# DIVERSITY AND DISTRIBUTION OF FAMILY: RUBIACEAE ALONG TRAIL AT GUNUNG STONG STATE PARK (GSSP), KELANTAN

by

**NUR HUSNA SYASYA BINTI SHAMSUL AMRI**

A report submitted in fulfillment of the requirements for the degree of Bachelor of Applied Science (Natural Resources Science) with Honors

**FACULTY OF EARTH SCIENCE**
**UNIVERSITI MALAYSIA KELANTAN**

**2023**

## DECLARATION

I declare that this thesis entitled “Diversity and Distribution of (Family: Rubiaceae) along Trail at Gunung Stong State Park (GSSP), Kelantan” is the result of my research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature :……

Name : NUR HUSNA SYASYA BINTI SHAMSUL AMRI

Date : 11 AUGUST 2024

## ACKNOWLEDGEMENT

I thank the Almighty for getting me this far, giving me good health to accomplish this research. I would also like to thank my supervisor, Dr. Nazahatul Anis binti Amaludin who lent me the continuous support, encouragement and guidance throughout the period of preparation and doing this research until it is done successfully.

Next, a special thanks to the Forestry Department of Kelantan which have gave us some facilities at Gunung Stong State Park during the period of our research and permitted us for our sampling process in the area. I am grateful because I managed to complete my research and thank those who helped me directly or indirectly. I want to take this opportunity to express my utmost gratitude to Mr. Zulkhairi and Mrs. Puteri, which has spent his time helping and giving positive support throughout the fieldwork.

I would like to thank my parents, Mr. Shamsul Amri Bin Mohamad Zin and Mrs. Zainab binti Man for encourage, supporting, and give me some spirit to finish my research successfully. Also, a lot of thanks to my fellow friends, Muhammad Hafizzudin bin Roslam, Sow Bao Jun, Nur Izati binti Baharom, Norerliana Syafika binti Abdullah, Muhammad Al-Hafiz bin Mat Razii and Ahmad Adham bin Abdul Aziz for giving me some support, spirit to complete this research and I am sorry if I have burdened or troubled anyone from the beginning of this final year project journey until the end. Lastly, I salute the entire University Malaysia Kelantan fraternity for giving me a conducive environment to thrive academically and for providing me with the resources I needed through my research.

**Diversity and Distribution of (Family: Rubiaceae) along Trail at Gunung Stong State Park (GSSP), Kelantan**



## ABSTRACT

This study was conducted to identify the diversity and distribution of Family: Rubiaceae Along Trail at Gunung Stong State Park (GSSP), Kelantan. The Rubiaceae family is one of the broad worlds and it is an important family of flowering plants in the botanical and has potential for human, medicinal uses and other functions. This species has been found in various places in Malaysia, but in Kelantan which has only a few recorded data related to Rubiaceae. The main objective of this study is to measure the diversity and distribution of Family: Rubiaceae along the trail in Gunung Stong State Park (GSSP), Kelantan using a random sampling method. It shows that the Rubiaceae family recorded at GSSP consists of 9 species with 41 individuals belonging to 6 genera. Diversity index for Family: Rubiaceae recorded using the Shannon Wiener-Index (H') was calculated at 1.60 and Simpson's Index (D) was 0.67. It is also expected to help in updating the database to assist stakeholders in managing high conservation value forests. By conducting this study can also prove Gunung Stong State Park (GSSP) as a forest 'High Conservation Value Forest (HCVF).

**Kepelbagaian dan Taburan Famili: Rubiaceae Sepanjang Laluan di Taman Negeri Gunung Stong (TNGS), Kelantan**



## ABSTRAK

Kajian ini dijalankan untuk mengenalpasti kepelbagaian dan taburan Famili: Rubiaceae sepanjang laluan di Taman Negeri Gunung Stong (TNGS), Kelantan. Famili Rubiaceae adalah salah satu keluarga penting tumbuhan berbunga dalam botani yang tumbuh secara meluas dan mempunyai potensi untuk kegunaan manusia, perubatan dan fungsi lain. Spesies ini telah ditemui di pelbagai tempat di Malaysia, tetapi di Kelantan hanya mempunyai sedikit data yang direkodkan berkaitan Rubiaceae. Objektif utama kajian ini adalah untuk mengkaji kepelbagian dan taburan Famili: Rubiaceae sepanjang laluan di Taman Negeri Gunung Stong (TNGS), Kelantan menggunakan kaedah persampelan secara rawak. Ia menunjukkan bahawa Famili Rubiaceae yang direkodkan di TNGS terdiri daripada 41 individuals, 9 spesies dengan 6 genera. Indeks kepelbagaian untuk Famili Rubiaceae yang direkodkan menggunakan Shannon Wiener-Index (H') dikira pada 1.60 dan Simpson (D') ialah 0.67. Ia juga diharapkan dapat membantu dalam mengemas kini pangkalan data untuk membantu pihak berkepentingan dalam menguruskan hutan bernilai pemulihraan tinggi. Dengan menjalankan kajian ini juga dapat membuktikan Taman Negeri Gunung Stong (TNGS) sebagai hutan bernilai pemuliharaan tinggi.

## TABLE OF CONTENTS

## LIST OF TABLES

## LIST OF FIGURES

## LIST OF ABBREVIATION

| | |
|---|---|
| **GIS** | Geographical Information System |
| **GPS** | Global Positioning System |
| **GSSP** | Gunung Stong State Park (GSSP), Kelantan |
| **HCVF** | High Conservation Value Forest |
| **HSK** | Hutan Simpan Kekal |
| **IUCN** | International Union for Conservation of Nature |
| **TNGS** | Taman Negeri Gunung Stong |

## LIST OF SYMBOLS

| | |
|---|---|
| **Σ** | Summation |
| **()** | Parentheses |
| **&** | Ampersand |
| + | Addition |
| × | Multiply |
| % | Percentage |
| cm | Centimeter |
| ft | Feet |
| m | Meter |
| mg | Milligram |

# CHAPTER 1

# INTRODUCTION

## 1.1 Background of Study

Rubiaceae was among of the 4 largest angiosperm families after Orchidaceae, Asteraceae and Fabaceae which mean flowering plants. Rubiaceae, also known as coffee, madder or bedstraw family contains 611 genera with 13,150 species of herbs, shrubs and trees. The distribution was mostly found in the tropical regions of the world (Koehbach & Gruber, 2015). Each type of species that grows had its own importance in terms of economics, medicine, and chemistry.

Rubiaceae has a comprehensive habitat distribution around the world which was better known as cosmopolitan distribution according to skepticism of the World Rubiaceae Checklist database. The heterogeneity of plants that grew within the Ruby family had been hybridized according to their respective growth areas which were more concentrated in the tropics humid forest, where mid- altitude habitats displayed the most variety (Davis et al, 2009). Different forest areas produced a variety of plant species and biomass. Often this family was known as the family of woody plants with most species. Based on an overview from the IUCN, Rubiaceae was among the plants included in the recorded red list category. 42% (1312) of this family had been recorded and declared as low concern in the red list of endangered species.

For example, *Erithalis odorifera* was listed as least concern but was not shown to be stable for population trends. This species grew as a shrub to a small tree up to 8 m tall and was found in forests or scrub areas, either growing in sandy areas or limestone substrates. (*Erithalis odorifera* - Native Plant Conservation Leon Levy, 2022). Additionally, Rubiaceae was also in the endangered category with 18.3%, and 571 species such as *Mitracarpus polycladus* were evaluated in 2017. This was a rare flowering plant in the coffee family that could be found in coastal scrub and dwarf forests with limestone substrates. The extinction rate of a species was affected by its small population.

**1.2 Problems Statements**

The range and discovery of this species of Rubiaceae family neither inside nor outside of Malaysia have generally been the subject of numerous studies. This genera and family are mostly found in tropical and subtropical areas (Davis et al., 2009). In Singapore, 52 genera and 150 species are considered native, and another species are exotic. The diversity of Rubiaceae is widely studied in foreign countries because this family is widespread in many species and form depends on habitat, ecology altitude and environmental. However, Rubiaceae in Malaysia is famous because there are several discoveries such as review made in Pulau Banding, Perak which found 139 individuals with 9 species. Among the species that were found are *Mitracarpus hirtus*, *Gardenia carinata*, *Aidia densiflora* (Adek et al., 2023).

