Population structure and conservation strategy of *Rafflesia zollingeriana* Koord. in Bandealit Resort, Meru Betiri National Park

N Maezulpah¹, B D Briliawan¹*, R Fairuz¹, D T Iman¹, M Pratama¹, D A Ahsania¹, Nurhayati¹, I Saidah¹, W Nurhaeni², S N Hidayati¹, E Khoirunnisa¹, A Tyas¹, A Hikmat²

¹Department of Silviculture, Faculty of Forestry, IPB University (Bogor Agricultural University), Bogor, Indonesia
²Department of Forest Resource Conservation and Ecotourism of the Faculty of Forestry, IPB University (Bogor Agricultural University), Bogor, Indonesia

*Corresponding author e-mail: bagastama_dipabriliawan@apps.ipb.ac.id

Abstract. Rafflesia is a rare species that become an icon for Indonesia. However, data on population dynamics and distribution of Rafflesia are are still limited. This study aimed to analyze the distribution and population structure of *Rafflesia zollingeriana* and its present condition in Meru Betiri National Park (TNMB). The research carried out at the Bandealit Resort used a purposive sampling method in two sample plots of 100 m x 100 m with *R. zollingeriana* as the midpoint. A sub-plot of 2 m x 2 m established at the location where *R. zollingeriana* found in the sample plot. This study observed 88 and 102 individuals of *R. zollingeriana* in Sample plot-1 and Sample plot-2, respectively. Population structure of *R. zollingeriana* found distributed at clusters in all plots.

1. Introduction

Indonesia is a country that has high biodiversity, both in terms of flora and fauna. One type of flora that is distinctive and has become an Indonesian icon is Rafflesia. Rafflesia is known as a plant that has the most significant single flower in the world. This plant is holoparasitic, a plant that is dependent on other plants for its food needs. This group of plants does not have chlorophyll grains. One type of rafflesia that spreads in Java is *Rafflesia zollingeriana* [1]. Currently, the country faced narrow distribution of *R. zollingeriana* due to its natural habitat recently only found in TNMB [2].

TNMB has an area of 58,000 hectares. It is geographically located between 8°21' - 8°35' South Latitude and 113°40' - 113°58' East Longitude. Administratively, part of TNMB located in Banyuwangi Regency, and another part in Jember Regency, East Java. Meru Betiri is an area affected by monsoons with rainy season from November to March and dry season between April to October. Average annual rainfall is 2,544 - 3,478 mm. According to the Schmidt and Ferguson climate classifications, Meru Betiri in the north and center belongs to climate type B, while the other parts belong to climate type C [3].

The existence of *R. zollingeriana* population in TNMB should be well-maintained due to its scarcity. Therefore, a regular inventory is needed to determine the population of *R. zollingeriana* in TNMB. This study aimed to analyze the distribution and structure of the population of *R. zollingeriana* in TNMB.
2. Method
The study carried out on 7 June 2018 until 11 June 2018 in the Bandealit Resort area, TNMB. Data were collected by purposive sampling method in two different sample plots of 100 x 100 m each with R. zollingeriana as the center point. The sample plots divided into 25 working area of 20 x 20 m. Then a 2 m x 2 m subplot was made at each location where Rafflesia zollingeriana was found in a sample plot. The data collected were: size, number, condition of Rafflesia zollingeriana knop and its host (Tetrastigma), seedlings and undergrowth plant, and abiotic data in each sample plot. Form 1 illustrated The form of plots and measuring plots at each research location.

![Sample plot](image)

3. Result and discussion
Total of R. zollingeriana found in sample plot-1 was 88 individuals [Figure 3]. The population of R. zollingeriana is spread in the southern part of TNMB. The sample plots are located in the hills. R. zollingeriana population found in hilly areas far from the coast [1].

