Diversity and Distribution of Pteridophytes (Family: Pteridaceae) in Gunung Stong State Park (GSSP), Kelantan

by

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

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DECLARATION

I declare that this thesis entitled "Diversity and Distribution of Pteridophytes (Family: Pteridaceae) in 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.

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Diversity and Distribution of Pteridophytes (Family: Pteridaceae) in Gunung Stong State Park (GSSP), Kelantan.

ABSTRACT

This study was conducted to identify the diversity and distribution patterns of pteridophytes within Gunung Stong State Park (GSSP), Kelantan, with a specific focus on the family Pteridaceae. Extensive field surveys were conducted across various elevations within GSSP, during which Pteridophyte species were identified, and meticulous documentation was carried out regarding their habitat preferences, elevation ranges, and ecological associations. Additionally, a random sampling method was used to collect data for taxonomic analysis. It had shown Pteridaceae family that was recorded at GSSP consisted of 11 species with 102 individuals belonging to five genera. Diversity index for Family: Pteridaceae was recorded using the Shannon Wiener -Index (H') as 2.183. The findings revealed a rich diversity of Pteridaceae species in GSSP, characterized by variations based on elevation, habitat type, and other microclimatic conditions. Notably, some ferns exhibited narrow altitudinal ranges, while others displayed broader distribution patterns. Understanding the distribution dynamics of Pteridaceae in GSSP is deemed essential for effective conservation efforts and informed ecosystem management, providing valuable insights into the unique fern flora thriving in this pristine tropical rainforest.

Kepelbagaian dan Taburan Pteridophytes (Famili: Pteridaceae) di Taman Negeri Gunung Stong (GSSP), Kelantan.

ABSTRAK

Kajian ini dijalankan untuk mengenal pasti kepelbagaian dan corak taburan pakis dalam Taman Negeri Gunung Stong (GSSP), Kelantan, dengan tumpuan khusus kepada famili Pteridaceae. Tinjauan lapangan yang meluas telah dijalankan merentasi pelbagai ketinggian dalam GSSP, di mana spesies pteridofit telah dikenal pasti, dan dokumentasi yang teliti telah dijalankan berkenaan keutamaan habitat, julat ketinggian dan persatuan ekologi mereka. Selain itu, kaedah persampelan rawak digunakan untuk mengumpul data untuk analisis taksonomi. Ia telah menunjukkan famili Pteridaceae yang direkodkan di GSSP terdiri daripada 11 spesies dengan 102 individu tergolong dalam lima genera. Indeks kepelbagaian untuk Famili: Pteridaceae akan direkodkan menggunakan Shannon Wiener-Index (H') dikira sebagai 2.183. Penemuan ini mendedahkan kepelbagaian spesies Pteridaceae yang kaya dalam GSSP, dicirikan oleh variasi berdasarkan ketinggian, jenis habitat dan keadaan mikroklimat yang lain. Terutama, sesetengah pakis mempamerkan julat altitudinal yang sempit, manakala yang lain menunjukkan corak taburan yang lebih luas. Memahami dinamik pengedaran Pteridaceae dalam GSSP dianggap penting dalam usaha pemuliharaan yang berkesan serta pengurusan ekosistem yang bermaklumat, memberikan pandangan berharga tentang flora pakis unik yang tumbuh subur di hutan hujan tropika asli ini.

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LIST OF ABBREVIATION

GSSP	Gunung Stong State Park
a.s.l	**a**bove sea level

LIST OF SYMBOLS

H'	The value of Shannon Wiener Diversity Index
$=$	Equal to
$-$	Negative value
$\sum_{i=1}^{s}$	Sum of propotion of S
pi	Proportion of individuals of species I
ln	The natural logarithm of p_i
S	The number of species in the community.

CHAPTER 1

INTRODUCTION

1.1 Background of Study

Gunung Stong State Park is a forested area surrounded by many mountain peaks at the backdrop, including Gunung Ayam, Gunung Tera, and Gunung Saji, located at Kelantan. This state is well known for its biodiversity and richness of natural resources, including Pteridaceae.

Gunung Stong State Park (GSSP), located in Kelantan, is a well-established nature tourism destination. Its popularity stems from its unique location and physical features. GSSP presence of the second highest waterfall in Southeast Asia, Jelawang Waterfall (Sarguna *et al*., 2017). The GSSP covers an area of 21,950 hectares and boasts high peaks, dense forests, caves, rivers, and waterfalls. Among its remarkable attractions is the 1422-meter-high Gunung Stong, a dome-shaped granite complex that has existed for over 500 million years. The park's thick jungle is inhabited by diverse wildlife, such as elephants, tigers, bears, gibbons, and hornbills. Additionally, it hosts a variety of flora and fauna, including the world's largest flower, the Rafflesia, and unique palm species like *Licuala stongensis.* Kem Baha, situated at the peak of Stong Waterfalls, is a camping site that provides place for hikers to rest before starting to hike to the peak of mountains.

As circumscribed in the most recent familial classification, Pteridaceae, a diverse family of ferns, includes more than 50 genera and over 1000 species, constituting approximately 10% of the total leptosporangiate fern diversity. In earlier phylogenetic studies, Pteridaceae was identified as a monophyletic group. Key features of this family include sporangia positioned along veins or in marginal coenosori, often shielded by reflexed segment margins (known as pseudoindusia). Chromosome numbers predominantly revolve around x = 29 or 30. Pteridaceae exhibits a cosmopolitan distribution, thriving in both wet tropical and arid regions. Its ecological versatility sets it apart from most other fern families, as it encompasses terrestrial, epiphytic, xeric-adapted rupestral, and even aquatic species (Schuettpelz *et al.*, 2007).

Within Southeast Asia, including Malaysia, there exists a notable scarcity of studies employing quantitative methods to assess fern diversity. Researchers pioneered herbaceous plant surveys, including ferns, using the quadrant method. Additionally, researchers have explored fern diversity in both man-made and natural forests in Malaysia, employing cubic quadrant techniques. However, documentation of pteridophyte distribution patterns remains deficient in Malaysia and other regions worldwide, especially when compared to angiosperms and other higher plants. The disproportionately low representation of ferns and mosses in most countries underscores the lack of comprehensive information available on these plant groups. (Rahmad & Akomolafe, 2018)

The diversity of pteridophytes, ferns and their allies are influenced by several key factors. These include rainfall, moisture levels, and habitat availability. Notably, most pteridophyte species thrive in tropical and moist temperate regions, with subtropical areas also supporting significant populations. Beyond their ecological roles, pteridophytes serve various practical purposes. They are commonly used as vegetables, feature in traditional remedies, and contribute to landscaping and gardening. From a nutritional perspective, edible pteridophytes offer a range of beneficial components, including proteins, vitamins, crude fibre, and minerals. Additionally, these plants contain compounds such as steroids, terpenoids, phenolic acids, and flavonoids. Pteridophytes were considered a source of medicines in ancient times but remain relatively under-explored. However, fern ethnobotany is not new, and there is a wealth of information regarding ferns and local cultures in the literature. On a global scale, offered the most thorough analysis of the usage of lycophytes and ferns, but they have also been studied ethnobotanically in South America. Asia has a great diversity of pteridophytes, but their uses have not been well recorded except for a few studies in China and India (Khoja *et al.*, 2022).

The study aims to determine whether pteridophytes are important to biodiversity because they provide habitat and food for various organisms, support pollinators, contribute to ecosystem stability, and offer cultural and medicinal resources. Conserving pteridophyte species is critical for sustaining ecosystem health and preserving the rich biodiversity they support.

1.2 Problem Statement

Pteridophytes play important ecological roles in various ecosystems. The taxonomic diversity of the species of pteridophytes within the Pteridaceae family, a comprehensive taxonomic study should be conducted. This involves collecting and examining specimens, including morphological, genetic, and molecular analyses. Many pteridophyte species have traditional medicinal and culinary uses. Researching their diversity can lead to discovering new species or varieties that have potential applications in medicine and food. This can have economic benefits and contribute to traditional knowledge preservation. However, understanding the diversity and distribution of pteridophyte species is crucial for biodiversity conservation. Many pteridophyte species may be endangered or vulnerable, and studying their distribution helps identify regions and habitats that need protection. Conservation efforts can be targeted towards preserving these species and their ecosystems. They provide food and habitat for wildlife, contribute to nutrient cycling, and can influence local hydrology. By studying their distribution, the ecological significance of various species and how ecosystems might be affected by changes in their populations can be better understood, and awareness about the importance of biodiversity and the need for conservation can be raised by engaging the public. It can also be a valuable educational resource for students and the general public.