A preliminary checklist of plant species of the Gunung Stong State Park Forest Reserve was conducted in 2005 (Chee Beng Jin, 2005). A total of 84 families, 254 genera, 406 species, and 10 subspecies were found, which also included collected a total of 15 genera and 18 species of plants from the family Rubiaceae (Chee et al., 2004). But the research related to the Rubiaceae family was still underexplored in Gunung Stong State Park (GSSP), Kelantan. Informational data about the diversity of Rubiaceae family species still needs to be searched and collected more and more. This study was conducted to update data related to the diversity and distribution of the Rubiaceae family in Gunung Stong State Park (GSSP), Kelantan.

## 1.3 Objectives

The objectives of this study are:

1. To identify the (Family: Rubiaceae) at Gunung Stong State Park (GSSP), Kelantan
2. To measure diversity and distribution (Family: Rubiaceae) at Gunung Stong State Park (GSSP), Kelantan.

## 1.4 Scope of Study

The study's purpose was to investigate the diversity and distribution of the family Rubiaceae. The specific area of this study was conducted in Gunung Stong State Park (GSSP), Kelantan. The method used in this study to determine the Family Rubiaceae is using random sampling along the trail. This was because in the growth of Family Rubiaceae different species had almost the same characteristics or had different factors, suitability, environment, habitats, and elevation to grow.

## 1.5 Significant of Study

The study provides important insight into the biodiversity of Gunung Stong State Park (GSSP), contributes to conservation efforts aimed at preserving near threatened and Researched Rubiaceae could help determine the species of Rubiaceae that were in the studied area. Rubiaceae species were recognizable and defined by generative and vegetative properties.

# CHAPTER 2

# LITERATURE REVIEW

## 2.1 World forests

Over 70% of the earth's surface was covered by water, leaving about 30% of the land area unoccupied. The world's land area was split up into many parts, including forests, barren regions (deserts, beaches, and salt flats), and glaciers. The world's forest area was 4.06 billion hectares were however it was not distributed equally. 10 nations account for 66% of the world's forest area. Trees were not the main life of the forest, but there is a diversity of plants, animals, and microorganisms that also played an important role in maintaining the ecology of the forest's natural resources and maintaining genetics. Forest biodiversity is affected by different elevation levels. Forest life adapts to the environment and the changes that occur to ensure the balance of the forest ecosystem (The State of the World's Forests 2020, 2020).

## 2.2 Malaysia forests

In Peninsular Malaysia, the forest that covers the earth was a tropical rainforest. Tropical rainforests were divided into two classes which was mixed forests and forests dominated by single species such as *Hopea subalata* in Kanching Forest Reserve, Selangor and it was recorded as critically endangered in 2007 by IUCN Red List Threatened Species and endangered by Malaysia Plant Red List in 2021 (Chua et al., 2004). The existence of Malaysia near the equator which was 1˚ and 7˚ North Latitude and 100˚ and 119˚ East Longitude, allowed the country to receive a large amount of sunlight for the process of tree growth in the forest. Layered soil structures with different heights had different plant species according to the suitability and need of the species to grow. Emergent, canopy, understory, and forest floor were forest layers in a forest profile. Renjong trees that belong to commercial trees such as balau, cengal and keruing were as high as 60 m - 70 m. The main silara was inhabited by plants from the kandis and kedondong family with a tree height of 20 m - 40 m. The lowered layer was inhabited by small trees and palm trees while the soil floor layer contains saplings, shrubs, and herbs (Malcom Demies et al., 2019).

## 2.3 Gunung Stong State Park (GSSP)

Situated in the Kuala Krai district northwest of Kelantan, Malaysia, lies Gunung Stong State Park (GSSP) with 21,950 hectares of land (Maseri, 2009). The diversity of biodiversity found in GSSP which was filled with flora and fauna as well as endemic life provides an attraction to the community indirectly the area could be exploited to become an ecotourism center such as Jelawang waterfall (Yusoff et al, 2005).

Near Gunung Stong, there were Gunung Ayam and Gunung Tera suitable for recreational activities and climbing because the different heights of the mountains provided different experiences. Gunung Stong State Park (GSSP) had been recognized as a 'High Conservation Value Forest (HCVF)' by declaring an area of 15ha in Compartments 11, 17 and 19 by the Kelantan State Forestry Department (Kelantan State Forestry Department, 2019). The Forest Stewardship Council (FSC) created the HCVF idea in the beginning for use in forest management certification. Forest managers must identify and manage any HCVF characteristics that exist in their specific forest management units to keep their FSC certification or improve the qualities that had been discovered. This recognition was done because a forest area had been considered too have economic, environmental, and social valued as well as forest areas that were considered exceptional or had a very high level of valued importance and was categorized as forest areas and Permanent Forest Reserves (HSK). *Tarenna maingayi* and *Saprosma glomerulata* from family Rubiaceae are included in group 28 taxa which are declared as endemic species in Peninsular Malaysia (Chee et al., 2004).

HCVF also can be related to the Rubiaceae family, which is in the HCV 5 category, meaning that a forest area gives its importance to meet the needs of society such as medicine. According to (I. FARIDAHHANUM & NURULHUDAHAMZAH, 1999), *Ixora coccinea* can be used to treat dysentery and stimulate gastric secretion by flower decoction.

**Table 2.3** The classification types of HCV

| TYPE OF HCV | ELEMENT |
|---|---|
| HCV 1 | Forest areas that contain concentrations of important biodiversity values at the global, regional or national level |
| HCV 2 | Forests are large landscape stages on a global, regional or national level |
| HCV 3 | Forest areas that are found in rare or endangered ecosystems, or that contain rare or endangered ecosystems |
| HCV 4 | Forest areas that provide basic nature services in critical situations |
| HCV 5 | Forest areas that are important to meet the basic needs of local communities (for example, in terms of livelihood or health) |
| HCV 6 | Forest areas that are very important to the traditional cultural identity of local communities |

Source: (Jabatan Perhutanan Negeri Kelantan, 2019)

## 2.4 Rubiaceae

Rubiaceae belongs to the family of flowering plants where most of the genus and species of this family produce flowers and fruits (Gruber, 2010). Arabian coffee, genus Coffea was one example of fruit that came from the Rubiaceae family (Al-Asmari et al., 2020). This Arabica coffee provides a positive impact on the world market (Ferreira et al., 2019). Southern Asia, especially Malaysia and Thailand had species from the Rubiaceae coffee family that were indigenous and cultivated plants.

However, the *Mitragyna speciosa* species had been banned by Thailand because it had been confirmed as a narcotic species and has been misused as a substitute for opium and chronic pain treatment (Tungphatthong et al., 2021). The *Mitragyna* content acted as a psychoactive component that produces an anesthetic loss of sensation without depressing respiration (Presti, 2002; Kowalczuk et al., 2013).

**Figure 2.1** shows *Coffee arabica* fruits from genus *Coffea*

Source: inaturalist (2024)

**Figure 2.2** shows *Mitragyna speciosa* from Rubiaceae family

Source: innaturalist (2023)

## 2.5 Subfamily

Early findings based on single characters and the number of ovules per locule, Rubiaceae were split up into two subfamilies, Cinchonoideae and Coffeoideae. But there were other opinions to determine the subfamily by emphasizing the size of the testa structure, the occurrence of albumin in seeds, raphides, and the 'ixoroid' pollen presentation mechanism (Ixoroideae) which could indirectly identified eight other subfamilies. Three of these subfamilies are Cinchonoideae, Rubioideae, and Guettardoideae (Bremekamp,1954;1966). Cinchonoideae, Ixoroideae, Rubioideae, and Antirheoideae are the latest classification 4 subfamilies of Rubiaceae.


