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Population and autecology of the endangered *Rafflesia meijeri* in Batang Gadis National Park, Indonesia

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Abstract. *Rambey R, Saputra N, Rambe IF, Nopandry B, Zunaidi S, Christy EL, Setiawan T, Afifuddin Y, Hartanto A. 2023. Population and autecology of the endangered* Rafflesia meijeri *in Batang Gadis National Park, Indonesia. Biodiversitas 24: 1845-1852.* Indonesia is renowned for its tropical forests, which harbor high biodiversity. One of the notable flora found in the Indonesian forest is the holoparasitic plant *Rafflesia*, which attaches to its host, *Tetrastigma* spp. Among the 30 species of *Rafflesia*, 11 species have geographical distribution in Indonesia, specifically in Sumatra, Java, and Kalimantan. *Rafflesia* is listed as Endangered by the IUCN Red List, highlighting the conservation importance of this plant group. The objective of this study was to determine the number of individuals, ecological conditions, and structure of plant species composition in the habitat of *Rafflesia meijeri* Wiriad. & Sari in two localities (i.e. Sopotinjak and Pagar Gunung) in Batang Gadis National Park. Population and autecology data of *R. meijeri* were collected using the nested plot method and the vegetation community was analyzed in terms of the Importance Value Index (IVI), biodiversity and richness indices. The results of the study indicated that in Sopotinjak there was one individual of *R. meijeri* in the bract phase, two individuals in the ruptured copule phase, and 13 individuals in the round copule phase. In Pagar Gunung, there were 19 individuals in the late blooming phase, seven individuals were in the bract phase, three individuals were in the copule phase, and two individuals were in the ruptured copule phase. Species with the highest IVI in the vegetation community around the habitat of *R. meijeri* from seedling, sapling, pole to tree level in Pagar Gunung were *Litsea firma* (Blume) Hook.fil., *Eugenia pyriformis* Cambess., *Cinnamomum burmanni* (Nees & T.Nees) Blume, and *Castanopsis javanica* (Blume) A.DC., respectively. Species that were significantly associated with *R. meijeri* in Sopotinjak were *Kyllinga brevifolia*, *Melastoma malabathricum* L., *Calamus paspalanthus* Becc, *Calamus rotang* L., and *Gliricidia sepium* (Jacq.) Kunth. The discovery of nine specimens of the host plant *Tetrastigma papillosum* (Blume) Planch. in Pagar Gunung and Sopotinjak indicates the importance conservation efforts aimed at conserving *R. meijeri*, as well as the flora and habitats that are intricately linked to it.

Keywords: Batang Gadis National Park, *Rafflesia meijeri*, structure composition, vegetation analysis

INTRODUCTION

Indonesia is renowned for its tropical forests, which boast high biodiversity, and among the notable flora found in the Indonesian forest is the holoparasitic plant *Rafflesia*. *Rafflesia*, belonging to the Rafflesiaceae family, produces no roots, stems, and leaves, and only displays its generative organs. This unique plant does not have chlorophyll, but instead, relies on its suction roots to absorb the nutrients required for its survival by attaching to its host plant, *Tetrastigma* spp. (Kamal et al. 2021; Molina et al. 2022). The *Rafflesia* plant is distinguished by its stunning and sizable flower that remains inconspicuous until the buds unfurl. Southeast Asia harbors 30 species of *Rafflesia* and is holoparasites of *Tetrastigma* species, all of which inhabit the tropical rainforest ecosystem, predominantly found in lowland to the medium forest and montane forest regions of Thailand, Peninsular Malaysia, Sumatra, Java, Anambas Island, Borneo, and the Philippines (Kedri 2018; Sari et al. 2019). Due to its brief lifespan and widespread distribution, gathering ongoing data on the plant population poses a challenge. Despite being a cherished flora icon in Indonesia, conservation efforts for the plant remain inadequate, with more emphasis placed on its symbolic significance rather than its protection. Indonesia, being home to the largest number of *Rafflesia* species in the world, holds tremendous responsibility for the conservation of this species.

