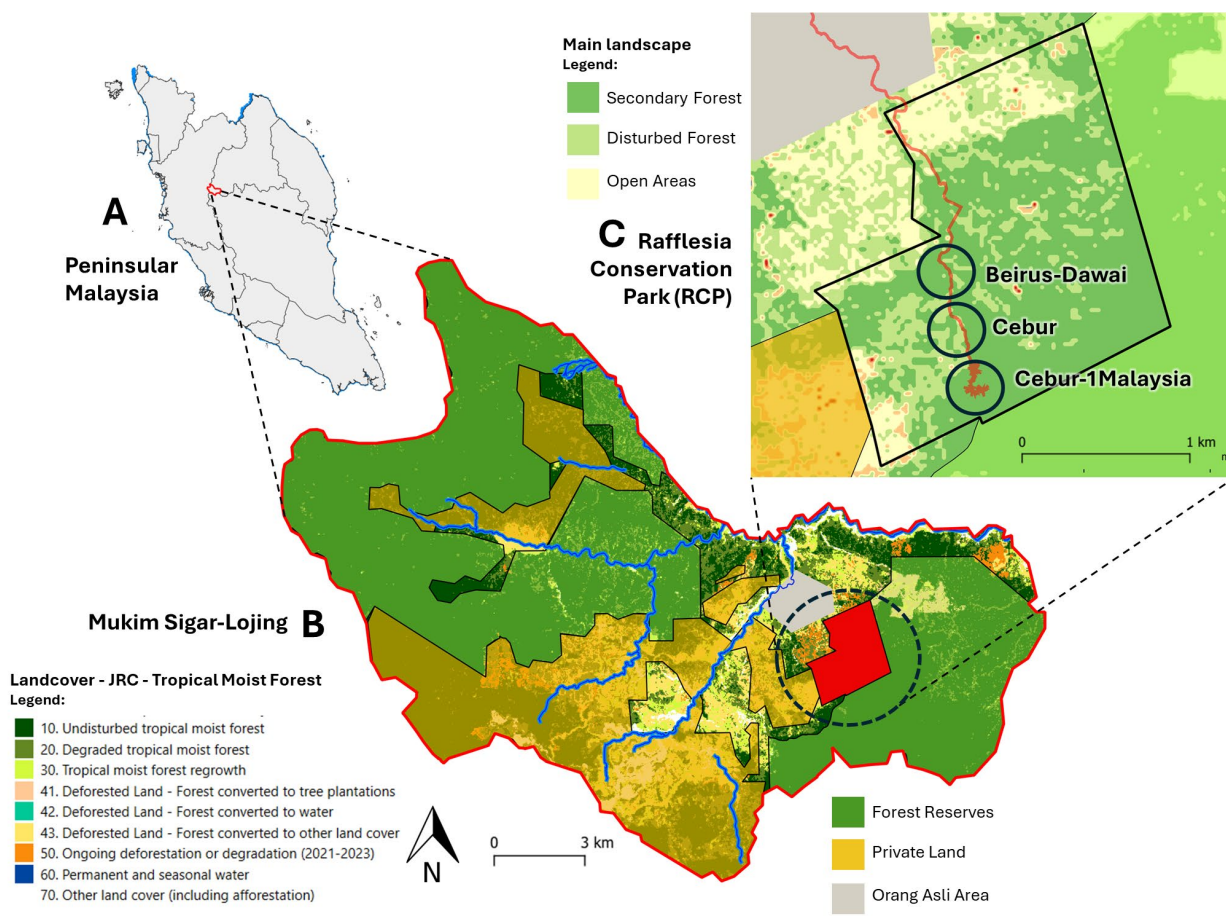


Figure 2. (A) Location of the Lojing Highlands, Kelantan, within the Titiwangsa Range, Peninsular Malaysia. (B) Mukim Siga-Lojing with forest reserves, private lands, and *Orang Asli* areas. (C) Rafflesia Conservation (red) within a mosaic of regenerating forests and agricultural lands. Land cover generated from JRC Tropical Moist Forest Transition (1990–2024) (Vancutsem et al., 2019).

3.0 RESULTS AND DISCUSSION

A total of 20 populations comprising 52 *R. kerrii* clusters were recorded in the RCP (Table 1). Most of the populations mapped fall into the “Active” category and are distributed at elevations ranging from 930 to 1,054 meters above sea level (asl.). Although the number of individuals in each population is relatively low, complete reproductive cycles, including the presence of cupule, bud, flower, decayed flower, and the formation of fruits were observed. This observation indicates that, despite the relatively low numbers of individuals, the reproductive cycles of *R. kerrii* remain ongoing, with the species demonstrating some capacity to sustain its reproductive functions under ecological pressures.