**Figure 2.5.1** and **Figure 2.5.2** Example of subfamilies which are Cinchonoideae and Ixoroideae

Source: *inaturalist* (2023)

## 2.6 Habitats

According to the overview of the IUCN Red List of Threatened Species, Rubiaceae dominates tropical and subtropical forest habitats with a total of nearly 3215 species. Despite the different environmental conditions, Rubiaceae could also adapt in savannah, scrubland, and rocky areas. Northern bedstraw was an example of a plant from the ruby family that lived on soil and rocks.

The typed of soil, the height of the plant became a parameter that affects the characteristics of each plant species respectively shows picture of subfamilies which was Cinchonoideae and Ixoroideae areas such as shrubs at the edge of forests, moist grasslands and thickets were examples of likely habitats for the most diverse Rubiaceae family in lowland tropical forests with a total of 1900 species (Tungphatthong et al., 2021). Different topographical positions gave differences in terms of soil moisture and nutrients available in the soil. From a geological point of view, factors that were considered to found out how trees are distributed in tropical forests through the geological basis, climate, and soil age (Fayolle et al., 2012).

## 2.7 Morphology

Rubiaceae has 3 types of tree groups in it, including shrubs, lianas, and herbs. Each of these groups has special characteristics that make them easier to recognize. These features helped make the tree identification process easier and faster.

**Table 2.7** The characteristics of Rubiaceae

| | CHARACTERISTIC | DETAILS |
|---|---|---|
| **1.** | **Leaves** | 1. Leaves commonly opposite and frequently less ternate (6-8) per nodes.<br>2. The whole edge of the leaf is very wavy. |
| **2.** | **Inflorescences** | 1. There is pollination on the terminal or axillary or both |
| **3.** | **Flower** | 1. Having a bisexual gender (rarely unisexual)<br>2. Sepals are similar in shape and size<br>3. Stamens as many as corollas |
| **4.** | **Fruits** | 1. Commonly simple or rarely multiple<br>2. The fruits fleshy, leathery or thinly woody with a gelatinous pulp<br>3. Variety of colour which red, yellow green |
| **5.** | **Seeds** | 1. One to many seeds per locule<br>2. There is 1 pyrene in each drupe<br>3. The outer skin has a smooth and carved structure |

## 2.8 Important of Rubiaceae

Rubiaceae was a forest resource that could been of importance, especially in the field of medicine and pharmacological activities. Humans take advantage of Borreria, which were genera from the Rubiaceae family that were used as herbal treatments for various ailments. According to (Chwas and Schltdl, 2004), *B. centranthoides* could been used to treat liver disease, and kidney disorders in Brazil. In addition, *B. eupatorioides* was an herb whose left can be used to treat diarrhea, urination, and respiratory infections. The presence of phytochemical content in the plant such as tannins, flavonoids, alkaloids, saponins and steroids allowed people to use *R. brasiliensis* as a medicine to treat eczema, burns and was active in curing avian malaria (Burkill, 1984). Eczema itself was inflammatory while alkaloids were anti inflammation. So, the use of *R. brasiliensis* was suitable for treating inflammation but the use was only sufficient.

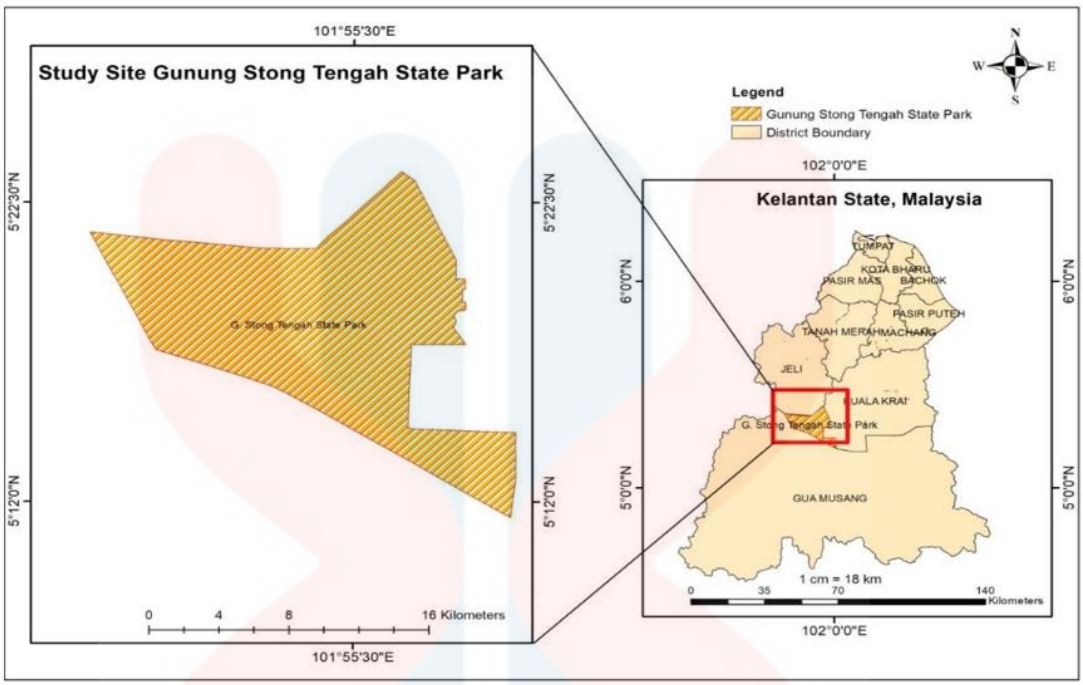
Genus Coffea from the family Rubiaceae discovered in Africa but commission universally used as beverages. Every common beverage such as coffee, tea and products from cocoa contain active ingredients, caffeine with different levels. The consumption of caffeine that was recommended was 400mg/day moderately to maintained human health. (Nawrot et al., 2003). Coffee had a good effect when taken in moderation but would lead to complications if excessive (Ahsan & Bashir, 2019). For example, there is a trend of opening cafes that sold caffeinated drinks, stimulating people to drink coffee, but for people who were addicted to coffee, it would give them side effects if not controlled. The side effects that would been experienced general toxicity, calcium balance and the effect on male fertility. Expectant mothers also are not suggested to drink caffeine higher than 4.6 mg/day because it may contribute to miscarriage (Nawrot et al., 2003).

# CHAPTER 3

# MATERIALS AND METHODS

## 3.1 Study Area

Study carried out in the Gunung Stong State Park (GSSP), south of Kuala Krai District, Kelantan at coordinates N 05º20.362", E101°58.521 which is managed by the Kelantan Forestry Department (Figure 3). The highest peak of Gunung Stong is at a height (1442 m), covering an area of 21,950 hectares surrounded by Basor Forest Reserve, Gunung Stong Utara, Gunung Stong Selatan and Balah Forest Reserve (Khamis et al., 2005). It was officially stated a preserved area by the Kelantan State Government in 2007 and it is one of the eco-tourism destinations in Malaysia because it is rich in flora and fauna. The variety of landscapes on display in Gunung Stong State Park (GSSP) starts from the limestone hills to fast-flowing rivers surrounded by thick tropical forest trees covering cool and hidden caves that hold many endemic species that have yet to be explored.




**Figures 3.1** An illustrating maps of study area in Gunung Stong State Park, Dabong, Kelantan.

## 3.2 MATERIAL

The items used to collect Rubiaceae samples were measured tapes, field books, cameras and GPS. Table 3.2 below is list of materials used and their function.

**Table 3.2** List of materials with their function

| NAME | FUNCTION |
|---|---|
| 1. Handheld Global Positioning System (GPS) | To provides precise coordinates of species and directions of prior study species to a specific location. |
| 2. Camera Phone | To capture and identify the species discovered using any software such as PlanetNet. |
| 3. Pen and book | To make handwriting report about the found species. |

## 3.3 METHODS

### 3.3.1 Sampling Method

General observation was the method chosen to collect data related to the Rubiaceae family. The observed location started from the foot of the mountain, Gunung Stong State Park up to the base camp at Kem Baha. The sampling went from elevation 100m to 500m. Along the way, there were various types of landforms, such as rocky soil structures, waterfall areas, waterfall edges and hillsides where the Rubiaceae family had the potential to live. It is also possible to show and understand how elevation and environmental conditions could affect the morphology of the tree.