Indonesia has been the site of the documentation of fifteen distinct species of *Rafflesia*, including *Rafflesia arnoldii* R.Br, *R. atjehensis*, *R. bengkuluensis* Susatya, Arianto & Mat-Salleh, *R. borneensis*, *R. ciliata*, *R. gadutensis* Meijer, *R. hasseltii* Suringar, *R. lawangensis* Mat-Salleh, Mahyuni & Susatya, *R. meijeri* Wiriad. & Sari, *R. micropylora* Meijer, *R. patma* Blume, *R. pricei* Meijer, *R. rochussenii* Teijsm. & Binn., *R. tuan-mudae* Becc., and

R. witkampi (Mursidawati 2017; Fauzan 2019). Budiharta et al. (2011) formulated the threat syndromes that imperil the existence of *Rafflesia* spp. in certain regions which derived from a complex interplay between biological factors, including intricate reproductive mechanisms, and habitat loss. These factors render the plant particularly vulnerable to even minor disturbance or destruction. In addition, the annual life cycle and parasitism to certain liana species, emphasize the need for conservation efforts to protect its small and endemic population (Kusuma et al. 2018; Chin 2022). These characteristics suggest that *Rafflesia* requires specific environmental conditions for breeding and growth. Additionally, *Tetrastigma*, the liana species that *Rafflesia* parasitizes, relies on other plants, typically large trees, to access sunlight (Renjana et al. 2022).

Any destructive changes to the habitat of *Rafflesia* might alter the suitable conditions for these species, leading to significant reductions in their population in nature. The presence and composition of vegetation in an ecosystem play a critical role in balancing the ecosystem and supporting the growth of *Rafflesia*. While vegetation is generally beneficial to an ecosystem, it often leads to competition among plant species (Laksana et al. 2018). As a result of such plant-environment interactions, plants develop exchange strategies between their functional traits, such as plant stature, leaf area, wood density, seed production, and their demographic attributes, including growth rate and survival, to cope with environmental pressures (Susatya 2020).

National parks, such as the Batang Gadis National Park in North Sumatra, are essential for conservation efforts, as they are recognized as the most effective way to protect species in their natural habitat (Ferreti-Gallon 2021). Therefore, it is important to conduct studies on the natural habitat of *Rafflesia*, as this will help identify its habitat and inform future conservation efforts (Ancheta 2021). The Batang Gadis National Park area is home to numerous *Rafflesia* populations, however, the *Rafflesia* population in this area remains unstudied. To gather more data and information on *Rafflesia meijeri* in the Batang Gadis National Park, population and ecological studies are imperative. The purpose of this study is to accomplish three main objectives: (i) to ascertain the number of individuals of *R. meijeri* in the Batang Gadis National Park; (ii) to examine the ecological conditions of the *R. meijeri* blooms in their natural habitat; and (iii) to analyze the structure of the vegetation composition of associated flora within the habitat of *R. meijeri*. The expected result of this study is to provide essential data for the conservation of *R. meijeri* in the future.

MATERIALS AND METHODS

Study area and period

This research was conducted in the Batang Gadis National Park, North Sumatra Province with two villages as sampling sites for *R. meijeri* i.e Sopotinjak and Pagar Gunung Village (Figure 1). The exact location of the sampling sites was disclosed for the conservation objective and can be given upon request to the corresponding author(s). This research was conducted from July to September 2021. The study area is located within an elevation range of 300 to 2,145 meters above sea level (a.s.l.). The average number of rainy days is 12-13 days per month, with an average precipitation of >1,717.5 mm per year. The average temperature ranges from 23°C to 25.4°C per month (monthly valence is not significant, influenced by elevation). Based on these averages, the Batang Gadis National Park climate classification, according to the Schmidt-Ferguson system, is type A. The topography of Mandailing Natal District is generally flat to steeply hilly. However, the topography of the forest area specifically includes hills and mountains with varying elevations, with an average slope of more than 40%. The Batang Gadis National Park is mainly composed of a tropical rainforest vegetation type, which is known for its high number of tree species, dense vegetation cover, and high tree density. Moreover, the park encompasses other vegetation types such as montane forest and submontane forest, which can be found at higher elevations. The tree density is 583 trees per hectare, higher than the average for other tropical rainforests in northern Sumatra. Identified species in this forest area include *Rafflesia* spp., *Nepenthes* spp., and *Amorpophallus* sp., as well as endemic species to Sumatra such as *Baccaurea dulcis* (Jack) Müll.Arg., *Hopea nigra* Burck, and *Shorea platyclados* Slooten ex Endert.

Vegetation sampling and analysis

Soil conditions, such as soil type, soil moisture, slope, litter thickness, and soil pH were recorded. *Tetrastigma* individuals were observed by counting the individuals surrounding the tree, including their species, number, and diameter. The nested sampling method was implemented to determine the habitat's condition and associations. The growth phase of *R. meijeri* was determined in the field based on its visual appearance as shown in Figure 2.