![Distribution of Rafflesia zollingeriana Koord.](image)

Sample plot-1 and Sample-plot-2 located at an altitude of 304 m asl and 176 m asl, respectively. There are two habitats of R. zollingeriana in TNMB, namely in rocky areas along the coast and in flat areas at an altitude of 300 m above sea level. The number of individuals found in the Plot sample-2 were 101 individuals [Figure 4]. From the observations, it can be seen that the distribution of R. zollingeriana tends to cluster and only occurs in a few plots. It is in line with observations made by Laksana [5] that the distribution of rafflesia was found to be uneven in all plots. Therefore, Rafflesia has found in
different morphology from the shape of knob to flower bloom as well as the differences in size of the circumference and diameter.

Figure 3. Distribution of *Rafflesia zollingeriana* Koord. (●) in Sample plot-2

The distribution of *Rafflesia zollingeriana* is spread in various zones, such as core zone, jungle zone, and utilization zone. Based on observations in these two sample plots, *Rafflesia zollingeriana* was found in the jungle zone of the TNMB. The population of *Rafflesia zollingeriana* located in the jungle zone is entirely safe from human disturbance. The population in this zone is more influenced by natural external factors and internal biological factors, while populations that are close to settlements and utilization zones need to be well-controlled because they are likely to be disturbed by human activities [1].

3.1. Characteristics of Biotic and Abiotic Habitats

The species found in the Sample plot-1 are 16 species (Figure 4), e.g. pascal kidang (*Aglaia variegate*), jejerukan (*Polyalthia ruphi*), walangan (*Pterospermum diversifolium*), talesan (*Persea odoratissima*), mangga (*Mangifera longipes*), klampis, bantengan, suren (*Toona sureni*), glintungan (*Bischoffia javanica*), rambutan, rotan manis (*Daemonorops melanocaeates*), sentul (*Sandoricum koetjape*), kembali jlamprangan, kepuh (*Sterculia foetida*), kemiri (*Aleurites moluccana*), and kenari (*Canarium denticulatum*). There were 18 species found in the Sample plot-2 (Figure 5), e.g. pascal kidang (*Aglaia variegate*), talesan (*Persea odoratissima*), kembali jlamprangan, walangan (*Pterospermum diversifolium*), jejerukan (*Polyalthia ruphi*), rotan manis (*Daemonorops melanocaeates*), leben, budengan (*Diospyros cauliflora*), bantengan, berasan, pakis gila, glintungan (*Bischoffia javanica*), rakis, and kenari (*Canarium denticulatum*)

Figure 4. Seedlings and undergrowth plant in Sample plot-1
Dominant species found in Sample plot-1 were pancal kidang (552 individuals) and jejerukan (126 individuals). Meanwhile, in the Sample plot-2 dominant species were individuals pancal kidang and kembang jalaprang with 485 and 29 individuals, respectively. Pancal kidang was found in almost all observation plots. It showed that pancal kidang has a good adaptability to live around the habitat of R. zollingeriana. The total number of seedlings and undergrowth found around R. zollingeriana in the Sample plot-1 were 741 individuals, whereas 615 individuals for Sample plot-2. This difference was likely influenced by abiotic factors, including temperature, humidity, density, and others.

Based on the observed abiotic data including temperature, humidity, and crown density data, it was found that in Sample plot-1 had a temperature of 25.13°C, a humidity of 76.75%, and a crown density of 93.33%, while the Sample plot-2 had a temperature of 27.09°C, humidity 74.63% and crown density of 78.13%. The condition of the forest floor in the Sample plot-1 was filled with lots of litter. Meanwhile, the Sample plot-2 has rocky characteristics with sparse canopy density. The humidity in all sample plots are low. It was because of the data collected in June during the dry season. The crown density obtained is also high, but it is assumed that a high temperatures have more effect on humidity than crown density.

| Abiotic       | Sample plot-1 | Sample plot-2 |
|---------------|---------------|---------------|
| Temperature [°C] | 25.13         | 27.09         |
| Humidity [%]   | 76.75         | 74.63         |
| Canopy density [%] | 93.33         | 78.13         |

3.2. Population Structure

Rafflesia is the largest single flower in the world with two households. Rafflesia is spread from the Malay Peninsula, the Philippines to Indonesia. Rafflesia blossom consists of several strands of perigone, in the middle, there is a circular ring called a diaphragm, at the bottom of the diaphragm there are a window and raiment feathers scattered on its walls. At the base of the flower, there are discs, prosessus, annulus, anther, and ovary. Vegetation analysis results from Sample plot-1 obtained data on the distribution of individual types of Rafflesia zollingeriana with a bud diameter range from 0.1 cm to more than 15 cm [Figure 6].