### 3.3.2 Species Identification

Species identification of each specimen of Rubiaceae was done in various ways. First, trees would been identified used the "PlanetNet Plant Identification" application by used photos taken first and re-identified at Universiti Malaysia Kelantan. Next, there was an official website that could been used to check and reconfirm the specimen named and their distribution, which is The International Plant Name Index (IPNI). A book titled "**A preliminary checklist of plant species of the Gunung Stong Forest Reserve, Kelantan, Peninsular, Malaysia"** used to find out the species that have been recorded in Gunung Stong State Park (Chee Beng Jin, 2005).

## 3.4 Data Analysis

### 3.4.1 Shannon -Wiener Index

Species diversity was the number of different species in a certain area or plot that would indicate their relative abundance. This index was used to quantify the diversity of species within a biological community or habitat (Shannon, 1948). The formula of Shannon Diversity Index, H shown as equation 3.1.

$$H' = -\sum\_(i = 1)\text{^}s\ (pi)In\ (pi) \qquad \text{(Equation 3.1)}$$

Where:

H' = Shannon diversity index

Pi = fraction of the entire population made up of species i

S = the number of species

∑ = sum of species 1 to species S

### 3.4.2 Simpson's Diversity Index (D')

This index is used to calculate a measure of diversity, considering the number of something as well as its abundance. The formula of Simpson's Diversity Index was:

$$D = \sum_{i-1}^{s} \left(\frac{n_i}{N}\right)^2 \qquad \text{(Equation 3.2)}$$

Where:

ni = the number of individuals in species i,

N = total number of individuals of all species

ni/N = pi (proportion of individuals of species i)

S = species richness

### 3.4.3 Relative Abundance

Relative abundance (pi) is the proportion representation of a species in a community or community sample. It is also defined as the proportion of species of a specific species relative to all the species of that species in that area. It is frequently shown. It is often represented on species interactions and community structure and is sometimes expressed as a percentage or ratio. The formula of relative abundance was:

$$p_i = \frac{n_i}{N} \times 100$$

(Equation 3.3)

Where:

$n^i$ = the number of individuals of the same species

N= the total number of individuals for all species

### 3.5 Geographic Information System (GIS)

A Geographic Information System (GIS) was a tool that facilitates the creation, management, and analysis of maps utilizing various data kinds. The position of each identified species would been displayed in this studied represented by different symbology to show different species. As a result, the pointed location of each species recorded used GPS handheld was mapped using mapping software to plot their distribution. After the sample was complete, the distribution of the Family: Rubiaceae in Gunung Stong State Park would been shown by the spots on the map.

# CHAPTER 4

# RESULTS AND DISCUSSION

## 4.1 Entries of Family Rubiaceae in Gunung Stong State Park

The Rubiaceae family has been found represented by 6 genera, 9 species and 41 individuals that grow along the trail leading to Kem Baha, Gunung Stong. All species were found and collected from more than 40 localities and coordinates by using random sampling methods along the trail. The coordinates of Family Rubiaceae are recorded using handheld Global Positioning System (GPS) receiver.

**Table 4.1** List number of individuals of Rubiaceae family in Gunung Stong State Park

| No. | Species Name | Common Name | No. of Individual | Relative Abundance (%) | Number of Genera | IUCN Status |
|---|---|---|---|---|---|---|
| 1 | *Coffea arabica* | Arabica coffee | **1** | 2.44 | **1** | Endangered (EN) |
| 2 | *Coffea humilis* | Humilis coffee | **1** | 2.44 | | Near Threatened (NT) |
| 3 | *Chassalia corallioides* | Beberas | **4** | 9.76 | | Not Evaluated (NE) |
| 4 | *Chassalia curviflora* | Bunga putih | **2** | 4.88 | | N/A |
| 5 | *Gaertnera vaginata* | Pokok api-api | **2** | 4.88 | **1** | Not Evaluated (NE) |
| 6 | *Ixora chinensis* | Jarum-jarum | **17** | 41.46 | **1** | Least Concern (LC) |
| 7 | *Ixora coccinea* | Jarum-jarum | **12** | 29.26 | | N/A |
| 8 | *Massularia acuminata* | | **1** | 2.44 | **1** | Least Concern (LC) |
| 9 | *Psychotria nervosa* | | **1** | 2.44 | **1** | Least Concern (LC) |
| **TOTAL** | **9** | | **41** | **100** | **6** | |

The analysis of the Family Rubiaceae indicates that, out of all the species discovered, Genus Ixora has the greatest number of individuals with 17 individuals of *Ixora chinensis* is represented, whereas *Ixora coccinea* has 12 individuals. This indicates that the study area is a suitable environmental area where pollinators and soil elements may be present. Four species including *Coffea arabica, Coffea humilis, Massularia acuminata,* and *Psychotria nervosa* have the fewest individuals, with one individual per species. This may be influenced by human disturbances, which makes the area less suitable for the growth of certain species.

International Union for Conservation of Nature (IUCN) developed The IUCN Red List Threatened Species is critical indicator of the global conservation status of biological species. It is an inventory of the extinction risk of species, with the goal of providing scientifically based information to guide actions to conserve biological diversity. Plants and animals are classified into 9 different categories according to the criteria or level of threat faced by species which Extinct, Extinct in the Wild, Critically Endangered, Endangered, Vulnerable, Near Threatened, Least Concern, Data Deficient, and Not Evaluated. Species are assessed based on factors such as population size, geographic range, and probability of extinction.

As for this study, *Coffea arabica* holds status as Endangered species but still until now there is no formal extinction risk assessment has been made for *Coffea arabica.* According to (Moat et al., 2019) climate change is one of the causes of the extinction of wild coffee. Coffea humilis also holds status in IUCN Red List as Near Threatened species. Only 1 species has been recorded in Gunung Stong State Park. These plants face lower extinction risks but not stable populations. Least Concern happens when species categorized as plentiful in the wild and not immediate risk of extinction. 3 species identified in Least Concern species are *Ixora chinensis, Massularia acuminata* and *Psychotria nervosa*.

**4.2 Species Diversity of Rubiaceae**

Species diversity was a biological diversity measurement method that measures the diversity, abundance and distribution of species in an ecological community. This study used 2 calculation methods to measure diversity, namely the Shannon-Weiner index and the Simpson Diversity index. Data collected was analyzed using the Shannon Diversity Index and Simpson Index. The number of species found in the sampling area represents the diversity of species. The analysis data shown as table below:

**Table 4.2** The values of diversity indices that used for Rubiaceae family found in Gunung Stong State Park, Kelantan

| No. | Species Name | Number Individuals (n) | pi | $pi^2$ | in(pi) | pi in pi |
|---|---|---|---|---|---|---|
| 1 | *Coffea arabica* | 1 | 0.0244 | 0.00059488 | -3.71357207 | -0.09057493 |
| *2* | *Coffea humilis* | 1 | 0.0244 | 0.00059488 | -3.71357207 | -0.09057493 |
| *3* | *Chassalia corallioides* | 4 | 0.0976 | 0.00951814 | -2.32727771 | -0.22705148 |
| *4* | *Chassalia curviflora* | 2 | 0.0488 | 0.00237954 | -3.02042489 | -0.1473378 |
| *5* | *Gaertnera vaginata* | 2 | 0.0488 | 0.00237954 | -3.02042489 | -0.1473378 |
| *6* | *Ixora chinensis* | 17 | 0.4146 | 0.17192148 | -0.88035872 | -0.36502679 |
| *7* | *Ixora coccinea* | 12 | 0.2927 | 0.08566330 | -1.22866542 | -0.35960939 |
| *8* | *Massularia acuminata* | 1 | 0.0244 | 0.00059488 | -3.71357207 | -0.09057493 |
| *9* | *Psychotria nervosa* | 1 | 0.0244 | 0.00059488 | -3.71357207 | -0.09057493 |
| | **TOTAL** | **41** | **1** | | | **-1.60866297** |
| | **TOTAL SPECIES** | **9** | | | **H'** | **1.60866297** |
| | | | | | **D'** | **0.6798780** |

Table 4.2 summarizes the biodiversity of a community of 9 species using the Shannon-Wiener Index (H'). The Shannon Wiener Index also referred to Shannon diversity index was a biodiversity indication that combines species richness and species equality in a habitat. The formula H = -Σ pi * ln(pi), where pi was the percentage of individuals in species i, was used for determining it.