During the survey, a total of eight blooming flowers were recorded, comprising five female and three male flowers. According to Nais (2001), *Rafflesia* is typically unisexual, and the ratio of male flowers is normally higher than the female flowers (7:1), however, the finding is in contrast with the report. A study by Nurchayati et al. (2025) reveals that the female flowers of *R. zollingeriana* tend to dominate the male flowers by 55% to 45%. A comprehensive survey on the ratio of male to female flower should be thoroughly conducted, in order to obtain valid data, so the rarity of the species can be explained accordingly. The diameter of these flowers ranged from 80 to 90 cm, reflecting the typical size range for mature blooms. In addition to the blooming flowers, 96 decayed flowers were observed, highlighting the high turnover rate and short-lived nature of the flowering phase. Furthermore, 89 healthy buds and 86 rotting or aborted buds were documented, yielding an almost 1:1 ratio of viable to non-viable buds. This near-equal proportion of healthy and failed buds underscores the precarious nature of *Rafflesia* reproduction, in which the potential for reproductive success is closely balanced with high likelihood of bud mortality. The fragile nature of this reproductive system suggests that, although *R. kerrii* is still capable of completing its life cycle, the success rate of reproduction remains low, which could have significant implications for the long-term survival of the species, especially in light of environmental and ecological challenges.

The high mortality rate is concerning and supports previous findings by Nais (2001), who explained that young buds at the early stage have a higher mortality rate than late-stage buds. Indeed, many buds fail to progress beyond the early developmental stage, resulting in aborted growth. The mortality rates of *Rafflesia* buds are alarmingly high, posing a threat to the long-term sustainability of *R. kerrii* populations. As a large proportion of buds fail to reach maturity, the overall chances of successful reproduction in *R. kerrii* remain critically low. This reproductive limitation is further underscored by field observations, which recorded more than 100 bud scars

indicative of aborted or senesced buds across the three study sites. These scars provide clear evidence of high bud mortality and suggest that only a small fraction of initiated buds survive to develop into fully mature, reproductive flowers. As a highly specialized holoparasite, *Rafflesia* is entirely reliant on a specific host species (*Tetrastigma* spp.) for water and nutrients. Additionally, being constrained by such high rates of bud mortality adds a significant layer of vulnerability to the species' life history strategy. The combination of obligate parasitism, low reproductive output, and high bud attrition poses a serious threat to the long-term persistence of *R. kerrii* in its natural habitat, particularly in the face of habitat disturbance and ecological imbalance.

From the survey, the distribution of *R. kerrii* was found to be concentrated in three main areas within the RCP, namely: (i) Beirus-Dawai, (ii) Cebur, and (iii) Cebur-1Malaysia (Figure 3A). These areas are geographically separated by natural landscape features, including rivers and hills, which likely play a significant role in shaping the ecological conditions of each site. The presence of the described topographical impediments potentially affects the microclimatic conditions in these areas, including temperature, humidity, and soil composition, which are crucial for the establishment and growth of *R. kerrii*. In addition, these physical topographies may influence pollinator and seed dispersal activities, thereby affecting the reproductive success of the species; rivers can form barriers to pollinator or seed disperser movement, potentially limiting population-to-population gene flow. Moreover, changes in altitude and vegetation in these areas may influence pollinator availability, affecting plant-pollinator interactions and the eventual successful reproduction of the species in each area (Pelser et al., 2017).

In the RCP area, Beirus-Dawai was identified as the initial site for *R. kerrii* populations, with a total of nine populations comprising 26 clusters recorded at elevations of 930 to 997 m a.s.l. Most of these clusters (84.62%) were classified as Active, with 11.54% categorized as Poorly Active and 3.85% as Dormant. Of interest, four blooming *Rafflesia* were spotted during the survey. Though the dominance of Active clusters indicates a relatively high rate of active reproduction, the presence of Poorly Active and Dormant clusters raises significant concern. These clusters reflect populations that are not in their optimal or arrested stages of development and might reflect ecological stress or poor conditions in which to reproduce. This is compounded by factors such as resource limitations, habitat degradation, climatic changes, or disturbances to symbiotic relationships between these clusters and the host plants, which could all contribute to the inability to reach their maximum reproductive potential. Poorly Active clusters may reflect that the