There were live buds and dead buds of the same type. Several individuals whose condition has been destroyed were found. We found 11 live buds for 0.1-5 cm diameter range flower, 36 live buds with 10 dead buds for 5.1-10 cm, 15 live buds with 5 dead buds for 10.1-15 cm, and 2 live buds for individuals > 15 cm in diameter. Six individuals found destroyed. For individuals who have been destroyed are individuals from Rafflesia zollingeriana that have bloomed, then died and destroyed.
Figure 6. Diameter of *Rafflesia zollingeriana* bud in Sample plot-1

Figure 7. Diameter of *Rafflesia zollingeriana* bud in Sample plot-2

In the observation on the Sample plot-2, we also measured the diameter of each individual. At the diameter of 0.1-5 cm, we found 17 live buds and 5 dead buds (Figure 7). Meanwhile, at 5.1-10 cm diameter, we found 19 live buds with 14 dead buds. At the diameter of 10.1-15 cm, we found 8 live buds and 3 dead buds. Finally, at the diameter of > 15 cm, 1 individual live bud was found and 2 individual dead buds were also found. Also, 30 individuals of *Rafflesia zollingeriana* were destroyed. Data collection in the two sample plots was done in June or during the dry season, where in addition to the distribution of live buds and dead buds and buds that have been destroyed, we also found blooming flowers of the type *Rafflesia zollingeriana*. The condition of *Rafflesia zollingeriana* from the two sample plots showed in Figure 8.
Figure 8. Condition of *Rafflesia zollingeriana* in Sample plot-2 and Sample plot-1

Based on data from the two sample plots, Sample plot-1 has a higher percentage of live buds (72.73%) than Sample plot-2 (44.55%). The percentage of dead buds in Sample plot-1 (17.05%) has a lower dead bud value compared to Sample plot-2 (23.76%). The blooming *R. zollingeriana* were also found in the two sample plots, in line with observations made by TNMB officers in the Krecek permanent plots in 2011 that found more flowers bloom in the dry season, even though the death of the buds also occurs a lot in that season. Although observations were made in the dry season (June-July 2012), blooming flowers were still found with 3 flowers in Sample plot-1 and 2 flowers in Sample plot-2. More *Rafflesia zollingeriana* found in Sample plot-2 (101 individuals) compared to Sample plot-1 (88 individuals). However, the Sample plot-1 had a higher number of living individuals (67) compared to Sample plot-2 (47).

### 3.3. Host Conditions

*Rafflesia* host is a *Tetrastigma* vines. *Tetrastigma* known as dioecious species, where male and female flowers are located in different individuals. The main characteristic of the genus is the flower divided into four stigmas, therefore it is called *Tetrastigma*. Fruit of this type of liana has juicy and soft fruit flesh, making it easy to eat and spread by birds. Propagation of this plant can be quickly done through vegetative means, either through the roots or stems. The characteristic of this liana was a discovery of tendrils (tendrils) which are usually opposite to the leaves. They are used to tie and propagate to other trees. The bark of old liana is grooved and is easy to break and tear, making it easy for *Rafflesia* seeds to inoculate.

In the area of *Rafflesia* distribution in Southeast Asia, only 57 types of *Tetrastigma* were found, and not all of them became *Rafflesia*’s hosts. Only ten species were recorded as hosts of *Rafflesia*, e.g. *Tetrastigma tuberculatum*, *T. curtisi*, *T. pedunculare*, *T. Scortechinii*, *T. diepenhorstii*, *T. papillosum*, *T. Tetrastigma glabratum*, *T. harmandii*, and *T. loheri*. There are two types of host found in the observation plot in Bandealit Resort, e.g. *T. lanceolarium and T. papillosum*. *Tetrastigma* is found growing in subplots 18-32. The average amount of *Tetrastigma* found in each observation plot was three sticks per subplots. The largest population found in subplots 18 and 23, with a total of 5 stems per subplots. The diameter of the *Tetrastigma* stem in the plot ranges between 3 and 18 cm, while the diameter of the root with the bud is between 0.5 cm and 7 cm. All of of *R. zollingeriana* grew at the root of the host.