1.3 Objectives

The objectives of this study are:

- To identify species of pteridophytes (Family: Pteridaceae) in Gunung Stong State Park (GSSP), Kelantan.
- To determine the distribution of pteridophytes (Family: Pteridaceae) in Gunung Stong State Park (GSSP), Kelantan.

LITERATURE REVIEW

2.1 Pteridophytes

Pteridophytes, often referred to as 'vascular cryptogams' or 'ferns and their allies', encompass around twelve thousand species of vascular plants. Ferns, which belong to the group of seedless vascular plants, are categorized within the plant kingdom as Pteridophyta. Like other vascular plants, pteridophytes have stems, fronds, pinnae, and roots. However, ferns differ from seed plants (such as gymnosperms and flowering plants) because pteridophytes do not produce seeds or flowers; instead, they reproduce through spores. Pteridophytes differentiate themselves from mosses and algae primarily through the presence of xylem and phloem, which enable the transport of water and nutrients. Just like gymnosperms and flowering plants, pteridophytes undergo a life cycle known as an alternation of generations, marked by a sexual phase (gametophyte) and an asexual phase (sporophyte). Male gametes, known as antherozoids, are abundantly produced within antheridia. These flagellated structures allow antherozoids to swim in water. In contrast, female gametes (egg cells) are immobile and develop individually within flask-shaped archegonia. When an egg cell fuses with an antherozoid, it forms a zygote, which subsequently undergoes mitotic divisions to develop into the diploid sporophyte (Yusuf, 2010).

Pteridophytes, which include ferns and their allies, inhabit diverse environments across the Earth, from terrestrial to aquatic ecosystems. They play a crucial role in many forest ecosystems, forming a significant part of the ground vegetation. Interestingly, about a third of these species grow on tree trunks and branches, making them a key element to the epiphytic plant communities. However, they are cryptogamic, meaning they do not produce flowers, seeds, or fruits, setting them apart from higher plants. Their reproductive method involves spores, similar to bryophytes and algae, but they are distinguished by the presence of vascular tissues. Ferns predominantly thrive in tropical forests at lower altitudes, although certain species also inhabit the understories of temperate forests (Yatskievych *et al.*, 2003).

Southeast Asia is home to approximately 4,400 species of ferns, with 1,165 of these species thriving in the tropical rainforests of Malaysia. The rich diversity of ferns in certain regions of Malaysia can be attributed to the presence of tropical rainforests. However, activities like logging, which are prevalent in Malaysian forests, pose a significant threat to the survival of these ferns. The limited knowledge about fern species composition, distribution, and conservation in Malaysia highlights the need for further study. Ferns also play a role in environmental purification by removing heavy metals through phytoremediation. While past research has mainly centred on taxonomy and inventory, quantitative studies on fern diversity and distribution remain relatively uncommon in Malaysia, potentially due to their inconspicuous characteristics within pteridophytes (Rahmad & Akomolafe, 2018).

2.2 Morphological Characteristics of Pteridophytes

Pteridophytes, which belong to the sexual generation known as sporophytes, have the unique ability to produce spores. Within the sporophyte generation, the arrangement of the young leaf (frond) in the bud is noteworthy. The young frond exhibits either a coiled pattern called circinate vernation or a hooked shape resembling a shepherd's crook, known as non-circinate vernation. The distinct feature aids in identifying ferns within their natural habitats.

As the young leaf develops, it starts to elongate and uncoil, and the leaf blade expands, resulting in the formation of the mature frond. The rhizomes of ferns exhibit a wide range of forms, from short and thick to long, creeping, and wiry. In certain fern species, the rhizomes are upright, while in tree ferns, they form a distinctive woody trunk. Dry structures, such as scales, bristles, or hairs, protect the young portion of the stipe and the coiled fronds in ferns. These structures are composed of an arrangement of flat cells. The hairs on these structures can be either glandular or non-glandular. The scales may be linear, lanceolate, oblong, peltate and flabellate and such descriptions are of taxonomic significance. The adventitious roots of pteridophytes contain primary xylem and phloem within the stele. Additionally, their cortex either includes an endodermis or lacks an exodermis with Casparian bands, along with lignified cortical walls. The leaves of these plants possess an endodermis, a layer of sclerenchyma, and a cuticle—all serving as barriers to apoplastic transport (Yusuf, 2010).

Furthermore, the physical structures of plants that grow in the sun and those that grow in the shade differ significantly. Shade plants typically have larger leaves with larger cells, fewer mesophyll tissues, and reduced densities of stomata and veins. In plant groups like pteridophytes, gymnosperms, and angiosperms, structures such as the endodermis or circum endodermal band, and the exodermis serve as barriers. These barriers limit the exchange of water and solutes, decrease the loss of oxygen following submersion, and adapt to terrestrial habitats (Wu *et al*., 2020). The majority of ferns possess specialized stems known as rhizomes, which are typically situated at the substrate level or slightly buried. Rhizomes are underground stems found in various plant species. Pteridophytes come in different sizes, thicknesses, and orientations. These structures play a crucial role in plant growth, nutrient storage, and vegetative propagation.

Tree ferns, in particular, have specialized stems that resemble trunks and can grow to heights of 20 meters or even higher. Stems in ferns exhibit various adaptations. Some stems develop adventitious roots and are covered with dense scales or hairs, especially near the growing tip. For instance, grape ferns (Ophioglossaceae) have somewhat tuberous stems, while horsetails (Equisetaceae) possess both rhizomes and fluted or ridged aerial stems. Most club mosses (Lycopodiaceae) have relatively unspecialized stems. Unlike the secondary growth seen in many seed plants, fern rhizomes remain structurally simple and do not produce wood. Even tree ferns rely solely on primary growth, supported by a thick layer of interwoven roots. In most ferns, the stem's vascular system forms a hollow cylinder, with interruptions where traces branch off to the leaves.

When examining the cross-section of fern rhizomes, most species reveal an irregular arrangement of vascular bundles. However, in some primitive ferns and their allies, the vascular system forms a solid, unbroken cylinder. Pteridophyte leaves exhibit diverse shapes and structures. While fern allies and certain primitive ferns have simplified leaves resembling scales, needles, or grass blades with minimal veining, true ferns often display intricate leaf patterns. In families like Gleicheniaceae, leaves can grow indefinitely, sprawling over nearby vegetation. The petiole (or stipe) of fern leaves varies in cross-section, from circular to angled or U-shaped, and may be covered in hairs or scales. These features serve as identifying characteristics for specific families or genera.

For most of the pteridophytes, the development of leaves follows a unique structure called ‘circinate vernation,’ resulting in a distinctive fiddlehead or crozier shape as the leaf unfurls. However, some genera modify this pattern, leading to the formation of a hook-like structure during leaf unfolding. Fern allies and grape ferns (Ophioglossaceae) do not exhibit circinate vernation; instead, fern allies and grape ferns (Ophioglossaceae) lack circinate vernation, instead expanding their leaves through unfolding or following an indefinite pattern. The leaf blade (lamina) varies from entire to highly divided, exhibiting pinnate, pedate, and palmate division patterns across different species. The petiole continues as the central axis of the leaf blade (known as the rachis), to which the pinnae (primary divisions or leaflets) attach. These pinnae may be entire or further compound. The final divisions of the leaf are referred to as pinnules, which can be either entire or lobed.

Leaf venation in ferns could be intricate, with progressively finer midveins (costae) and lateral veins. Pinnules may have unbranched or branched venation, including free or anastomosing veinlets. Fern leaves vary in texture, from smooth (glabrous) to covered in hairs and scales. Some species have glandular, sticky leaves, while others secrete a powdery substance called farina, often on the leaf underside. Thickness also varies; filmy ferns (Hymenophyllaceae) have leaves just two cell layers thick. Thick, leathery leaves or those with dense coverings are adaptations to dry habitats and intense sunlight (Yatskievych *et al*., 2003).