populations are striving to sustain the nutrient absorption necessary for growth and development, whereas Dormant clusters could mirror a 'rest' state due to environmental factors (i.e. seasonal changes or water scarcity) that deter the cycle of reproduction. The combination of these inactive clusters with Active clusters highlights a fragile balance in population dynamics, where a significant proportion of individuals may not be contributing to the gene pool, potentially limiting the species' ability to reproduce successfully over time. The spatial heatmaps (Figure 3B–H) show a high density of various phenological stages, including buds, blooming flowers, and scars, especially in the northern part of Beirus-Dawai, suggesting this area may serve as a reproductive hotspot. However, the overlapping zones of rotten buds and flowers also imply high floral turnover or abortive development, a pattern echoed by Thorogood et al. (2022), who described similar dynamics in the parasitic plants population. The frequent occurrence of decayed buds and flowers within a reproductive hotspot could suggest underlying ecological pressures, such as pollinator scarcity, resource competition, or microclimatic stress, that inhibit full floral development and reduce the species's overall reproductive success.

Cebur was the second site, with five populations and eight clusters were recorded at elevations between 972 to 1,006 m a.s.l. All clusters were classified as Active. Observers recorded three blooming flowers, 27 rotten flowers, 12 rotten buds, 15 healthy buds, and four cupules. The number of clusters is lower than in Beirus-Dawai, but this population appears relatively stable. The heatmap (Figures 3B–3H) reveals a moderate but consistent presence of all phenological stages - particularly buds and flowers - indicating healthy reproductive cycles at a smaller scale. Cebur may serve as a secondary reproductive hub, providing stability for *R. kerrii*'s reproductive strategy within the RCP. Though not as large or productive as Beirus-Dawai, Cebur is vital for the species ongoing persistence. Its steady reproduction helps buffer more vulnerable populations and reduces reliance on a single area. Multiple stages from budding to blooming and steady flower and bud turnover show Cebur offers suitable conditions for ongoing reproduction. This, in turn, support resilience, spatial distribution, and genetic exchange across different clusters, which are essential for the species' long-term viability and adaptation to environmental pressures.

The Cebur-1Malaysia area recorded six populations with 18 clusters, all classified as Active, located at elevations ranging from 1,009 to 1,052 m a.s.l. One blooming flower was documented along with 50 rotten flowers, 49 rotten buds, 41 healthy buds, and 16 cupules. This site showed a well-

distributed phenological stage, with no clusters falling under Dormant or Poorly Active status. The high number of both healthy and degraded reproductive parts, as illustrated in the phenological heatmaps, reflects high turnover rates but also indicates strong reproductive activity. Among the three sublocalities within the RCP, Cebur-1Malaysia exhibited the most balanced and stable reproductive conditions, suggesting that it supports the most viable population of *R. kerrii* within the park. This assessment is based on the consistently Active status of all recorded clusters, with no populations categorized as Dormant or Poorly Active, in contrast to the fluctuations seen in the other sublocalities. The stable presence of multiple phenological stages, including healthy buds, blooming flowers, and cupules, along with a moderate turnover rate of both healthy and decayed flowers, reflects a robust reproductive cycle. These factors indicate that Cebur-1Malaysia is not only capable of maintaining a continuous flow of reproductive activity but also likely to benefit from favourable ecological conditions, such as optimal microclimate, soil nutrients, and pollinator availability, which together promote successful pollination and seed production. This area indicates a population that is genetically diverse and sustainable, which contributes to the long-term viability of *R. kerrii* within the RCP.

Altogether, the cluster status maps and phenological heatmap (Figure 3) indicated that *R. kerrii* was spatially clustered and phenologically dynamic, with varying levels of stability across the sites surveyed. These patterns highlight the species' dependence on well-localised microhabitats and the requirement for site-specific conservation actions (Barcelona et al., 2009). The existence of reproductive hotspots, together with overlapping decay zones, points to a delicate reproductive ecology vulnerable to microclimatic changes or host plant fitness, requiring long-term monitoring and protection of the *R. kerrii* population within the RCP.

Rafflesia commonly grows on moist forest slopes, near to water sources. Farah et al. (2018) reported that seasonal climate conditions in Southeast Asia, especially water availability, temperature, and photoperiod, stimulate the flowering of *Rafflesia*. Studies by several researchers (Siahaan et al., 2024; Wahab et al., 2021; Hayati et al., 2021) found that *Rafflesia* was highly localized to specific soil physico-chemical and edaphic conditions, even though it occurred across broader forested areas or microhabitats. These highly specific ecological requirements highlight the species' vulnerability to habitat alteration.