Vegetation analysis data were also collected from two locations of *R. meijeri* habitat, namely Sopotinjak and Pagar Gunung, using observation plots measuring 100 m × 100 m each. The sites were divided into 25 plots for observing the tree level and 10 m × 10 m for the pole level, 5 × 5 for the sapling level, and 2 × 2 for the seedling and understorey level. Soil type was determined in the field, soil moisture was measured using a hygrometer, and litter thickness and slope were measured. pH data was obtained by direct measurement using a pH-meter. Measurements of the height and diameter of the host plant, on which the *R. meijeri* buds/flowers grew, were taken for each host plant found. Additionally, the tree species that the host plant climbed on were also recorded.

Data analysis

The analysis of the data involved calculating the Importance Value Index (IVI), which was obtained by adding the Relative Density (RD), Relative Frequency (RF), and Relative Dominance (RD) or basal area for the tree and pole classes. For the sapling and seedling classes, the RD was not included in the calculation (Rambey et al. 2021). Species diversity was assessed using Shannon's Diversity Index (H') and Margalef's species richness index (D_{mg}) followed by calculation of species evenness index (J').

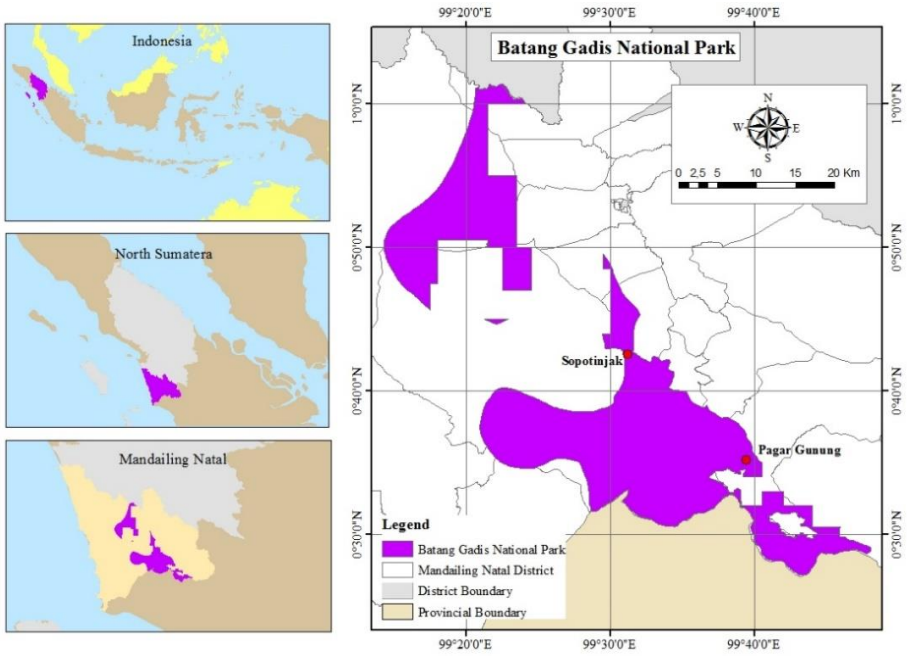

Figure 1. Map of study area showing the research location (red dot) for *Rafflesia meijeri* habitat, Batang Gadis National Park, North Sumatra, Indonesia

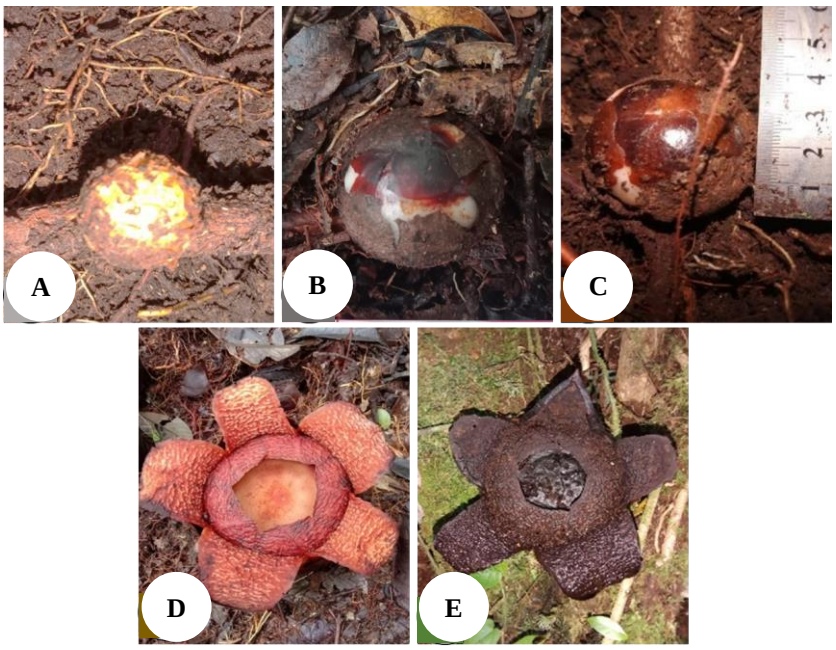

Figure 2. Growth phase of *R. meijeri* documented during this study; A: Copula; B: Copula-Bract Transition (CBT), C: Bract, D: Anthesis or blooming, and E: Rotten phase