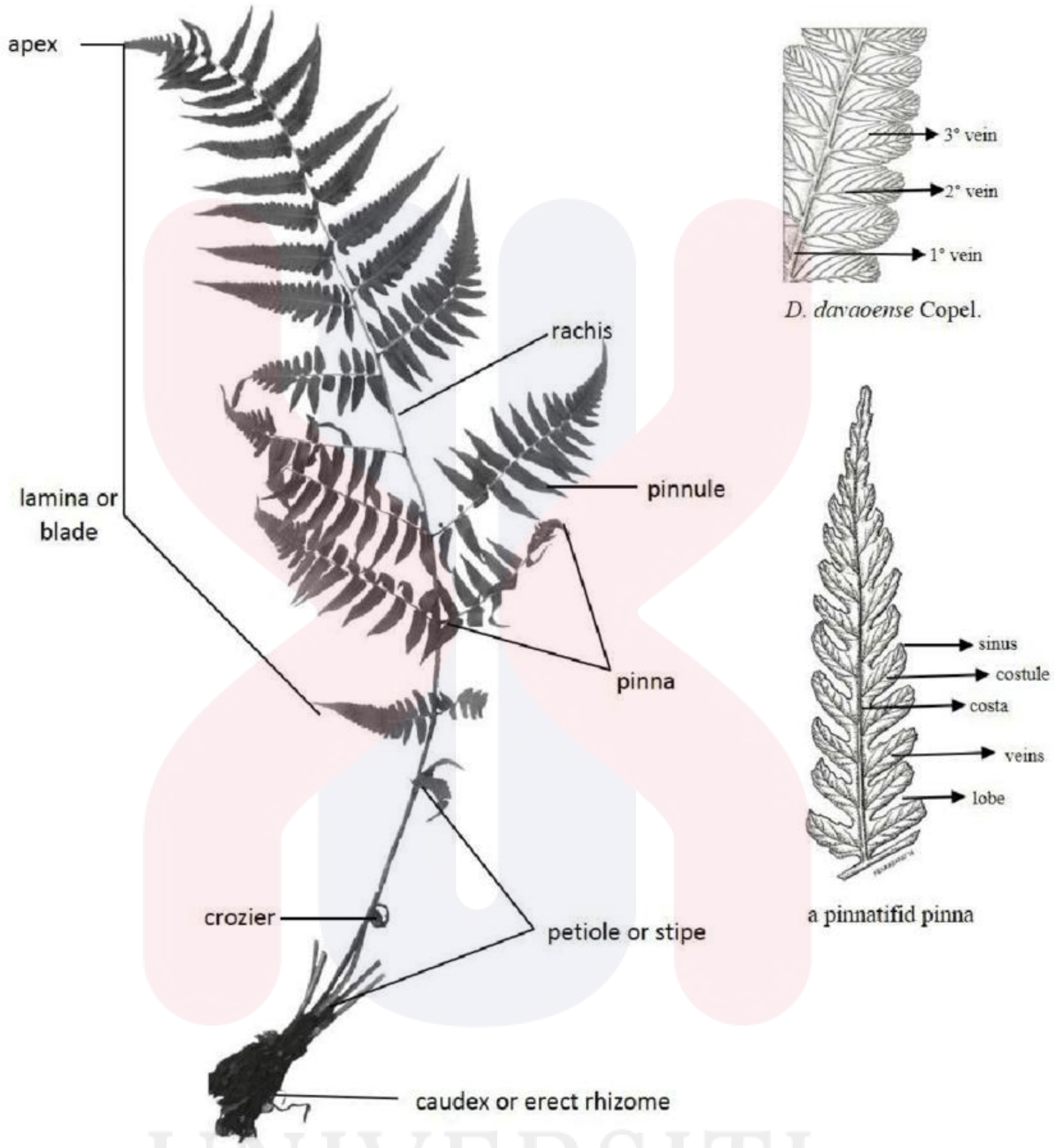


Figure 2.1: The morphological structure of Pteridophytes. Source: (Conda *et al.*, 2017)

2.3 Distribution of Pteridophytes in Malaysia

In all the sampled locations within USM, a total of twenty-three distinct fern species from fourteen different families were identified. The Thelypteridaceae and Polypodiaceae families exhibited the highest diversity, with five and four species respectively. In less-disturbed forests, 15 fern species were observed, while more-disturbed forests and urbanized areas had 11 species each. The prevalence of fern species varied across different environments. In less disturbed forests, *Lindsaea napaea* was the most common, accounting for 63.4% of the species observed. In contrast, *Pyrrosia lanceolata* was the most abundant in both more-disturbed forests (36.0%) and urbanized sites (47.0%), as depicted in Figure 2.2 (Rahmad & Akomolafe, 2018).

In the study area, a diverse collection of 3762 pteridophytes was documented, comprising 32 species from 13 families and 20 genera. The families Polypodiaceae and Davalliaceae, with genera *Microsorum* and *Davallia* respectively, were observed to have the greatest species richness and were frequently encountered in the area., with the ecological resilience of pteridophytes, significantly enhance the biodiversity of a lush forest. They are broadly categorized into two groups: true ferns and their allies. Globally, there are approximately 12,000 pteridophyte species, with true ferns making up about 97% of this number and the remaining 3% being their allies, also known as Lycophytes.

The global pteridophyte population, with around 12,000 identified species, is notable for its remarkable diversity in form, texture, and even colour. Plant List, a comprehensive database of plant species, records pteridophyte taxa across 48 families and 587 genera. This list includes 47,439, scientific plant names specifically ranked for pteridophytes, with 10,620 of these, being accepted species names. In the tropical rainforests of Malaysia, located in Southeast Asia, about 4400 species are recognized, and 1165 species have been documented. This highlights the rich biodiversity of pteridophytes in this region (Saharizan *et al.*, 2021).

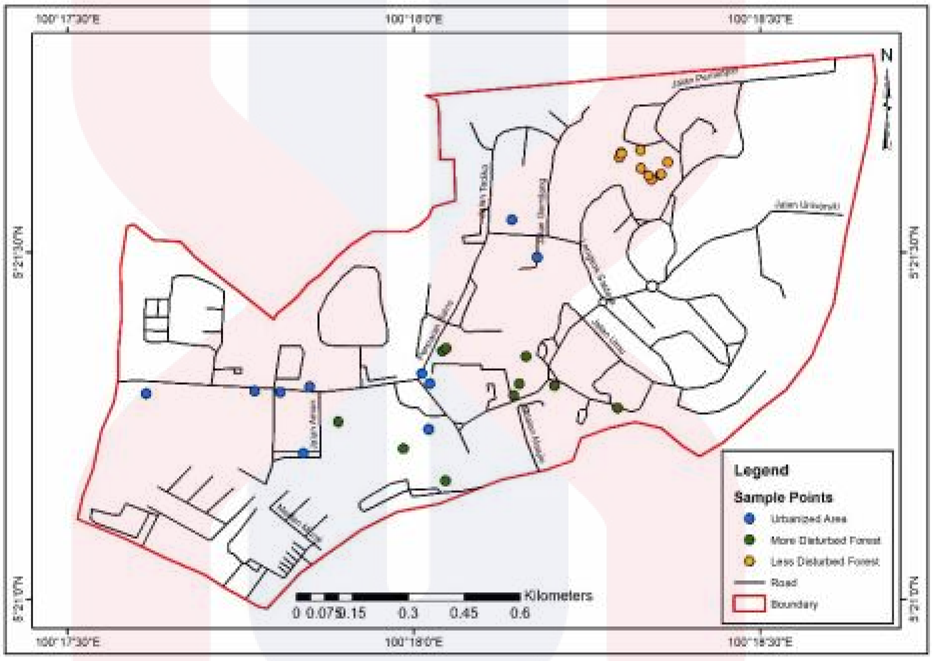


Figure 2.2: The distribution of Pteridophytes in Universiti Sains Malaysia (USM) main campus.

2.4 Usage and Function of Wild Pteridophytes

While only a limited number of pteridophyte species have economic significance, their most recognized use is in horticulture. Pteridophytes are commonly cultivated as garden plants, and indoor greenery, and are featured exhibits in conservatories and greenhouses. The species *Ruhmora adiantiformis*, commonly known as the florist's fern, is particularly notable. Its leaves are finely segmented but sturdy and resistant to wilting, making them ideal for use in floral arrangements. Another horticultural application involves using sections of the rot-resistant root mantles that cover tree fern stems (known as orchid bark) to act as a growing medium for orchids and other epiphytic plants. However, this practice has contributed to the endangerment of many fern species, leading to strict international regulations and trade treaties governing the commercial trade of tree fern products. Additionally, certain ferns have practical uses in crafts. For instance, the petioles of some climbing ferns in the Schizaeaceae family are used in tropical regions to create colour patterns in basketry and bracelets. Furthermore, leaves from *Pteridium* (bracken) are utilized to produce green dye.

Tree fern *Cibotium* have rhizomes which are dense, long, golden hairs, that have been used since ancient times to create animal figurines, sometimes referred to as the 'vegetable lamb of Tartary'. Another group of pteridophytes, the clubmosses (Lycopodiaceae), have a long history of utilization. Their microscopic spores contain non-volatile oils, making them effective as dry industrial lubricants. In the past, fern spores were used to prevent latex items like surgical gloves and condoms from sticking together. However, this practice has been largely abandoned due to the discovery that spores can cause skin irritation and allergic reactions in some individuals. Nowadays, these spores find applications in flash powder for photography and as fingerprint powder in forensic investigations. Additionally, various ferns serve as food. Young fern leaves are commonly steamed as a vegetable or dried for use in stews and sauces. One such edible species is *Diplazium esculentum*, which is specifically cultivated for this purpose in certain regions in Asia. (Yatskievych *et al.*, 2003).