According to Pelser et al. (2013), habitat fragmentation poses a severe threat to species like *Rafflesia*, as it isolates populations, hampers the movement of pollinators and dispersal agents, and makes it difficult for

plants to reproduce, thereby decreasing genetic diversity and increasing extinction risk. Pollination in *Rafflesia* is mediated by carrion flies, which are highly sensitive to habitat disturbance. Reduced forest connectivity could therefore directly impact pollination success, limiting seed production and recruitment.

The alarming risk of *Rafflesia* extinction is further exacerbated by irresponsible human activities within the RCP. This is in line with Fauzan et al. (2021), who stated anthropogenic activities, for instance, unsustainable ecotourism, logging, and land conversion, had brought *Rafflesia* to the brink of extinction. A total of nine populations were found severely disturbed by local anthropogenic activities. Several host plants (*Tetrastigma hookeri*), essential for *R. kerrii* survival, were indiscriminately cut. As holoparasitic plants, the genus relies entirely on its host for water and nutrients, and host removal results in the inevitable death of *Rafflesia* (Nais, 2001). As shown in Figure 4, an irresponsible action such as cutting the host plant and buds of *Rafflesia* may threaten the long-term viability of the species population. Qayyum et al. (2023) further reported that 2.3% of *Rafflesia* mortality is directly attributable to cutting host plants. Despite 1,000 acres being designated as a conservation zone under RCP, regulations are not enforced strictly enough to optimally protect *Rafflesia*. Strict law enforcement is urgently needed to control human activities on *R. kerrii* and its host plants within the RCP. Although conservation measures have been put in place, the lack of adequate enforcement leaves the species vulnerable to irresponsible actions (e.g., cutting host plants and removing *Rafflesia* buds), threatening the population's survival. Effective law enforcement would not only restrain and prohibit harmful activities but would also be useful for educating the local communities on the values of conserving the species. Raising public awareness and community engagement could foster a sense of stewardship, nurturing local support for conservation actions and sustainable activities that do not compromise the integrity of the park's ecosystem. An immediate action is crucial to protect the species from facing the same situation as other *Rafflesia* species reported at the edge of extinction and rarely seen, such as *R. atjehensis*, *R. rochussenii*, and *R. bengkuluensis* (Rahmaudil & Oksari, 2024).

As a measure to sustain the survival of *R. kerrii* in the RCP, the following strategies are suggested:

- (i) Enhanced research collaboration – effective collaboration between stakeholders (universities, NGOs, and government agencies) is crucial for collecting complete data on the population of *R. kerrii*, their habitat preferences, and the challenges they encounter. Comparison with Thailand, where *R. kerrii*

has also been reported, could provide comparative informations.

- (ii) Community involvement – community participation in *Rafflesia* monitoring and conservation can help instil a sense of guardianship and responsibility among them. Community-based conservation has worked elsewhere in Malaysia in other biodiversity hotspots.
- (iii) Long-term monitoring program – this program helps generate precise information on species population dynamics, the fitness of the host plant, and the effects of environmental variability, providing insights into conservation approaches.
- (iv) Education and outreach activities – extending knowledge and awareness among local communities, schools, and tourists, facilitating the reduction of harmful practices, and building pride in conserving this iconic species. Interpretive trails and guided tours can foster eco-tourism while also protecting vulnerable populations.
- (v) Policy advocacy – a stronger alliance with policymakers is needed to lessen the risks of habitat degradation, illegal harvesting, etc. Introducing penalties for unethical actions in RCP would be a deterrent.

4.0 CONCLUSION

In conclusion, the status of *R. kerrii* population in RCP is positive, though there has been a slight decline in numbers, and Lojing Highlands remains the wealthiest *R. kerrii* population in Peninsular Malaysia. But with no concerted conservation action, sooner rather than later, there will be more losses. Efforts from all stakeholders are necessary in helping to safeguard this iconic species. Constant awareness campaigns should be implemented to educate communities about the need to conserve *Rafflesia*. Furthermore, tourist activities should be closely monitored to reduce ecological disturbance. Also, a rotational visitation system should be established in three sites within the RCP (Beirus-Dawai; Cebur; Cebur-1Malaysia), allowing each area 'periodic rest', thus reducing stress on the habitat. Finally, *R. kerrii* is more than a botanical oddity; it has become a flagship species for the conservation of tropical rainforests. Conservation strategies require a combination of ecological science, community stewardship, and strong governance. A well-managed RCP could serve as a model for *Rafflesia* conservation and an inspiration for sustainable eco-tourism in Malaysia.