RESULTS AND DISCUSSION

Rafflesia meijeri population

Conservation strategies for *Rafflesia* species usually entail conserving their natural habitats from further degradation. Other strategies may include the establishment of protected areas or national parks in locations where *Rafflesia* species are present to ensure their long-term preservation. The conservation of *Rafflesia* species is vital not only for the survival of these distinctive and ecologically significant plants but also for the protection of the forests and ecosystems in which they exist. *Rafflesia* species perform a crucial function in preserving the biodiversity and ecological well-being of these habitats, and their disappearance could have wide-ranging ecological consequences. ***R. meijeri*** flower is the newest *Rafflesia* species found in Batang Gadis National Park and is the most abundant species among other *Rafflesia* (Rambe 2019).

The results of the study found that there were 16 and 31 individuals of *R. meijeri* in Sopotinjak Village and Pagar Gunung Village, respectively with various growth phases. The number of individuals of *R. meijeri* at each location in detail can be seen in Table 1. The number of *R. meijeri* individuals in Sopotinjak was lower compared to Pagar Gunung, due to the lower abundance of *Tetrastigma* in the former location. It is worth noting that *R. meijeri* is endemic to North Sumatra, and in 2010, it was also discovered in the Nature Recreation Park (TWA) Sicikeh-cikeh, North Sumatra (Wiriadinata and Sari 2010).

Tetrastigma population as host of *R. meijeri* in Sopotinjak and Pagar Gunung

At the Pagar Gunung and Sopotinjak locations, the host plant of *R. meijeri* was *Tetrastigma papillosum* (Blume) Planch., a member of the Vitaceae family (Zakaria et al. 2017). These climbing plants or lianas require nearby trees as structural hosts for their vines and interact with other trees in their vicinity (Amalia et al. 2020). Generally, *Tetrastigma* plants grow in the hills and mountain forests (379-991 m. asl), at the edge of primary forests and along rivers (Rahayu 2018). In the Sopotinjak area, three individual hosts of *R. meijeri* (*T. papillosum*) were found, with only two hosts having *R. meijeri*. In contrast, the Pagar Gunung area had six individual hosts, with only five having *R. meijeri*. The diameter of the *T. papillosum* root on which *R. meijeri* grew at the study site was 1.5 to 4 cm. These findings suggest that *Rafflesia* is capable of growing on hosts with small roots, not just large ones. Details of the host diameter of *T. papillosum* at Pagar Gunung and Sopotinjak locations can be seen in Table 2.

Habitat conditions of *Rafflesia meijeri*

In general, the habitat of *R. meijeri* in Batang Gadis National Park is characterized by high soil moisture, with a moisture content of 87% at the Sopotinjak location and 82% at the Pagar Gunung location (Table 3). The average litter thickness is 13.6 cm at the Sopotinjak location and 10.8 cm at Pagar Gunung. The average soil pH is 6.9 at the Sopotinjak location and 6.8 at the Pagar Gunung location, indicating a neutral soil pH as it is close to 7 overall. This finding is consistent with a study by Pranata et al. (2019) on the ecology of *R. arnoldii* in Pandam Gadang, West Sumatra, where the soil pH around 7. The habitat of *R. meijeri* in Pagar Gunung Village is at an average altitude of 1,451 m a.s.l. In the *Rafflesia* habitat in the Mandapajaya forest, Kuningan district, the *Villebrunea rubescens* population dominates the tree vegetation (Supartono 2018). The thickness of the litter may also be a differentiating factor in the presence of *Rafflesia*. When the litter thickness is low, *Rafflesia* is not found, as litter plays a crucial role in returning nutrients to the forest floor. Most of the nutrients are derived from litter, which undergoes decomposition and converts complex organic compounds into inorganic compounds that produce mineral nutrients utilized by plants (McClaugherty et al. 1985).