Based on the journal published by (Rout *et al*., 2009) which investigated the use of 33 fern species from 21 families in treating various diseases. These species were collected from the Similipal Biosphere Reserve. The majority of the ethnomedicinal information provided in this study is novel and previously unreported. While these herbal remedies are claimed to be highly effective, a comprehensive clinical study is necessary for their better utilization. The ethnomedicinal data can serve as a foundation for the discovery of new compounds with active principles, contributing to phytochemical, pharmacognostical, pharmacological, and clinical research. Indigenous communities traditionally use many of these medicinal pteridophytes to treat common ailments. These include gastrointestinal issues such as stomach aches, peptic ulcers, diarrhoea, and dysentery; skin conditions including wounds, abscesses, eczema, and scabies; chest complaints; snake bites; urinary problems; bone fractures; hypertension; glandular swellings; and they are also used as a tonic. In each village and community, some experts practice these treatments, maintaining an effective local health tradition.

The collected data reveals that most of the herbal remedies derived from these plants are consumed orally. These plants are used in various forms, including juice, extract, decoction, paste, infusion, and powder. The majority of the preparations involve a combination of plants, with single-plant remedies being less common. In other regions of the country, it's quite usual to use mixtures of plant species to treat specific ailments. The local population in the study area maintains a strong belief in the effectiveness and success of herbal medicine. Currently, some species of ferns and their allies have been lost or eradicated due to deforestation and 'Akhand shikar' (forest fires) in the Similipal Biosphere Reserve. However, the reality is that illegal activities such as forest looting and poaching, carried out by 'jungle pirates', are causing irreversible damage to the biosphere throughout the year.

Rather than exploiting ferns and their allies for their economic and ornamental value, efforts should be made to conserve them. The recommendation is to safeguard rare fern species and their allies in the Similipal forest by preventing their indiscriminate collection and destruction. The ongoing deforestation and fragmentation of habitats pose a serious threat to the growth of wild plants. The decline of traditional ethnobotanical knowledge, coupled with over-exploitation and habitat destruction, threatens the survival of wild plants. Therefore, documenting traditional knowledge should be prioritized to aid in resource conservation and the preservation of this rapidly disappearing knowledge. With properly recognized, valued, and implemented, ethnobotanical knowledge can contribute holistically to both the environment and society (Rout *et al*., 2009).

CHAPTER 3

METHODOLOGY

3.1 Study Site

The selected site for the study is Gunung Stong State Park (GSSP), situated in Kelantan. It lies between the coordinates of 5.3396° N and 101.9742° E, GSSP is nestled amidst mountain peaks, rivers, and caves. The Park is home to nine mountains, among which Gunung Ayam (1504 m), Gunung Stong (1422 m), and Gunung Baha (1309 m) are popular choices for hikers. Gunung Stong is particularly renowned for its untouched natural biodiversity.

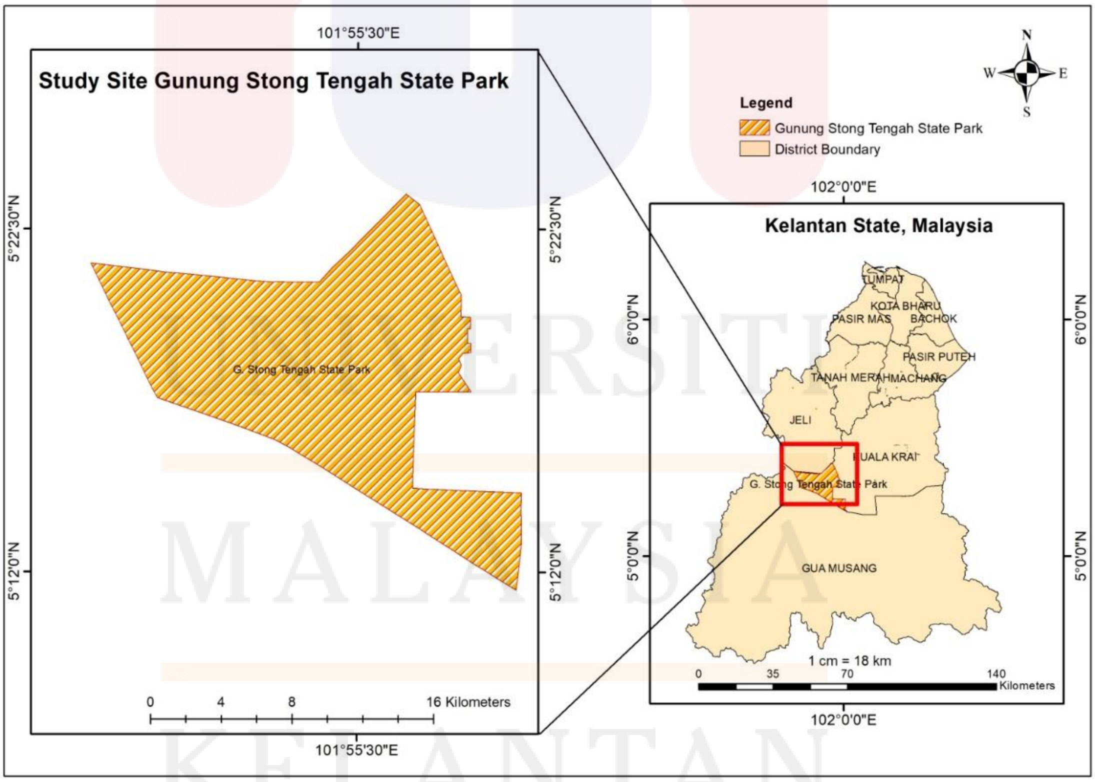


Figure 3.1: Location Gunung Stong State Park (GSSP), Kelantan.

3.2 Materials

In this study, a variety of tools were employed to gather pertinent data. These include a pen and book for recording observations, a smartphone camera for capturing visual data, an airtight polythene bag for sample collection, and handheld GPS for accurate location tracking. These instruments collectively facilitate a comprehensive and systematic data collection process.

Table 3.1: List of materials

Name	Function
Global Positioning System (GPS) receiver	To provide coordinates that give the exact position of targeted species in GSSP.
Smartphone camera	To capture and identify the species found using any app like PlantNet.
Noted book and pen	To write and record the species found.
Airtight polythene bag	To keep the specimens in a clean and protected space.

3.3 Method

3.3.1 Random Sampling of Pteridophytes

Random sampling at elevation 457-529 meters is a crucial method for selecting a subset of data from a larger population. Its primary objective is to evaluate if the chosen sample accurately mirrors the entire population. This study was centred on Pteridaceae, a fern family, within the Gunung Stong State Park (GSSP), Kelantan. Coordinates were utilised to pinpoint the exact locations of all Pteridaceae types. Detailed information about the identified Pteridaceae species was diligently documented in a notebook and later incorporated into the results. The fundamental principle of random sampling is to guarantee an impartial selection procedure. In each demarcated area, every component—a specific location or a distinct segment—might have an equal chance of selection.

3.3.2 Observing Method

The upcoming approach is characterised by broad observation. Observational studies at Gunung Stong State Park (GSSP) were carried out to collect supplementary data. Throughout the sampling process, pertinent characteristics of pteridophytes will be documented. An estimate of the area inhabited by species of the Pteridaceae family was provided by this observational method. The dispersion of various Pteridaceae types within GSSP is a crucial element that is to be comprehended in this study.

3.3.3 Species Identification

In the research area, Pteridaceae are recorded as essential data. To identify Pteridaceae species, collectors focus on specific structural parts. Plant identification was identified with the assistance of the forest guide and PlantNet application. It is crucial to thoroughly identify the Pteridaceae in GSSP because Pteridaceae species often share similar characteristics with other Pteridaceae species, making them difficult to distinguish. The book "Ferns of Malaysia" by G. Holttum specifically focuses on the ferns of Malaysia and offers comprehensive information on their identification, ecology, and distribution (Holttum, 1966).

3.3.4 Software ArcGIS

ArcGIS, a comprehensive Geographic Information System (GIS) software, integrates location data with descriptive information. In this study, it plays a pivotal role by allowing researchers to create detailed distribution maps of pteridophytes within the GSSP. By analysing spatial patterns and visualizing species distribution, ArcGIS informs conservation efforts and contributes to our understanding of the fern's habitats. ArcGIS is used in this study to create the distribution map of pteridophytes (Family: Pteridaceae) in GSSP.