The indicative range of values for the Shannon Diversity index was from 0 to infinity, where the higher the valued (H'), the higher the diversity value. In this case, 9 tree species from the Rubiaceae family with 41 individuals were used to determine the relative number of individuals (pi) of each species. The total diversity of each species was measured by calculating through the formula. The results of the diversity calculation with 9 species showed a value of 1.609, where it was found that the growth of diverse flowering plants *Ixora chinensis* and *Ixora coccinea* was found with 17 and 12 individuals respectively. This value shows that the Rubiaceae family had high species diversity in this studied area and had an even distribution of species.

The same data was also used to calculate Simpson's diversity index (D). Using formula (1-D), which analyzes the biodiversity by including both species and evenness of distribution calculated used the data. The value of the number in the sample (n) was multiplied by 'n-1' values was calculated, resulting in 1312. To complete this formula to get (D), the value of 1 is subtracted by the sum value of 'n(n-1)' divided by the value of N (N-1) and resulting 0.680. This value indicates that the forest had a high diversity of flowering trees and well-balanced ecosystems with other communities.

### 4.3 Distribution of Rubiaceae in Gunung Stong State Park, Kelantan

Gunung Stong State Park had been declared by the Kelantan State Forestry Department as a 'high conservation valued forest' (HCVF) where endemic plants were found that require protection from any disturbances and threats. The diversity of species in this forest was very diverse consisting of dipterocarp, non-dipterocarp, and flowering tree family such as the Rubiaceae family. Plants in this family showed a very diverse growth pattern. This was because there were factors such as soil type, altitude, and areas close to water that support trees from the Rubiaceae family to grow within the Gunung Stong State Park.

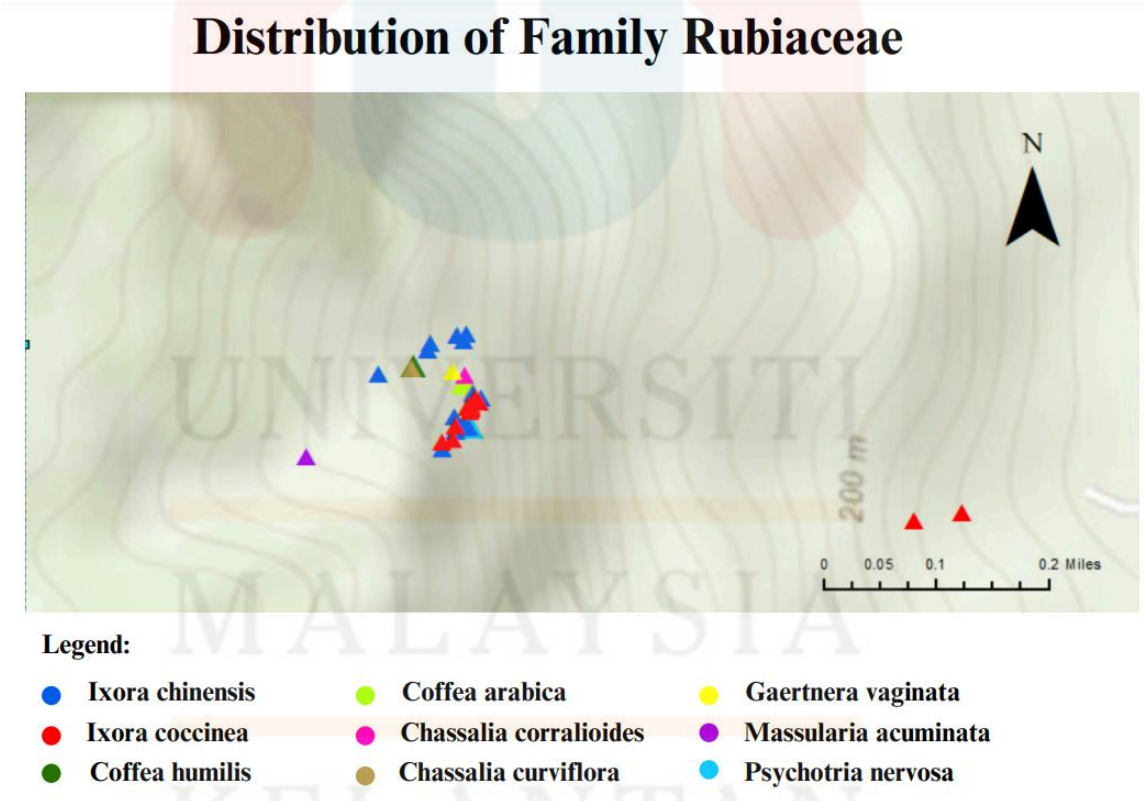



**Figure 4.3** The distribution of Rubiaceae in Gunung Stong State Park

### 4.2.1 *Ixora chinensis*

**Figure 4.2.1** The *Ixora chinensis* in Gunung Stong State Park

Based on the map image above, *Ixora chinensis* had the greatest propagation. *Ixora chinensis* could live and been found from lowland to high elevation. The species *Ixora chinensis* found near basecamp which was Kem Baha at around 400m-500m elevations, had been found by as many as 17 individuals.

*Ixora chinensis* grow close together in a single area where they form clustered growth. *Ixora* flowers had a color that is a bit light but still vibrant to the eyes. Due to having striking color that came in variety of shades including bright red and orange (T et al., 2023). The morphology of *Ixora chinensis* were 1m – 2m height, thin woody stem. The arrangement of left is opposite, and the venation is also simple.

*Ixora* is known to be an evergreen species. Fruits were fleshy, spherical berries, dark blood red or purplish black when ripe. Berries contain 1-2 seeds. In the lowland area, this flower is used as an urban landscape decoration because of its beautiful and bright flower color. However, the morphology of *Ixora chinensis* trees in landscape and mountainous areas is different.

### 4.2.2 *Ixora coccinea*

**Figure 4.2.2** The *Ixora coccinea* in Gunung Stong State Park

*Ixora coccinea*, also known as jungle geranium, had been found near basecamp which was Kem Baha at around 400m-500m elevations. There were 12 individuals *Ixora coccinea* found at the studied site. *Ixora coccinea* grow close together in a single area where they form clustered growth.

*Ixora* species flowers were the easiest to recognize and identified the type of flower. Ixora flowers had a vibrant and showy color. Due to having striking colors that came in variety of shades including red, pink, orange and yellow (T et al., 2023) (Anisha Devendran & G. Gnanave, 2020). Although the morphology of *Ixora* species looked almost the same, there are still characteristics of each tree that showed their differences.

In Kem Baha, this flower was found with a height structure reaching 1-3 meters tall, thin stem, thin woody stem. The leaf shape of ixora coccinea is linear with pinnate venation. Arrangement of opposite leaf positions. Flower growth occurs in the form of dense clusters at the ends of branches, forming a cyme that expands. This tree had small fruit, less than 0.5cm long, rounded like a cherry (T et al., 2023). The fruit is a kind of drupes which has a fleshy filling that surrounds one seed. Before ripening, the fruit is reddish green, when fully ripe it turns dark red.

### 4.2.3 *Chassalia curviflora*

**Figure 4.2.3** The *Chassalia curviflora* in Gunung Stong State Park

The genus *Chassalia* contains about 120 accepted species, but most were from Africa and Madagascar (Turner, 2019). This flower came from Singapore, Malaysia, and Borneo. A total of 2 individuals of *Chassalia curviflora* were found within 50 meters from the backed area of base camp. The distribution *Chassalia curviflora* scattered because these two plants grow in two different places.