Vegetation analysis on *Rafflesia meijeri* habitat

At the *R. meijeri* habitat located in Sopotinjak, a total of 32 species of undergrowth were identified, out of which six species of plants had an importance value index (IVI) exceeding 10%. The species with the highest IVI at the undergrowth level was *Schefflera aromatica* (Araliaceae), with an IVI value of 28.42, indicating a high level of environmental tolerance. In the Pagar Gunung area, 19 plant species were identified at the undergrowth level, with *S. aromatica* also exhibiting the highest IVI value of 48.73%, indicating its dominance in the study area. The IVI values at the undergrowth level can be found in detail in Table 4. The occurrence of *Tetrastigma* and *Rafflesia* is strongly influenced by the associated flora, which plays a crucial role in providing support and creating suitable habitats for these plants. *Tetrastigma*, a liana that grows in the understorey of forests, relies on the host tree for support, and is associated with plant species such as *Dioscorea*, *Piper*, and *Uvaria*, which may constitute a suitable microhabitat for *Tetrastigma*'s growth and survival (Liu et al. 2021). The presence of certain dominant plant species in the study area, including *Schefflera* spp., may indicate habitat suitability for *Rafflesia*. Stand constituents in ecosystems aim to utilize existing resources in the habitat, and the adaptability of vegetation types plays a crucial role in sustaining vegetation growth from seedling to maturity stages. Gunawan et al. (2011) emphasized that the growth of vegetation from the seedling stage to maturity is influenced by adaptability and tolerance to the surrounding environment.

Table 1. *Rafflesia meijeri* population per growth phase in the two study sites in Batang Gadis National Park

Station	Copula	Copula-Bract Transition (CBT)	Bract	Anthesis	Rotten	Total
Sopotinjak	-	-	1	2	13	16
Pagar Gunung	2	17	7	2	3	31

Table 2. Root diameter of *Tetrastigma papillosum* as the host for *Rafflesia meijeri*

Host	Species	Diameter cm)	Location	Occurrence of *R. meijeri*
#1	*Tetrastigma papillosum*	4.0	Sopotinjak	+
#2	*Tetrastigma papillosum*	1.5	Sopotinjak	+
#3	*Tetrastigma papillosum*	2.5	Sopotinjak	–
#4	*Tetrastigma papillosum*	4.0	Pagar Gunung	+
#5	*Tetrastigma papillosum*	3.0	Pagar Gunung	+
#6	*Tetrastigma papillosum*	2.5	Pagar Gunung	+
#7	*Tetrastigma papillosum*	3.0	Pagar Gunung	–
#8	*Tetrastigma papillosum*	2.0	Pagar Gunung	+
#9	*Tetrastigma papillosum*	3.5	Pagar Gunung	+

Note: +: Present, –:Absent

Table 3. Physical environmental parameters of *Rafflesia meijeri* and host plants

Station	Plot	Altitude (m asl.)	Slope (◦)	Light intensity (lux)	Air temperature (ºC)	Litter thickness (cm)	pH	Soil relative humidity
Sopotinjak								
Host (1)	3	1,285	45	256	23.2	17	7	93
Host (2)	8	1,298	30	216	23.7	16	7	84
Host (3)	20	1,280	45	200	23.6	8	6.7	84
Average		**1,287**	**40**	**224**	**23.5**	**13.6**	**6.9**	**87**
Pagar Gunung								
Host (1)	1	1,459	10	270	26,3	13	6.5	81
Host (2)	2	1,450	15	275	20.5	15	6.5	83
Host (3)	5	1,463	14	300	22.3	10	7	81
Host (4)	6	1,453	25	280	21.2	7	7	84
Host (5)	7	1,451	10	284	22.5	9	7	81
Host (6)	8	1,452	20	280	21.5	9	7	82
Average		**1,451**	**14.8**	**281.8**	**22.5**	**10.5**	**6.8**	**82**

Table 4. Importance Value Index (IVI) of understorey stage at the habitat *Rafflesia meijeri* in Batang Gadis National Park, Indonesia