3.3.5 Calculation of Species Diversity and Species Abundance

Species diversity can be calculated by using the Shannon -Wiener Index as follows:

$H' = -\sum_{i=1}^{s} \quad pi * lnpi$ .... Equation 1

Where:

H' = The value of Shannon Wiener diversity Index

p_i = proportion of individuals of species *I*,

ln is the natural logarithm of p_i

S = The number of species in the community.

Later, the number of individuals found in the area will be recorded and inserted in the formula to get the index value.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Diversity and Abundance of Pteridophytes (Family: Pteridaceae) in Gunung Stong State Park (GSSP), Kelantan.

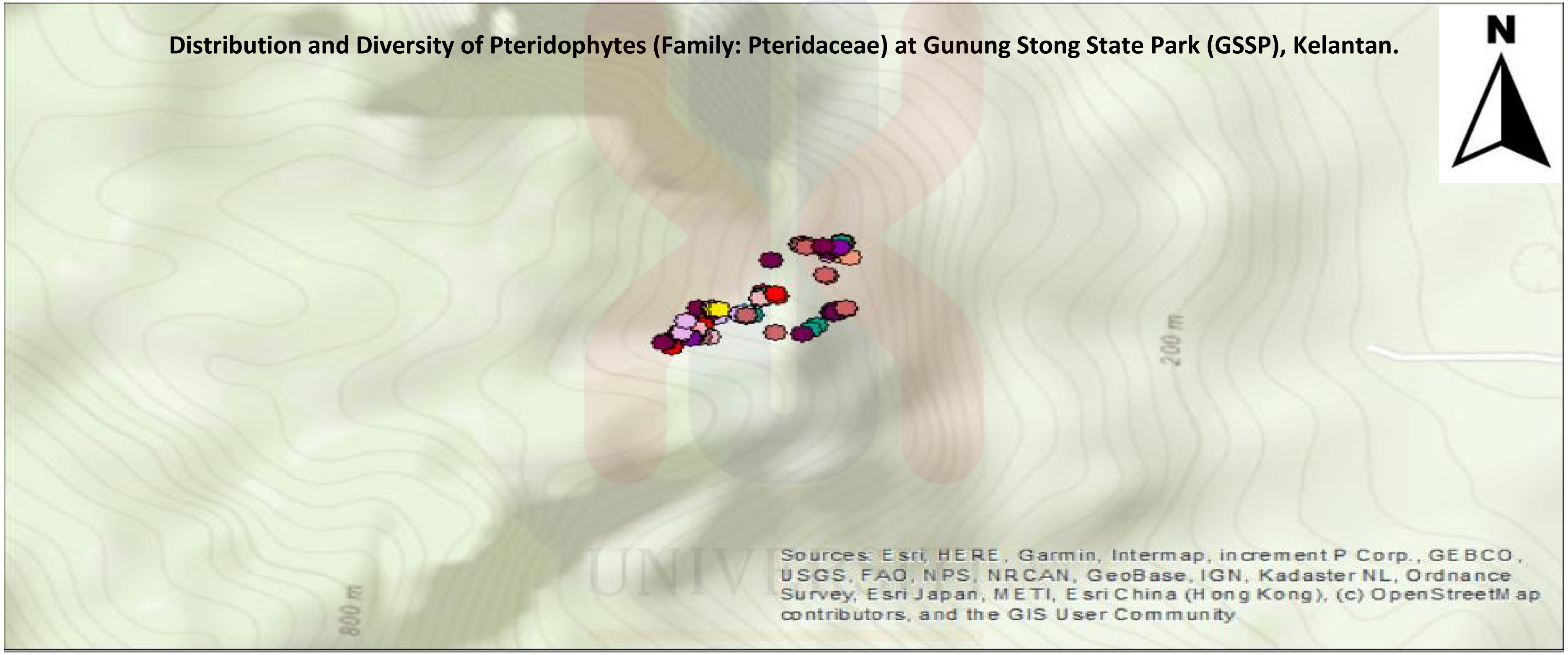
The fieldwork at the GSSP took place over five days, from April 25th to April 29th. The sampling process began at the base of the GSSP and extended to Kem Baha. During this fieldwork, we meticulously recorded the coordinates of pteridophytes along the trails using handheld GPS (Garmin GPS 64s). Additionally, we captured coordinate information and photographs of individual pteridophytes using a smartphone. Subsequently, we created a distribution map using ArcMap version 10.8.

The pteridophytes were observed from the base of the GSSP to Kem Baha. Their distribution pattern exhibited clustering, which is commonly referred to as a "clumped distribution." In such a pattern, individuals tend to aggregate in specific patches or clusters within their habitat. Factors contributing to this distribution pattern may include resource availability, social interactions, and environmental conditions.

Figure 4.1 illustrates the distribution map of Pteridaceae at the GSSP, highlighting the clumped distribution. Additionally, table 4.1 presents the collected data related to these pteridophytes.

Table 4.1: List of Pteridaceae found and recorded in GSSP, Kelantan.

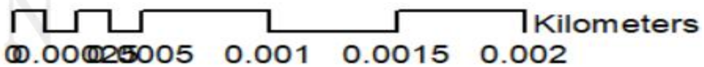
No	Common Name	Species (Family Pteridaceae)	No of individuals	IUCN Red List
1	Delta maidenhair fern	*Adiantum raddianum*	7	Not Evaluated (NE)
2	Tape fern	*Haplopteris elongata*	7	Least Concern (LC)
3	Ribbon fern	*Pteris cretica*	9	Not Evaluated (NE)
4	Faurie's Brake Fern	*Pteris fauriei*	20	Not Evaluated (NE)
5	Golden leather fern	*Acrostichum aureum*	14	Least Concern (LC)
6	Heart Fern	*Hemionitis seticaulis*	8	Not Evaluated (NE)
7	Maidenhair fern	*Adiantum diaphanous*	4	Not Evaluated (NE)
8	Rough maidenhair fern	*Adiantum hispidulum*	4	Not Evaluated (NE)
9	Tailed maidenhair	*Adiantum caudatum*	2	Not Evaluated (NE)
10	Chinese brake fern	*Pteris vittata*	22	Not Evaluated (NE)
11	Broadleaf maidenhair	*Hemionitis radiata*	5	Not Evaluated (NE)



Legend

Figure 4.1: Map of Pteridaceae distribution at GSSP, Kelantan. Each colour shows a species name as shown in the map legend.

Acrotischum aureum	*Adiantum raddianum*
Adiantum caudatum	*Haplopteris elongata*
Adiantum diaphanous	*Hemionitis radiata*
Adiantum hispidulum	*Hemionitis seticaulis*
Pteris cretica	*Pteris fauriei*



4.1.1 Species Diversity of Pteridaceae at GSSP, Kelantan.

Based on the data collected, the species diversity of Pteridaceae at Kem Baha, GSSP, was calculated using the Shannon-Weiner diversity index formula, as shown in Table 4.2 below. The resulting species diversity index for GSSP is 2.183. According to Zach (2022), a higher value of H' shows a higher diversity.

Table 4.2: Species Diversity of Pteridaceae at GSSP, Kelantan.

Scientific name	Number of individuals	pi	lnpi	pilnpi
Adiantum raddianum	7	0.068627	-2.67906	-0.18386
Adiantum diaphanous	4	0.039216	-3.23868	-0.12701
Adiantum hispidulum	4	0.039216	-3.23868	-0.12701
Adiantum caudatum	2	0.019608	-3.93183	-0.07709
Haplopteris elongata	7	0.068627	-2.67906	-0.18386
Pteris cretica	9	0.088235	-2.42775	-0.21421
Pteris fauriei	20	0.196078	-1.62924	-0.31946
Acrostichum aureum	14	0.137255	-1.98592	-0.27258
Hemionitis seticaulis	8	0.078431	-2.54553	-0.19965
Pteris vittata	22	0.215686	-1.53393	-0.33085
Hemionitis radiata	5	0.04902	-3.01553	-0.14782
	102			-2.18339
			H'	**2.183389**

4.1.2 *Adiantum raddianum*

At the study site, seven individuals of *Adiantum raddianum* were discovered. The scattered distribution of *Adiantum raddianum* is due to specific habitat preferences, limited spore dispersal for reproduction, ecological constraints related to soil type and nutrient availability, competition with other plant species, and human impact through urbanization and habitat destruction. *Adiantum* stands out as one of the most easily recognizable leptosporangiate fern genus. *Adiantum raddianum* is not listed on the IUCN red list due to it is not a high-profile species. Despite the remarkable diversity in leaf complexity across its species, all *Adiantum*, a leptosporangiate fern genus, is easily recognizable due to its remarkable leaf diversity. All *Adiantum* ferns share a distinctive feature absent in other ferns: sporangia directly borne on the reflexed leaf margin, forming what is known as a 'false indusium' or 'pseudoindusium.' With over 200 species, *Adiantum* ranks among the top ten most diverse fern genera. Its unique synapomorphy—sporangia borne on indusia rather than laminae—makes it widely distributed in tropical and subtropical regions. Many cultivars, including those derived from *A. raddianum*, are popular ornamentals. While some species occur in temperate areas, maidenhair ferns are typically absent from xeric or frigid climates. The far-reaching *A. capillus-veneris* L. can be found on all continents except Antarctica. Despite diverse leaf morphologies—from simple to highly pinnate—all *Adiantum* ferns share the distinctive feature of sporangia borne on reflexed leaf margins, forming 'false indusia.' This unique attribute defines Adiantum as a 'natural' group, even with variations in leaf structures, including the pseudostate blade architecture seen in *A. pedatum* and related species (Huiet *et al.*, 2018).