The form of plant growth depends on the place of growth, whether it was a garden or a forest. Usually in the garden or landscape, the growth form of *C. curviflora* was in the form of a shrub while in the wild forest it would been in the form of a small tree. The maximum growth of *C. curviflora* when reaching a height of 2m. The leaf arrangement is the opposite of simple venation. The texture of mature foliage was leathery. The length of the leaf was 6-20 cm with a width of 2.5-7 cm. White flowers were the signature color of this species. The flower clusters were 3-5 cm long and grew at the ends of the branches. The white petals were 1.5-2 cm long, on a curved flower tube. The type of fruit is ellipsoid, black, and the size is 5-6mm wide.

This type of flower used fauna pollination which is the attraction of birds (NParks | Chassalia Curviflora, 2023). This plant is not only used for landscaping but also for health medicine. A decoction of the root is taken to treat pneumonia and cough. The left could be used to treat ulcers and headaches (Gopal et al., 2016).

### 4.2.4 *Chassalia corallioides*

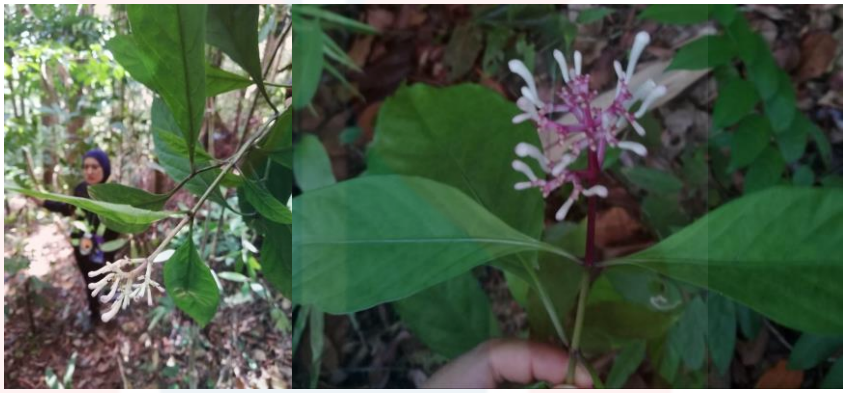


**Figure 4.2.4** The *Chassalia corallioides* in Gunung Stong State Park

*Chassalia corallioides* was described as an endemic species to La Reunion Island but there was no updated data in Malaysia related to any discovery in Malaysia. At Kem Baha, the deep species had been found as many as 4 individuals at an altitude of 500 meters above sea level. *Chassalia corallioides* shrub or small tree, 1–4 m tall was one of the most abundant shrub species found in lowland and mid-altitude tropical moist forests. The distribution of *Chassalia corallioides* scattered because these two plants grow in different places. The flowers produced were white with a tube with five pink or purple lobes. Inflorescences were terminal and cymose, containing 20-400 flowers.

The ovary was inferior, the style is purple, and the stigma is bifid. Stamens were purple in color and showed dehiscence through longitudinal slits. *C. corallioides* were morphologically distylous which means males with short styles had larger corollas than females with long styles, and the anthers are joined directly to the corolla tube (Pailler & Thompson, 1997). This flower produces nectar that smells sweet. This attracted pollinators such as moths, flies and beetles that are sensitive to the sweet smell. The unripe fruit is green and turns purple black after maturity (Pailler et al., 1998). This became a source of food for the birds. These small animals became pollinating agents through pollen attached to their body parts and from fruit seeds eaten by birds. This plant had two different types of left despite being found at the same elevation, but still had the same opposite left arrangement and simple venation.

### 4.2.5 *Gaertnera vaginata*

**Figure 4.2.5** *The Gaertnera vaginata* in Gunung Stong State Park

According to the Plants of the World Online website, *Gaertnera vaginata* was native to 32 countries including Malaya, Thailand and Vietnam. The genus *Gaertnera* contains about 89 accepted species (*Gaertnera* Lam. | World Plants Online | Kew Science, 2024). *Gaertnera vaginata* was one of the species where there was only 1 individual. The growth distribution *Gaertnera vaginata* cannot be measured because it only grows as one individual. Common names given to this species include 'Pokok api-api'.

It was found at a height of 499m above sea level. *G. vaginata* was one of the most abundant species found in lowland tropical moist forests, mid-altitude tropical moist forests and cloud forests. *G. vaginata* was a small tree; its growth height is 1-7m high. The texture of the skin was smooth. The flowers were white with a long corolla tube. Inflorescences were terminal and cymose containing 10-30 flowers (Pailler et al., 2002) The immature left had a brownish green color and when mature the color changes to a deep green color. The arrangement of the left was opposite, and the shape of the leaves was oval, simple, penny veined.

This tree had small, rounded fruits like cherries. The fruit was a type of drupes that had purple-blue flesh. *G. vaginata* could grow in ecology in mixed dipterocarp that was slightly undisturbed to disturbed (open), mostly on hillsides and ridges and along rivers and stream.

### 4.2.6 *Coffea arabica*

**Figure 4.2.6** The *Coffea arabica* in Gunung Stong State Park

Arabic coffee (*Coffea arabica*) was a plant that belongs to the genus Coffea in the Rubiaceae family. It had become the most famous species of Coffea, its used had been commercialized more than 75% to produced products. *C. arabica* was mostly used for economic and commercial purposes. Native terrestrial habitat (mountain). *C. arabica* originates as an understory plant in the rainforest (AlAsmari et al., 2020). *Coffea arabica* was one of the species where there was only 1 individual. The growth distribution of this tree cannot be measured because it only grows as one individual. Wild coffee could grow throughout the forest except in very shady and humid sites. Growth rates were very low during the main rainy season (Schmitt, 2006).

Shade and low humidity had a positive effect on coffee quality, but to a lesser extent than altitude. Elevation favors the production of large and heavy beans. The accumulation of fatty substances increases the intensity of organoleptic characteristics such as aroma, body, acidity, taste, and preference (Lara-Estrada & Vaast, 2007).

*C. arabica* plant is a small tree or tree. It could grow between 2m-8m in height. The color of the flower is white, sweet, and striking. Characteristics of plant left usually had broad left and evergreen leaves. Leaves felt shiny and smooth. Fruit color gold/yellow, green, red/burgundy. The fruit typed was a berry with two seeded berries that gradually mature to yellow, light red and dark red when ripe. The colorful color of the fruit attracted animals to indirectly helped the seed dispersal process as a pollinator. Pollination by the attraction of birds and bees due to the sweet fruit. Wild coffee berries could be eaten while the seeds were dried, roasted and ground to make coffee.

### 4.2.7 *Coffea humilis*

**Figure 4.2.7** The *Coffea humilis* in Gunung Stong State Park

*Coffea humilis* was a plant that belongs to the genus *Coffea* in the Rubiaceae family *Coffea* mostly grown in the tropical and subtropical of the world Berthaud and Charrier, 1988). In Kem Baha, this plant was found at an altitude of 500m -550m. *Coffea humilis* was one of the species where there was only 1 individual. The growth distribution of this tree cannot be measured because it only grows as one individual.

The *Coffea* genus could withstand high heights without affecting tree growth, although it could not withstand freezing temperatures. The structural growth characteristic of tiny trees. It had a maximum growth of two meters. However, because of its small size, this tree had not yet achieved its maximum development stage when it was discovered. Flowers of C. humilis were white with a hint of purple near the flower's tip. C. humilis had broad, evergreen left on its foliage. The left had a glossy, smoothed finish. Fruit color: green, burgundy, gold/yellow. A berry with two seeds that ripens to yellow, light red, and dark red when ripe was the fruit type.

Caffeine attracted pollinators, particularly honeybees, by recreating a memory of a scent that invites them to return to the plant's blooms. Pollination by the attraction of birds and bees due to the sweet fruit.

### 4.2.8 *Psychotria nervosa*

**Figure 4.2.8** The *Psychotria nervosa* in Gunung Stong State Park

According to the Plants of the World Online website, the genus *Psychotria* includes 1645 species and some of them were originates from Malaya, Java and India (Plants of the World Online | Kew Science, 2024). Commonly called "wild coffee" (Rubiaceae) because the fruit resembles a real coffee bean (Gilmen 2011).