Local name	Scientific name	Family	RD (%)	RF (%)	IVI (%)
Sopotinjak					
Sibarebe	*Scheffera aromatica*	Araliaceae	20.6	7.74	28.42
Sirunggug	*Selaginella doederleinii*	Selaginellaceae	9.91	5.63	15.54
Sibarebe daun kecil	*Scheffera arbolicora*	Araliaceae	8.58	3.52	12.10
Bunga pancur	*Impatiens batanggadisensis*	Balsaminaceae	4.83	7.04	11.87
Rubaton	*Impatiens balsamina*	Balsaminaceae	5.92	5.63	11.55
Talas hutan	*Colocasia esculenta*	Araceae	3.02	7.74	10.76
Pagar Gunung					
Silambang	*Scheffera aromatica*	Araliaceae	32.34	16.39	48.73
Sirunggug	*Selaginella doederleinii*	Selaginellaceae	28.73	12.29	41.03
Goya-goya	*Glochidion* sp	Phyllanthaceae	11.59	8.19	19.79
Jornang	*Daemonorops draco*	Arecaceae	4.25	9.83	14.08
Pakis biasa	*Nephrolepis excalata*	Nephrolepidaceae	2.96	8.19	11.16

RD: Relative Density; RF: Relative Frequency; IVI: Importance Value Index

Table 5. Importance Value Index (IVI) of seedling stage at the habitat *Rafflesia meijeri* in Batang Gadis National Park, Indonesia

Local name	Scientific name	Family	RD (%)	RF (%)	IVI (%)
Sopotinjak					
Ayundolok rata	*Eugenia polyantha*	Myrtaceae	8.54	9.64	18.19
Simarkopi-kopi	*Afrocanthium burttii*	Euphorbiaceae	8.54	9.64	18.19
Jailan	*Aporosa nitida*	Philanthaceae	8.54	8.77	17.31
Ayundolok	*Eugenia pyriformis*	Myrtaceae	7.03	8.77	15.80
Oteng	*Castanopsis javanica*	Fagaceae	6.53	6.14	12.67
Mayang tarutung	*Palaquium gutta*	Sapotaceae	5.52	6.14	11.66
Topis	*Polyalthia hypoleuca*	Annonaceae	6.03	5.26	11.29
Pagar Gunung					
Modang	*Litsea firma*	Lauraceae	18.37	15.38	33.73
Ayundolok	*Eugenia pyriformis*	Myrtaceae	14.59	13.46	28.05
Mayang	*Palaquium rostratum*	Sapotaceae	12.43	11.76	24.19
Andis	*Sapium baccatum*	Euphorbiaceae	8.54	4.90	16.79
Pinang hutan	*Pinanga kuhlii*	Arecaceae	7.56	7.84	15.41
Sitarak	*Artocarpus elasticus*	Moraceae	6.48	6.86	13.34
Monis-monis	*Cinnamomum* sp	Lauraceae	5.40	7.84	13.24
Oteng	*Castanopsis javanica*	Fagaceae	5.40	6.86	12.26

RD: Relative Density; RF: Relative Frequency; IVI: Importance Value Index

Table 6. Importance Value Index (IVI) of sapling stage at the habitat *Rafflesia meijeri* in Batang Gadis National Park, Indonesia

Local name	Scientific name	Family	RD (%)	RF (%)	IVI (%)
Sopotinjak					
Ayundolok rata	*Eugenia polyantha*	Myrtaceae	12.06	14.52	26.59
Ayu orsik	*Quercus gemelliflora*	Fagaceae	8.04	9.40	17.44
Simarkopi-kopi	*Afrocanthium burttii*	Euphorbiaceae	8.04	7.69	15.73
Ayundolok	*Eugenia pyriformis*	Myrtaceae	7.03	6.83	13.87
Loba-loba	*Eugenia* sp	Myrtaceae	5.52	6.83	12.36
Pagar Gunung					
Ayundolok	*Eugenia pyriformis*	Myrtaceae	22.60	17.39	39.99
Modang	*Litsea firma*	Lauraceae	19.86	17.39	37.25
Mayang	*Palaquium rostratum*	Sapotaceae	10.95	11.95	22.91
Andis	*Sapium baccatum*	Euphorbiaceae	9.58	7.60	17.19
Monis-monis	*Cinnamomum burmanii*	Lauraceae	6.84	8.69	15.54
Sitarak	*Artocarpus elasticus*	Moraceae	6.16	8.69	14.86
Oteng	*Castanopsis javanica*	Fagaceae	6.16	6.52	12.68

RD: Relative Density; RF: Relative Frequency; IVI: Importance Value Index

Table 7. Importance Value Index (IVI) of pole stage at the habitat *Rafflesia meijeri* in Batang Gadis National Park, Indonesia