Figure 4.2: *Adiantum raddianum*

4.1.3 *Haplopteris elongata*

At the study site, seven individual tape ferns were discovered. There is no specific IUCN status available for this species. *Haplopteris elongata,* has a scattered distribution. It thrives in wet tropical biomes, often growing as an epiphyte or lithophyte. Factors contributing to this distribution include specific habitat preferences, limited spore dispersal for reproduction, and ecological constraints related to soil type and nutrient availability. Additionally, competition with other plant species and human impact through urbanization and habitat destruction play a role. The tape fern exhibits distinct characteristics: it possesses a short to moderately long-creeping, branched rhizome densely covered in scales and dark roots with spreading ginger hairs. Its fronds, linear in shape, measure 25-90 cm in length and three to five (-10) mm in width, tapering at both ends. The lamina, dark green and glossy, is thinly coriaceous and features a prominent midvein in broad-leaved forms, along with very oblique lateral veins. While often confused with *H. ensiformis*, *H. elongata* can be differentiated by its uniformly coloured rhizome scales (compared to the darker middle band in *H. ensiformis*), flatter and lighter green fronds, and more revolute croziers as depicted in Figure 4.3. In hot lowland and tropical swamp forests, large specimens of the tape fern may exhibit elongated creeping rhizomes and broad, apple-green fronds. As an epiphyte, it thrives on other epiphytes, humus, moss, fallen logs, and large boulders within rainforests (Field, 2020).

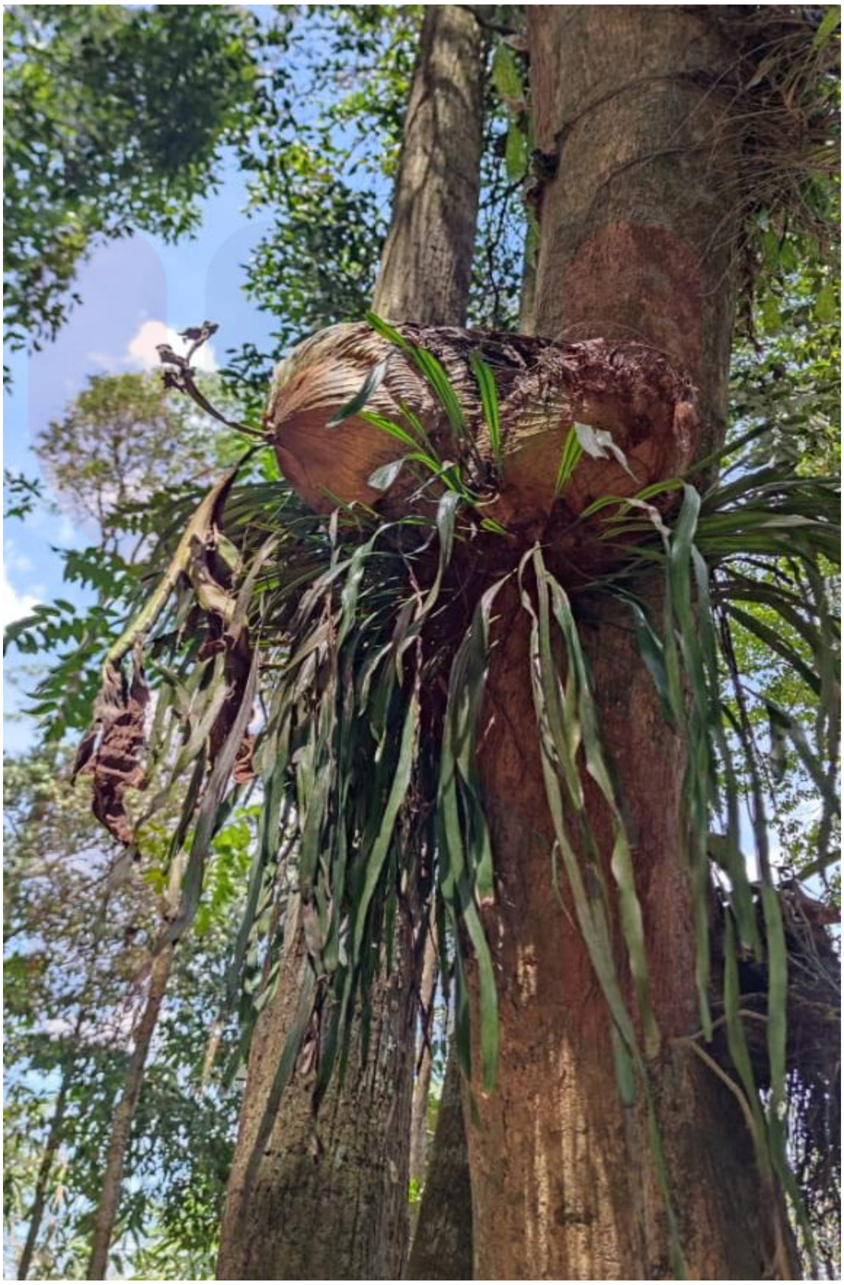


Figure 4.3: *Haplopteris elongata*

4.1.4 *Pteris cretica*

Pteris cretica, commonly known as Brake Fern, was discovered at the study site in the form of nine individuals. *Pteris cretica* has a pantropical distribution. This fern species can be found in various regions, including the Mediterranean, Japan, tropical Asia, and parts of Africa. Moreover, *P. cretica* is widely distributed from tropical to temperate regions of Europe, Africa, Asia, and North and South America (Jaruwattanaphan *et al*., 2013). This species is not evaluated by the IUCN. These ferns exhibit diploid characteristics, with a height ranging from 35 to 70 cm. Their rhizomes ascend and are covered with scales. Brake Fern fronds exhibit dimorphism: fertile fronds are erect, taller, and have narrow pinnules, while sterile fronds are shorter, spreading, and possess wider pinnules. The sterile frond's stipe is thin, long, and straw-coloured. The lamina is unipinnate, rarely ovate, and has a glabrous, papery texture. The pinnae are opposite, and the pinnules are lanceolate, with a roughly cuneate base and an acuminate apex. In contrast, the fertile fronds are longer, with greater linear pinnae that generally have a cuneate base. The spores of *Pteris cretica* are trilete, tetrahedral, and spheroidal, with a lociniate pattern. When viewed proximally, they exhibit a straight laesura, while the distal view reveals a hemispherical shape with a cristate, tuberculate surface. The equatorial view displays an equilateral flange in the middle, and the spores measure between 45–50 and 50–55 µm. *Pteris cretica subsp. cretica* thrives in terrestrial habitats near moist and shady areas, such as water banks, streams, and canals, at altitudes ranging from 250 to 1,200 meters. (Irfan *et al*., 2021).