Table 1: Summary of *Rafflesia kerrii* population status within Rafflesia Conservation Park (RCP).

Site	Population /Cluster	Elevation (m), asl.	Total Floral Development						Status
			Cupules	Buds	Unhealthy/ dead bud	Blooming Flowers	Rotten Flowers	Scars	
Beirus-Dawai	9/26	930 - 997	14	33	25	3	19	>50	Active; Poorly Active; Dormant
Cebur	5/8	972 – 1,006	4	15	12	3	27	<50	Active
Cebur-1Malaysia	6/18	1,009 – 1,052	16	41	49	2	50	>50	Active
Total	20/52		34	89	86	8	96	>100	

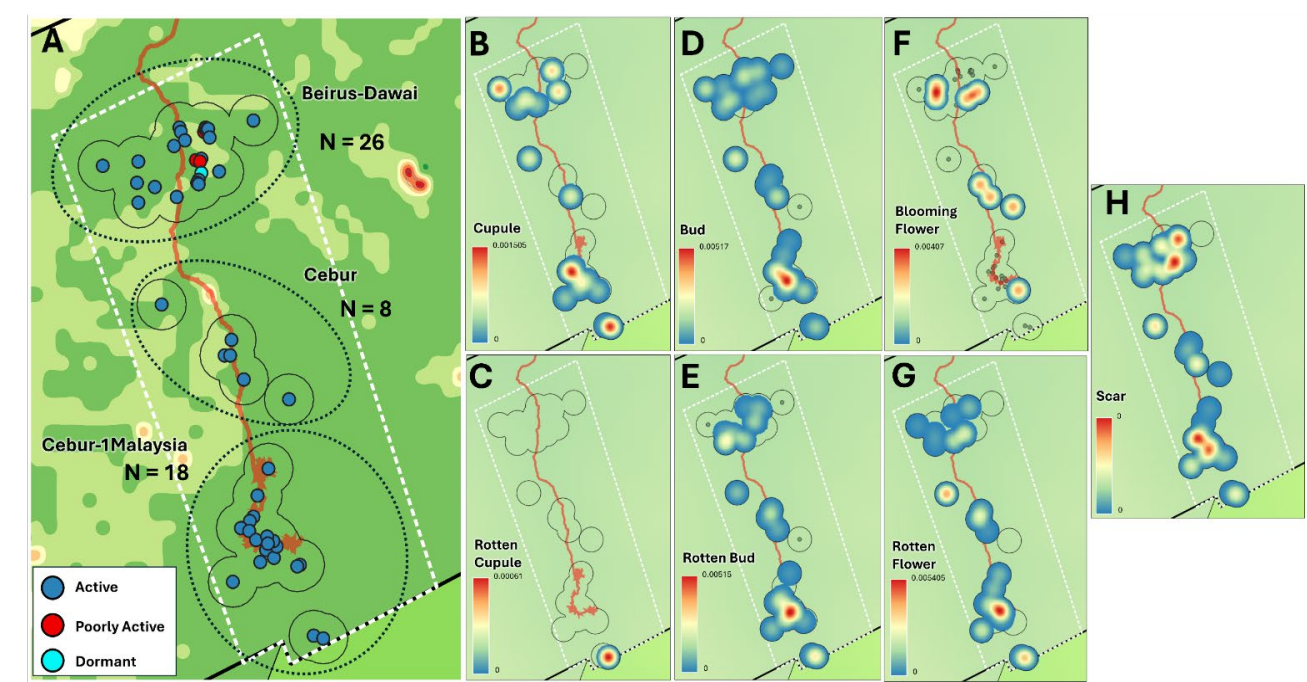


Figure 3: Spatial distribution and phenological heatmaps of *Rafflesia kerrii* in Rafflesia Conservation Park: Beirus-Dawai, Cebur, and Cebur-1Malaysia. (A) Map of cluster and activity status comprised of Active (blue), Poorly Active (red), and Dormant (cyan). (B–H) Kernel density heatmaps showing the intensity of different phenological stages: (B) Cupule, (C) Rotten Cupule, (D) Bud, (E) Rotten Bud, (F) Blooming Flower, (G) Rotten Flower, and (H) Scar.



Figure 4.A-C: The host plant and bud of *R. kerrii* in the Rafflesia Conservation Park (RCP) have been chopped and cut down.

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