A total of 1 individual of *Psychotria nervosa* was found at Kem Baha. The growth distribution of this tree cannot be measured because it only grows as one individual. There were two forms of growth which are shrubs and small trees. The height of this tree could reach up to 4 to 10 feet tall. The foliage of this tree shows an opposite arrangement of leaves. The shape of the leaf was elliptical, the whole edge of the leaf with pinnate venation. This species was also known as an evergreen species, not showy but still shiny. The flowers are white.

Coffee beans attracted the attention of birds with their bright red oval shape less than 0.5 inches long. The fruit was also fragrant, birds used coffee fruit as a food source Various plant parts were employed in ethno-medical formulations, particularly by tribes in Bangladesh and southern India, to cure fungal infections, diarrhea, boils, asthma, colds, stomach aches, and leg swelling. (Biswas et al. 2010; Porto et al. 2009).

### 4.2.9 *Massularia acuminata*

**Figure 4.2.9** The *Massularia acuminata* in Gunung Stong State Park

*Massularia acuminata* was one of species found at Taman Negeri Gunung Stong count as 1 individual. The growth distribution of this tree cannot be measured because it only grows as one individual. This species was found near a water stream at basecamp area at elevation (478m). This species grows as small trees that reached up to 30 feet. The left was glossy dark green and obovate in shape. *Massularia acuminata* provides many benefits to humans and animals.

In terms of human health, in Nigerian ethnomedicine *Massularia acuminata* left were used as a medicine for oral thrush and tumors (Oriola et al., 2022). Aphrodisiac and chewing stick, Massularia acuminata was a tropical plant used in ethnomedicine. Moreover, it was used to treat diarrhea and oral infections (Daniel Akpe efiak Ambe et al., 2023).

**Table 4.3** Comparison of habitat and distribution form of Family Rubiaceae

| No. | Species Name | Habitats | Habitus Form | Distribution Form |
|---|---|---|---|---|
| **1** | *Coffea arabica* | Undisturbed slope area | Small tree | Not define |
| **2** | *Coffea humilis* | Basecamp walking path area, close to water sources | Small tree | Not define |
| **3** | *Chassalia corallioides* | Sloping and open areas | Small tree | Scattered |
| **4** | *Chassalia curviflora* | Undisturbed area, dense with big trees and saplings | Small tree | Random |
| **5** | *Gaertnera vaginata* | Sloping and open areas | Small tree | Not define |
| **6** | *Ixora chinensis* | A relatively slope area, along walking path area, moisture area | Small tree | Clustered |
| **7** | *Ixora coccinea* | A relatively slope area, along walking path area, moisture area | Small tree | Clustered |
| **8** | *Massularia acuminata* | Open walking path area, moisture area | Small tree | Not define |
| **9** | *Psychotria nervosa* | Open walking path area, moisture area | Small tree | Not define |

# CHAPTER 5

# CONCLUSION AND RECOMMENDATION

## 5.1 CONCLUSION

As conclusion, the objectives of this study have been accomplished. The conclusion from this study is that 41 individuals from 9 species and 6 genera has been discovered. This proves that the diversity of flowering plants in the forest area is still abundant and protected from threats. The most abundant species is *Ixora Chinensis* with 17 individuals that are often found in Gunung Stong State Park (GSSP), Kelantan while *Coffea arabica, Coffea humilis, Massularia acuminata dan Psychotria nervosa* are least abundant spesies. All coordinates are plotted using the Geographic Information System to form the distribution of the Rubiaceae Family found along the trail in Gunung Stong State Park, Kelantan. The diversity value of the Rubiaceae family in Gunung Stong State Park, Kelantan can be counted in the high category with a total of H'= 1.60 and D'= 0.67.

## 5.2 RECOMMENDATIONS

Several strategies can be suggested to understand and conduct research related to the Diversity & Distribution of Family: Rubiaceae along the trail in Gunung Stong State Park, Kelantan. By increasing the breadth of study area that can help obtain data and more help represent the state park itself.

This can indirectly allow an inventory of species to be made including scientific names, morphological characteristics, and their exact location. The second is the use of Global Positioning System (GPS) and Geographic Information Systems (GIS) in a comprehensive way to identify and consolidate the recorded Family Rubiaceae distribution map. This technology helps increase the growth factor and the potential area for life. In addition, studies on ecology are needed to understand the role of Rubiaceae in contributing to a balanced ecosystem such as providing food for animals and growth for society.

## REFERENCES


Ahsan F, & Bashir S. (2019). Coffee Consumption: Health Perspectives and Drawbacks. *Coffee Consumption: Health Perspectives and Drawbacks*, *2*(1). Retrieved November 15, 2023, from https://www.scholarena.com/article/Coffee-Consumption-Health-Perspectives-and-Drawbacks.pdf

Achacoso, S. C., Walag, A. M. P., & Saab, L. L. (2016). A rapid assessment of foliage spider fauna diversity in Sinaloc, El Salvador City, Philippines: a comparison between habitats receiving different degrees of disturbance. *Biodiversity*, *17*(4), 156–161. Retrieved August 1, 2024, from https://doi.org/10.1080/14888386.2016.1258331

Al-Asmari, K. M., Zeid, I. M. A., & Al-Attar, A. M. (2020). Medicinal Properties of Arabica coffee (Coffea arabica) Oil: An Overview. Advancements in Life Sciences, 8(1), 20–29. Retrieved November 15, 2023, from http://als-journal.com/submission/index.php/ALS/article/download/1024/463

Anisha Devendran, & G. Gnanave. (2020). A Review on Ixora Coccinea: Traditional Use, Phytochemical and Pharmacological Studies. *Journal of Chemical and Pharmaceutical Sciences*, *Volume 13*(Issue 1). Retrieved November 15, 2023, from https://www.jchps.com/issues/v13/i01/JCHPS20191301004.pdf

Biswas, A., Bari, M. A., Roy, M., & Bhadra, S. K. (2010). Inherited folk pharmaceutical knowledge of tribal people in the Chittagong Hill tracts, Bangladesh. *Indian Journal of Traditional Knowledge*, *9*(1), 77–89. Retrieved November 11, 2023, from http://nopr.niscair.res.in/bitstream/123456789/7159/1/IJTK%209%281%29%2077-89.pdf

Burkill, H. (1985). The useful plants of West Tropical Africa. Vol. 1. Families A-D. *The Useful Plants of West Tropical Africa*. Retrieved May 19, 2024, from https://www.cabdirect.org/cabdirect/abstract/19861648637. pp. 441-415

Chee Beng Jin. (2005). A preliminary checklist of plant species of the Gunung Stong Forest Reserve, Kelantan. In *Gunung Stong State Park: Management, Physical Environment, Biology and Socioeconomy*. (Vol. 32). JABATAN PERHUTANAN SEMENANJUNG MALAYSIA. Retrieved May 19, 2024, from https://www.researchgate.net/publication/248381595_A_preliminary_checklist_of_plant_species_of_the_Gunung_Stong_Forest_Reserve

Chua, L. S. L., H, N., Mamat, H., & Saw, L. G. (2003). Conservation status of Hopea subalata (Dipterocarpaceae) in Peninsular Malaysia. *Journal of Tropical Forest Science*, *16*(3), 171–282. Retrieved July 1, 2024, from https://www.researchgate.net/publication/273129276_Conservation_status_of_Hopea_subalata_Dipterocarpaceae_in_Peninsular_Malaysia

Conserva, L. M., & Ferreira, J. C., Jr (2012). Borreria and Spermacoce species (Rubiaceae): A review of their ethnomedicinal properties, chemical constituents, and biological activities. Pharmacognosy reviews, 6(11), 46–55. Retrieved July 1, 2024, from https://doi.org/10.4103/0973-7847.95866

Davis, A. P., Govaerts, R., Bridson, D. M., Ruhsam, M., Moat, J., & Brummitt, N. (2009). A Global Assessment of Distribution, Diversity, Endemism, and Taxonomic Effort in the Rubiaceae. *Annals of the Missouri Botanical Garden*, *96*(1), 68–78. Retrieved June 2, 2024, from https://doi.org/10.3417/2006205