### 3.4. Conservation Strategy

Maintaining the presence of *R. zollingeriana* in the TNMB is very important, because besides being part of the world heritage of science and tourist attractions, *R. zollingeriana* is an icon of flora conservation for TNMB. The population of *R. zollingeriana* in TNMB has decreased dramatically, which is about 60% from individuals living. The decline in the population mainly due to habitat destruction due to the
natural disaster of the tsunami in 1994 [6]. Whereas for higher places, the removal of *R. zollingeriana* buds by the surrounding population is thought to have played a significant role in reducing the population of *Rafflesia zollingeriana*. Based on a marketing survey of medicinal plants in Banyuwangi in 2000, it was found that *R. zollingeriana* buds were sold in traditional markets. The bud of *Rafflesia zollingeriana* as a traded commodity will accelerate the rate of decline of this rare flora population in the TNMB.

These conditions show us that the decline in the population of *R. zollingeriana* in TNMB is mainly caused by human behavior that illegally used this endangered flora for medicinal plant. Therefore, it is necessary to raise awareness-raising activities to the community about the importance of forest preservation, especially the preservation of endangered species such as *R. zollingeriana*. The security measures for the *R. zollingeriana* habitat in the TNMB which have been carried out by the management need to continue improving. Regular monitoring of the development of the population of *Rafflesia zollingeriana* at its distribution sites should be done. Conservation actions also need to be taken to prevent the extinction of *R. zollingeriana* in TNMB, both for in situ and ex situ conservation.

In situ conservation should be carried out by TNMB Office as the manager of TNMB. Actions that can be taken are to increase the protection and supervision of the inventoried population, conduct collaborative research with other stakeholders and conduct socialization to local communities regarding the importance of conservation of *R. zollingeriana* [7]. In-situ conservation is a conservation effort in its natural habitat. This approach must be one part of sustainable and integrated forest management. In-situ conservation efforts must be prepared with consideration of the biological character and attributes of the Rafflesia population, the environment, and the socio-economic conditions of the local community.

Ex-situ conservation needs to be done considering the population of *Rafflesia zollingeriana* in TNMB continues to be threatened. Ex-situ conservation can be carried out by botanical garden institutions or other ex-situ conservation institutions. The action taken is by transplanting and inoculating [8] into new habitats outside TNMB. Ex-situ conservation for Rafflesia is still a huge problem. This approach will be very important if there are no other alternatives to protect this type. Two ways can be done with this approach, namely by inoculating Rafflesia seeds into its host, or by the second method, namely through the transplanting method.

Socialization of the importance of *Rafflesia zollingeriana* needs to be done to increase stakeholder awareness. Socialization can be done by working with communities, other agencies, and organizations needed to optimize conservation [9]. The importance of the conservation of *Rafflesia zollingeriana* must be disseminated massively through various mass media in Indonesia and at the international level. At the local level, a workshop can be held to discuss the ecological and economic benefits of the conservation of *R. zollingeriana*, which involves all parties. Besides, socialization about the importance of the conservation of *R. zollingeriana* can be done in various mass media. It can be done in connection with the number of social media users today, so that the spread of news in the mass media can be useful, especially for young people as the next generation of the nation.

It is developing ecotourism *R. zollingeriana* by involving local communities. The development of the ecotourism of *R. zollingeriana* can provide economic and ecological benefits for the community, improving the community’s economy can improve community conservation of *R. zollingeriana*. Therefore, stakeholder participation is needed to form a tourism program that can increase the economic value of the community and increase the ecological value, especially community conservation of *R. zollingeriana*.

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