Figure 4.4: *Pteris cretica.*

4.1.5 *Pteris fauriei*

Pteris fauriei, a fern species, was observed at the study site with a total of 20 individuals. *Pteris fauriei*, also known as the Cretan brake fern, has a pantropical and clustered distribution. It is native to South and East China, extending to Temperate East Asia, and from the Philippines to the Caroline Islands. This perennial fern primarily grows in subtropical biomes. The distribution of ferns like *Pteris fauriei* results from a combination of factors, including efficient spore dispersal mechanisms and adaptations that allow them to thrive in diverse tropical and subtropical regions. There is no specific IUCN status available for this species. Within the *P. fauriei* species, two recognized varieties exist: *P. fauriei var. fauriei* and *P. fauriei var. minor*. The former typically has herbaceous laminae and thrives in cooler environments, while the latter features coriaceous laminae and is commonly found in warmer habitats. Interestingly, in Taiwan, there are undescribed *Pteris* plants often mistaken for *P. fauriei* var. *fauriei* due to their herbaceous laminae. However, these plants have broader laminae and pinnae compared to other bipinnatifid *Pteris* species documented in Taiwan. Beyond Taiwan, *P. natiensis Tagawa*—an apomictic and diploid fern endemic to Japan—resembles the Taiwanese species morphologically. Notably, *Pteris* species in general have wide pinnae (up to 7 cm across) and fewer pairs of lateral pinnae (usually 2–5 pairs). Additionally, the terminal pinnae of sterile fronds are larger than the lateral ones. These distinguishing characteristics help differentiate the undescribed species from both *P. fauriei* var. *fauriei* and *P. fauriei* var. *minor* in Taiwan. (Chao *et al*., 2017).

Figure 4.5: *Pteris fauriei*

4.1.6 *Acrostichum aureum*

Acrostichum aureum, commonly known as golden leather fern is a well-known mangrove fern. At the study site, ten individuals of this species were identified. *Acrostichum aureum* has a pantropical and clustered distribution. It is found in tropical and subtropical areas worldwide, including the Caribbean, South and Southeast Asia, Australasia, and both East and West Africa. This large fern grows in swamps, mangrove forests, salt marshes, and along riverbanks. Despite its tolerance for raised salinity levels, spores germinate better in fresh water. The golden leather fern thrives in wet tropical biomes and can even regenerate in dense stands within mangrove forests. This species is listed as Least Concern (LC) by the IUCN. It is widespread in mangrove ecosystems and is not currently at risk. Belonging to the family Pteridaceae and the genus *Acrostichum*, it stands out as the sole fern genus that thrives in the marine intertidal zone. Its global distribution primarily encompasses coastal regions in tropical and subtropical areas. Notably, *A. aureum* plays a dominant role in various mangrove ecosystems worldwide, including those in Nigeria.

The fern's anatomical and molecular adaptations allow it to thrive under challenging conditions, such as tidal fluctuations, turbulence, floods, high salinity, and long-term climate changes. Traditional practitioners alike are increasingly interested in *A. aureum* due to its ethnomedicinal properties as it produces phytochemicals that hold promise for managing diseases like cancer, diabetes, ulcers, and viral infections.

Across different countries, various parts of *A. aureum* have been traditionally employed to treat a range of ailments. Different parts of *A. aureum* are widely used traditionally to cure various ailments and diseases in different countries across the world as shown in Table 4.3 below. *A. aureum* has a rich tradition of therapeutic use across various countries. Its skin applications include treating abscesses, boils, and skin infections using leaves in lotions, creams, and ointments. In Malaysia, Sri Lanka, and Vietnam, powdered or ground rhizomes are employed to address wounds, non-healing ulcers, and bleeding. Furthermore, in Sri Lanka, the leaves are utilized for conditions like hemorrhoids, gastritis, dysentery, and inguinal hernia.

Acrostichum aureum which is commonly known as Golden Leather Fern has a diverse range of traditional uses across different cultures. It serves as an antidote for snakebites in India, while its fertile fronds and roots are employed to treat syphilitic ulcers, pharyngitis, and diabetes. In Fiji, various parts of the fern address chest pains, fever, elephantiasis, asthma, sore throat, and constipation. Additionally, it is believed to enhance healthy pregnancies. The fern's applications extend to respiratory ailments, acting as a styptic, anthelmintic, and astringent in bleeding. Leaves of *A. aureum* are used to cure cloudy urine in Bangladesh and Costa Rica. In China, the rhizome treats worm infections, ulcers, and bladder issues. Young fronds are sold as vegetables in Sri Lanka, Malaysia, and Indonesia. The fern also plays a role in stopping bleeding, relieving pain, and treating hypotension, worms, and digestive problems. Beyond medicine, it serves as plant support, thatching material, and even fodder for livestock. (Akinwumi *et al*., 2022)

Table 4.3: Traditional medicinal uses of *Acrostichum aureum*.

Country/Region	Part used	Uses in Traditional Medicine
India	Fronds	Antidote for venomous snakebites
		Antifungal
	Fronds and roots	Syphilitic ulcers, pharyngitis, chest pain and diabetes
Malaysia	Rhizomes	Wounds, snake bite and boils
	Fronds	Hypotension, worms, digestive issues
Fiji	Plant	Sore throat, chest pains, elephantiasis purgative and febrifuge
Bangladesh	Leaves	Cure cloudy urine in women
	Rhizome	Wounds, peptic ulcers, boils
Malaysia	Leaves	Stop bleeding
China	Rhizome	Worm remedy, inveterate ulcers
		Bladder complains
Borneo	Fertile Fronds	Syphilitic ulcers
Costa Rica	Leaves	Emollients
Kerala	Whole plant	Astringent in hemorrhage
Panama	Young fiddleheads	Medicinal bath for infant
Vietnam	Rhizome	Wound healing
Colombia	Young fiddleheads	Extract fish bones from the throat
Suriname		Abortifacient
Nigeria	Roots	Baby lotion
	Leaves	Skin infection and stomach pain

Source: (Akinwumi *et al*., 2022)

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Figure 4.6: *Acrostichum aureum*

4.1.7 *Hemionitis seticaulis*

Hemionitis seticaulis which is commonly known as Heart Fern is a delicate plant species found at the study site, with a total of five individuals. *Hemionitis seticaulis,* has a scattered distribution. It is native to Tropical Asia, New Zealand, and New Caledonia. This fern primarily grows in wet tropical biomes. Factors contributing to its scattered distribution include specific habitat preferences, limited spore dispersal for reproduction, and ecological constraints related to soil type and nutrient availability. There is no specific IUCN status available for this species. Belonging to the Pteridaceae family, specifically the Hemionitis genus, this fern is native to Southeast Asia. Its slender rhizomes and distinctive appearance make it a sought-after choice for cultivation in various regions. *Hemionitis seticaulis* as shown in Figure 4.7 is known for its distinctive appearance and is cultivated in various regions. The *Hemionitis seticaulis*, a fern with more than just aesthetic appeal, has a rich history as a healing plant. In the verdant landscapes of Asia, traditional medicine has recognized its potential in addressing cancer and diabetes. The unassuming leaves, often overlooked, hold valuable medicinal properties, providing a natural remedy for those who are aware.

Figure 4.7: *Hemionitis seticaulis*

4.1.8 *Adiantum diaphanous*

Adiantum diaphanous, commonly known as Filmy Maidenhair, is a delicate fern species found at the study site. *Adiantum diaphanous* exhibits a scattered distribution. While it occurs in multiple regions across its range, individual populations are spread out rather than concentrated in dense clusters. In its natural habitats—moist, shaded environments like rainforest and stream banks—this fern grows in isolated pockets where conditions favour its growth. There is no specific IUCN status available for this species. There are a total of three individuals of this species. Its distribution extends across the Malesian-Pacific region. In Australia, it thrives near water, often growing on rocks or soil along creeks and rivers within closed forests. Along the East Coast of Australia, from Cape York to Victoria and on Norfolk Island, this fern is commonly encountered. Beyond Australia, it extends to New Zealand, southern China (Hainan), Vietnam, Malesia, Taiwan, Japan, and even as far east as Fiji. Notably, *A. diaphanous* stands out due to its proliferous root nature, a feature that distinguishes it from other species in the *Adiantum* genus. It forms clonal colonies through root bud proliferation. *A. diaphanous* (Figure 4.8) is the only species in the genus to form clonal colonies by proliferation from root buds (Bostock, 1992).

Figure 4.8: *Adiantum diaphanous*

4.1.9 *Adiantum hispidulum*

Adiantum hispidulum, with the presence of four individuals at the study site, exhibits distinct hair characteristics. *Adiantum hispidulum* displays a scattered distribution. It occurs in parts of Southeast Asia, including Indonesia and Malaysia. This fern thrives in various environments, such as open forests, rocky areas, and stream banks. While it prefers humid, shaded locations, it can also adapt to less dense forest areas. This species is not listed on the IUCN Red List. *Adiantum hispidulum*, discovered during a botanical expedition to Hong Thong Waterfall in Phu Kradueng National Park, Loei Province, NE Thailand, has a fascinating distribution history. Previously known to occur in tropical Africa, Madagascar, Mauritius, India, China (through Malaysia to Australia), as well as New Zealand and Pacific islands, this attractive fern species is commonly referred to as rough maidenhair or rosy maidenhair. It has gained commercial significance in several countries, including Thailand, and can be easily propagated from spores (Boonkerd & Pollawatn, 2013). It is commonly found in various regions and is not currently at risk. Notably, no glabrous (hairless) plants were observed. However, the ferns showed dimorphism in hair nature most had short, stiff hairs measuring 0.1–0.8 mm, while others featured longer, lax hairs ranging from 0.3 to 1.0 mm. These variations correspond to different species, including *A. pubescens* and different varieties of *A. hispidulum* (Brownsey *et al*., 2019). *Adiantum hispidulum* as shown in Figure 4.9.