Local name	Scientific name	Family	RD (%)	RF (%)	RBA (%)	IVI (%)
Sopotinjak						
Oteng	*Castanopsis javanica*	Fagacaceae	6.28	10.67	42.99	59.95
Ayundolok	*Eugenia pyriformis*	Myrtaceae	8.57	12.62	12.14	33.33
Ayundolok rata	*Eugenia polyantha*	Myrtaceae	9.14	10.67	9.66	29.98
Lancat bodi	*Aglaia odorata*	Meliaceae	6.28	7.76	9.52	23.58
Sitarak	*Artocarpus elasticus*	Moraceae	8.57	7.76	0.61	16.95
Ayu orsik	*Quercus gemellifora*	Fagaceae	2.58	4.85	3.23	10.94
Pagar Gunung						
Monis-monis	*Cinnamomum burmanii*	Lauraceae	18.47	17.72	18.31	54.41
Ayundolok	*Eugenia pyriformis*	Myrtaceae	16.30	15.19	16.73	48.22
Andis	*Sapium baccatum*	Euphorbiaceae	11.95	12.65	14.18	38.80
Modang	*Litsea firma*	Lauraceae	11.95	12.65	12.09	36.61
Mayang	*Palaquium rostratum*	Sapotaceae	10.86	11.39	9.45	31.71
Sitarak	*Artocarpus elasticus*	Moraceae	9.78	7.59	7.84	25.22
Oteng	*Castanopsis javanica*	Fagacaceae	5.43	6.329	4.98	16.75
Ayu gading	*Helicteres isora*	Malvaceae	5.43	5.06	5.84	15.97
Ayu orsik	*Quercus gemellifora*	Fagaceae	3.26	3.79	4.21	11.27

RD: Relative Density; RF: Relative Frequency; RBA: Relative Basal Area; IVI: Importance Value Index

Table 8. Importance Value Index (IVI) of tree stage at the habitat *Rafflesia meijeri* in Batang Gadis National Park, Indonesia

Local name	Scientific name	Family	RD (%)	RF (%)	RBA (%)	IVI (%)
Sopotinjak						
Oteng	*Castanopsis javanica*	Fagacaceae	20.08	14.66	7.81	42.56
Ayundolok	*Eugenia pyriformis*	Myrtaceae	9.60	10.00	15.61	35.21
Ayu Orsik	*Quercus gemellifora*	Fagaceae	5.67	6.00	7.29	18.97
Ayu pora	*Ficus procera*	Moraceae	4.36	4.00	7.27	15.63
Simartanaon	*Schima wallichii*	Theaceae	3.49	4.00	4.95	12.44
Modang Tano	*Litsea cubeba*	Lauraceae	2.62	4.00	5.40	12.02
Goring-goring	*Glochidion obscurum*	Phyllanthaceae	2.62	4.00	4.44	11.06
Pagar Gunung						
Oteng	*Castanopsis javanica*	Fagacaceae	22.17	15.60	23.63	61.40
Modang	*Litsea firma*	Lauraceae	16.52	13.47	11.82	41.82
Mayang	*Palaquium rostratum*	Sapotaceae	12.60	12.05	11.87	36.53
Ayundolok	*Eugenia pyriformis*	Myrtaceae	11.73	10.63	10.93	33.30
Ayu orsik	*Quercus gemellifora*	Fagaceae	7.82	9.21	6.71	23.75
Angkirnyam	*Pterospermum* sp	Malvaceae	3.47	4.25	13.97	21.71
Monis-monis	*Cinnamomum burmanii*	Lauraceae	5.21	7.09	3.46	5.77
Simartarutung	*Durio griffithii*	Malvaceae	3.47	4.25	3.91	11.64
Beringin	*Ficus benjamina*	Moraceae	3.04	4.25	3.35	10.65
Ayu Gading	*Helicteres isora*	Sterculaceae	3.47	4.96	1.95	10.40

Table 9. Shannon's diversity index and Margalef's species richness at the habitat *R. meijeri* in Batang Gadis National Park

Structure	Shannon's Diversity Index (H')	Category	Margalef's species richness (Dmg)	Category
Sopotinjak				
Shrub	2.93	Moderate	32.85	High
Seedling	3.02	High	22.81	High
Sapling	3.08	High	26.81	High
Pole	3.10	High	26.80	High
Tree	3.12	High	31.81	High
Pagar Gunung				
Shrub	2.05	Moderate	19.85	High
Seedling	2.52	Moderate	18.85	High
Sapling	2.36	Moderate	18.80	High
Pole	2.27	Moderate	12.77	High
Tree	2.43	Moderate	15.81	High