Edward F. Gilman. (2024). *FPS494/FP494: Psychotria nervosa Wild Coffee*. Ask IFAS - Powered by EDIS. Retrieved June 2, 2024, from https://edis.ifas.ufl.edu/publication/FP494

*Erithalis odorifera - Leon Levy Native Plant Preserve*. (2022, December 14). Leon Levy Native Plant Preserve. Retrieved May 18, 2024, from https://levypreserve.org/plant-listings/erithalis-odorifera/

Fayolle, A., Engelbrecht, B. M. J., Freycon, V., Mortier, F., Swaine, M., Réjou-Méchain, M., Doucet, J., Fauvet, N., Cornu, G., & Gourlet-Fleury, S. (2012). Geological substrates shape tree species and trait distributions in African moist forests. *PLOS ONE*, *7*(8), e42381. Retrieved May 18, 2024, from https://doi.org/10.1371/journal.pone.0042381

Ferreira, T., Shuler, J., Guimarães, R. J., & Farah, A. (2019). CHAPTER 1. Introduction to Coffee Plant and Genetics. In Royal Society of Chemistry eBooks (pp. 1–25). Retrieved October 10, 2023, from https://doi.org/10.1039/9781782622437-00001

Gopal, G. R., Anuja, G. I., Latha, P. G., Nair, A. J., Gangaprasad, A., Sudhakaran, P. R., Muraleedharan, D., & Nair, G. M. (2016). Anti-Hepatotoxic Property of Roots and Leaves of Chassalia curviflora (Wall.) Thwaites against CCl4 Induced Liver Damage in Rats. *International Journal of Pharmaceutical Sciences and Drug Research*, *8*(05). Retrieved May 17, 2024, from https://doi.org/10.25004/ijpsdr.2016.080506

Gruber, C. W. (2010). Global cyclotide adventure: A journey dedicated to the discovery of circular peptides from flowering plants. Biopolymers, 94(5), 565–572. Retrieved May 17, 2024, from https://doi.org/10.1002/bip.21414

I. FARIDAHHANUM, & NURULHUDAHAMZAH. (1999). The use of medicinal plant species by the Temuan Tribe of Ayer Hitam Forest, Selangor, peninsular Malaysia. *The Use of Medicinal Plant Species by the Temuan Tribe of Ayer Hitam Forest, Selangor, Peninsular, Malaysia*. Pertanika J. Trop. Agric. Sci, 22(2), 85–94. Retrieved July 5, 2024, from https://core.ac.uk/reader/42991080

Jabatan Perhutanan Negeri Kelantan. (2019). *Kawasan Hutan Bernilai Pemeliharaan Tinggi HCVF*. Retrieved June 11, 2024, from https://jpnk.kelantan.gov.my/index.php/ms/info-perhutanan/maklumat-mc-i/kawasan-hutan-bernilai-pemeliharaan-tinggi-hcvf

Khamis, S., Manap, T. A., Saleh, K., & Latiff, A. (2005). An additional annotated checklist of seed plants of Gunung Stong Forest Reserve. In *Gunung Stong State Park : Management, Physical Environment, Biology and Socioeconomy*. Jabatan Perhutanan Semenanjung Malaysia. Retrieved June 6, 2024, from https://www.researchgate.net/publication/248381600_An_additional_annotated_checklist_of_seed_plants_of_Gunung_Stong_Forest_Reserve

Koehbach, J., & Gruber, C. W. (2015). Cyclotides in the Rubiaceae. In *Advances in Botanical Research* (pp. 51–78). Retrieved November 21, 2023, from https://doi.org/10.1016/bs.abr.2015.09.002

Kowalczuk, A., Łozak, A., & Zjawiony, J. K. (2013). Comprehensive methodology for identification of Kratom in police laboratories. Forensic Science International, 233(1–3), 238–243. Retrieved November 21, 2023, from https://doi.org/10.1016/j.forsciint.2013.09.016

Lara-Estrada, L., & Vaast, P. (2007). Effects of altitude, shade, yield and fertilization on coffee quality (Coffea arabica L. var. Caturra) produced in agroforestry systems of the Northern Central Zones of Nicaragua. Retrieved November 21, 2023, from https://doi.org/10.13140/RG.2.1.4689.1289

Nawrot, P. S., Jordan, S. A., Eastwood, J., Rotstein, J., Hugenholtz, A., & Feeley, M. (2003). Effects of caffeine on human health. *Food Additives and Contaminants*, *20*(1), 1–30. Retrieved November 15, 2023, from https://doi.org/10.1080/0265203021000007840

*NParks | Chassalia curviflora*. (2023). Retrieved June 1, 2024, from https://www.nparks.gov.sg/florafaunaweb/flora/5/6/5639

Oriola, A. O., Aladesanmi, A. J., Idowu, T. O., Akinkunmi, E. O., Oyedeji, A. O., Ogunsina, M. O., Arthur, G., & Schweizer, F. (2022). Saponin from Massularia acuminata Inhibits the Growths of Some Microbial and Human Cancerous Cells in vitro. *Chemistry Africa*, *5*(6), 1959–1966. Retrieved June 28, 2024, from https://doi.org/10.1007/s42250-022-00488-0

Pailler, T., & Thompson, J. D. (1997). Distyly and variation in heteromorphic Incompatibility in Gaertnera Vaginata (Rubiaceae) endemic to La Reunion Island. *American Journal of Botany*, *84*(3), 315–327. Retrieved June 28, 2024 from https://doi.org/10.2307/2446005

Pailler, T., Humeau, L., Figier, J., & Thompson, J. D. (1998). Reproductive trait variation in the functionally dioecious and morphologically heterostylous island endemic Chassalia corallioides (Rubiaceae). *Biological Journal of the Linnean Society/Biological Journal of the Linnean Society*, *64*(3), 297–313. Retrieved May 31, 2024, from https://doi.org/10.1111/j.1095-8312.1998.tb00335.x

Pailler, T., Maurice, S., & Thompson, J. D. (2002). Pollen transfer patterns in a distylous plant with overlapping pollen-size distributions. *Oikos*, *99*(2), 308–316. Retrieved May 31, 2024, from https://doi.org/10.1034/j.1600-0706.2002.990211.x

*Plants of the World Online | Kew Science*. (2024). Plants of the World Online. Retrieved July 30, 2024, from https://powo.science.kew.org/taxon/urn:lsid:ipni.org:names:326020-2

Porto, D. D., Henriques, A. T., & Fett-Neto, A. G. (2009). Bioactive Alkaloids from South American Psychotria and Related Species. The Open Bioactive Compounds Journal, 2(1), 29–36. Retrieved July 25, 2024, from https://doi.org/10.2174/1874847300902010029

Presti, D. E. (2002). Psychoactive drugs. In *Encyclopedia of The Human Brain* (pp. 75–82). Academic Press. Retrieved November 21, 2023, from https://doi.org/10.1016/b0-12-227210-2/00290-9

Schmitt, C. B. (2006). Montane Rainforest with Wild Coffea Arabica in the Bonga Region (SW Ethiopia): Plant Diversity, Wild Coffee Management and Implications for Conservation [PhD]. In *ResearchGate*. https://www.researchgate.net/publication/262514208_Montane_Rainforest_With_Wild_Coffea_Arabica_in_the_Bonga_Region_SW_Ethiopia_Plant_Diversity_Wild_Coffee_Management_and_Implications_for_Conservation

Tungphatthong, C., Urumarudappa, S.K.J., Awachai, S. *et al*. Differentiation of *Mitragyna speciosa*, a narcotic plant, from allied *Mitragyna* species using DNA barcoding-high-resolution melting (Bar-HRM) analysis. *Sci Rep* 11, 6738 (2021). Retrieved November 15, 2024, from https://doi.org/10.1038/s41598-021-86228-9

Turner, I. (2019). A nomenclatural synopsis of Chassalia (Rubiaceae) in Asia. *Feddes Repertorium*, *130*(4), 396 404. Retrieved May 31, 2024, from https://doi.org/10.1002/fedr.201900002