Figure 4.9: *Adiantum hispidulum*

4.1.10 *Adiantum caudatum*

Adiantum caudatum, commonly known as Tailed Maidenhair is a fern species discovered at the study site, with a total of three individuals. *Adiantum caudatum* displays a scattered distribution. It occurs in tropical and subtropical regions across Asia, including India, Sri Lanka, Thailand, Malaysia, Indonesia, and the Philippines. This fern thrives in moist, shaded environments such as rainforest and stream banks. It is also adaptable, often growing in disturbed habitats like roadsides and forest edges. There is no specific IUCN status available for this species. Belonging to the Pteridaceae family, this plant genus encompasses around 200 species distributed globally across temperate and tropical regions. In traditional medicine, *A. caudatum* is valued for its diverse medicinal properties. It serves as a remedy for ailments such as cough, diabetes, jaundice, fever, skin diseases, diarrhea, and wounds. Ayurveda also recognizes its potential in treating conditions like prameha (diabetes), Atisara (diarrhea), pravahika (dysentery), and fever. Phytochemically and pharmacologically potent, this fern is frequently cited in various medical systems. Its distribution spans the lower slopes of hills in Punjab, Rajasthan, Bengal, Tamil Nadu, and Maharashtra.

Typically, favouring humus-rich, moist, and well-drained sites—ranging from foundation soils to vertical rock walls—*A. caudatum* offers promise for tissue culture through spores. This approach ensures maximum genetic diversity within a short timeframe, promoting resource sustainability. Additionally, in vitro culture of spores and gametophytes reduces pests and contamination compared to conventional soil-based cultivation. Despite its significance, there are still knowledge gaps regarding the prothallium structure, gametophytic phase, and complete life cycle of this medicinal fern. Investigating its reproductive biology and establishing micropropagation protocols are crucial for conservation efforts. Furthermore, extracting secondary metabolites from tissue-cultured plants will enhance our understanding of its medicinal properties, particularly its potential as an anti-diabetic agent (Gayathiri *et al*., 2018).

Figure 4.10: *Adiantum caudatum*

4.1.11 *Pteris vittata*

The *Pteris vittata* has the common name- Chinese brake fern, there are 31 individuals of Chinese brake fern found at the study site. *Pteris vittate* exhibits a clustered distribution. It is native to tropical and subtropical regions worldwide, including parts of Asia, Africa, Australia, and the Americas. The fern grows in isolated pockets where conditions are favourable, and its ability to colonize disturbed areas contributes to its widespread presence across various landscapes. This species is not listed on the IUCN Red List. It is known for its ability to hyperaccumulate arsenic. By using scanning electron microscopy (SEM), researchers discovered intriguing features in the pinnae of *Adiantum caudatum*. The epidermal cells displayed elongated shapes with raised periclinal and sinuous anticlinal walls. These pinnae were hypostomatous, featuring randomly scattered anomocytic stomatal complexes positioned at the same level as the epidermis. Within each vascular bundle, the xylem strands resembled seahorses (hippocampus). In contrast, the pinnae exhibited triangular vascular bundles with uniform mesophyll organization, consisting of homogenous lobed parenchyma cells. The fern's indumentum included trichomes on the pinnae and scales on the rachis and stipe. Additionally, the roots developed a dense network of long root hairs, approximately 244 μm in length. The sporangia, found in submarginal positions along both pinna margins, had oblong shapes and short, thick stalks. Their annulus was vertically positioned, resulting in transverse sporangium dehiscence. Paraphyses—uniseriate, unbranched, and septate—intermingled with the sporangia. Lastly, the globose spores featured a thick reticulum on their exine, with round tubercles in the areoles. The exine of the globose spores was adorned with a thick reticulum in which the areoles contained round tubercles as shown in Figure 4.6 (Bondada *et al*., 2006).

Figure 4.11: *Pteris vittata*

4.1.12 *Hemionitis radiata*

Hemionitis radiata, also known as *Adiantopsis radiata*, stands out as the most distinctive species within the *Adiantopsis* genus due to its unique palmate morphology. *Hemionitis radiata*, commonly known as the Radiated Fern or Heart Fern, displays a scattered distribution. It is native to tropical and subtropical regions of the Americas, including Central and South America (countries like Mexico, Brazil, and the Caribbean islands). This fern prefers moist, shaded environments such as rainforest understories, stream banks, and other humid areas. It often grows on rocks, in crevices, or on the forest floor. Its scattered presence reflects its adaptation to specific microhabitats within its broader geographic range. There is no specific IUCN status available for this species. The pinnae of *Adiantopsis radiata* radiate outward from a single point at the stipe apex, creating a characteristic appearance. However, young *A. radiata* can be mistaken for young *A. pedata* and *A. pentagona*, as all three taxa share a similar ternate juvenile form. To differentiate them reliably, consider the indurated arcus cell count: *A. radiata* has a mode of 20 indurated arcus cells, while *A. pedata* and *A. pentagona* exhibit modes of 14 and 16, respectively. Additionally, note that the stipes of *A. radiata* lack carinae, unlike the always adaxially bicarinate stipes of *A. pedata* and *A. pentagona*. Another useful distinguishing feature lies in the ultimate division shape and orientation: *A. radiata* typically has oblong ultimate divisions with rounded apices, while *A. pedata* displays more frequently oblanceolate ultimate divisions with distinctly toothed apices that ascend. Interestingly, *Adiantopsis radiata* plays a role in a fascinating pattern of reticulate and morphological evolution, as it hybridizes with various pinnate taxa to produce pedate derivatives (Barker & Hickey, 2006).

Figure 4.12: *Hemionitis radiata*.

Table 4.4: Type of distribution of all species found within GSSP

Scientific name	Elevation (m) a.s.l	Type of distribution
Adiantum raddianum	*457-482*	Scattered distribution
Adiantum diaphanous	*483-514*	Scattered distribution
Adiantum hispidulum	*471-515*	Scattered distribution
Adiantum caudatum	*489-503*	Scattered distribution
Haplopteris elongata	*475-497*	Scattered distribution
Pteris cretica	*498-504*	Scattered distribution
Pteris fauriei	*458-517*	Clustered distribution
Acrostichum aureum	*487-515*	Clustered distribution
Hemionitis seticaulis	*465-487*	Scattered distribution
Pteris vittata	*457-492*	Clustered distribution
Hemionitis radiata	*462-485*	Scattered distribution

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 CONCLUSION

Overall, the study revealed the species richness of pteridophytes, particularly within the family Pteridaceae in Gunung Stong State Park (GSSP). The results indicated the presence of 11 species, totaling 102 individuals across five genera of Pteridaceae in GSSP. The distribution types of pteridophytes included scattered and clustered depending on the species' behaviours. Pteridophytes exhibit several essential characteristics that contribute to their successful growth. Pteridophytes spore-based reproduction enables wide dispersal and colonization. Additionally, pteridophytes exhibit adaptability to varying environmental conditions, such as light levels and soil types. Underground rhizomes serve as nutrient storage organs and facilitate vegetative growth. Furthermore, their unique leaf morphology, often characterized by intricate fronds, maximizes photosynthesis efficiency.

5.2 RECOMMENDATION

It is suggested to spend more time doing sampling work to collect Pteridophytes at Gunung Stong State Park, especially in different months. This can update the number of species found at Gunung Stong State Park for further research. To enhance the understanding of pteridophyte diversity and distribution in Gunung Stong State Park (GSSP), researchers propose two key strategies. Firstly, extending fieldwork duration allows for the observation of species across various life stages, thereby increasing the chances of detecting rare pteridophytes with sporadic growth patterns. Additionally, interannual climate fluctuations are accounted for during longer study periods. Another recommendation is to systematically explore different microhabitats within the park. By sampling ecological niches such as forest floors, rock crevices, and tree canopies, scientists can uncover species preferences and adaptations. This method allows for the identification of specialized habitats where specific pteridophytes thrive, contributing to a comprehensive understanding of their ecological roles and distribution patterns.

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