A total of 23 plant species were found in Sopotinjak, but only 7 had an IVI above 10% in the seedling community (Table 5). *Eugenia polyantha* (Myrtaceae) had the highest IVI at 18.19%. In contrast, in a study by Laksana et al. (2018) at the habitat of *Rafflesia zollingeriana* in Meru Betiri National Park, *Polyalthia rumphii* (Annonaceae) had the highest IVI at the seedling level with 71.84%. In Pagar Gunung, 21 plant species were found at the seedling level, but only 8 species had an IVI above 10%, with *Litsea firma* (Lauraceae) had the highest IVI of 33.73%. Similarly, in Sopotinjak, 27 plant species were found at the sapling level, but only 5 species had an IVI above 10%, and *E. polyantha* (Myrtaceae) had the highest IVI of 26.59% (Table 6). In Pagar Gunung, 19 plant species were found at the sapling level, but only 7 species had an IVI above 10%, and *E. pyriformis* (Myrtaceae) had the highest IVI of 39.99%. At the pole level, 27 plant species were found in Sopotinjak, but only 6 species had an IVI above 10%, and *Castanopsis javanica* had the highest IVI of 59.95% (Table 7). In contrast, a study by Erlinda et al. (2018) at the habitat of *Rafflesia tuan-mudae* in West Kalimantan, showed that, *Blumeodendron* sp had the highest IVI at 14.90%. At the pole level, 13 plant species were found, and *Cinnamomum burmanii* (Lauraceae) had the highest IVI of 54.41%, while *Artocarpus elasticus* (Moraceae) had the lowest IVI of 2.35%. Finally, at the tree level, 32 plant species were found in Sopotinjak, but only 7 species had an IVI above 10% (Table 8), and *Castanopsis javanica* (Fagaceae) had the highest IVI of 42.56%. In comparison, in Pagar Gunung, 16 plant species were found at the tree level, and *C. javanica* had the highest IVI of 61.40%. Different plant species have different levels of importance value (IVI) in the habitats of *Tetrastigma* and *Rafflesia* at the studied locations.

Some species, such as *E. polyantha*, *C. javanica*, and *L. firma*, had high IVI values in multiple locations and at different levels of vegetation. These species may be important indicators of suitable habitats for *Tetrastigma* and *Rafflesia*, as they provide support, nutrients, and microhabitats for these plants to grow and thrive. In addition, the dominance of *C. javanica* stands in the study sites suggests that this species plays a critical role in the occurrence of overall vegetation in these areas. In a recent investigation conducted by Opeña et al. (2021), the predominant plant species thriving within the *Tetrastigma* habitats in Philippines were discovered to be wild bamboo and wild ferns. Alongside these, other plant species, including agricultural crops, native and endemic species were also identified in the proximity, and it is hypothesized that they provide a supporting growing environment for the *Tetrastigma* plants by offering partial shade. Therefore, understanding the relationships between *Tetrastigma*, *Rafflesia*, and associated flora is essential for the conservation and management of these rare and unique plants in Batang Gadis National Park.

Diversity and richness indice of vegetation community at *Rafflesia meijeri* habitat

The species diversity and richness indices of vegetation community at all growth stages at the habitat of *R. meijeri* in Sopotinjak and Pagar Gunung Batang Gadis National Parks are presented in Table 9. The diversity index values observed in Sopotinjak ranged from moderate to high, with values ranging from 2.93 to 3.12 (Table 9). The high diversity of species in Sopotinjak at the Batang Gadis National Park highlights the intricate nature of the community and the variety of plant species found in the forest. In Pagar Gunung, the diversity index was classified as moderate with value range of 2.05 to 2.52 (Table 9). The Margalef's species richness index (D_{mg}) at the Sopotinjak location falls within the high category, with values ranging from 22.81 to 32.85. Similarly, for the Pagar Gunung location, the Margalef species richness index (D_{mg}) also falls within the high category, with values ranging from 12.77 to 19.85.

A forest that displays a high level of species richness and evenness indicates a healthy ecosystem, as it showcases a diverse range of ecological niches occupied by a wide variety of species. Such diversity may also suggest that the forest is more resistant to environmental disturbances, and has the capacity to maintain ecosystem functions and services over an extended period of time. To conserve *Rafflesia*, an *in situ* conservation is necessary, which involves protecting and preserving its natural habitat, such as in the Batang Gadis National Park. Another successful method of vegetative propagation is by grafting *Tetrastigma* impregnated with *Rafflesia* onto normal *Tetrastigma* plant stems (Wicaksono et al. 2016). In addition, ex-situ conservation can also be achieved by grafting infected *Tetrastigma* onto plants in botanical gardens or arboretums. Therefore, it is important to conduct inventories and observations of hosts that are suitable for growing *Rafflesia* as part of conservation efforts.

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