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Terrestrial Fern Diversity in Palak Siring Waterfall and Its Potential to Support Junior High School Science learning

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Abstract: The Palak Siring Waterfall is a natural tourism object located in Kemumu Village, Armajaya District, North Bengkulu Regency were the area have variety of vegetation. This research aims to analyze the Terrestrial Fern Diversity in that area. The benefits of ferns in an ecosystem are as one of the pioneer organisms that open and start a new life in an ecosystem, food sources, and planting media. The method used is transect by forming (five) plots based on the slope of the land, consist of flat, sloping, rather steep, steep, and very steep areas. Plot size of 20 x 20 m placed along the transect line. Based on the survey was found 22 species with 13 types of family ferns in the Palak Siring Waterfall. The Diversity Index value of ferns (*pteridophyta*) belongs to the medium category. This certainly indicates that there is a fern that can adapt to the environment as well as other plants in area. Diversity of fern have the potential to be applied to junior high school science learning through several Basic competencies, materials, and forms of learning activities.

Keywords: Diversity; Fern; Palak Siring; Bengkulu

Introduction

Indonesia is one of the rich countries in producing natural forest resources that stretch wide in almost every region. However, due to interferencehumans, including habitat loss, new harmful pathogens, environmental pollution, and the climate crisis, etc., account for about 40% of the world's crops faced with the risk of extinction (Zhao et al., 2022). One of the plants that we can find in almost every area of Indonesian forests is a fern (*Pteridophyta*). Ferns are vascular plants that produce spores and undergo alternation of generations, with the *gametophyte* generation and separate sporophytes that exist as free-living plants (Praptosuwiryo et al., 2019). Due to its wide distribution pattern and ability to live in terrestrial, epiphytic, and aquatic habitats. According to Jones et al., (2020) Ferns typically occupy wet shaded habitats and are most common in humid environments due to insufficient control over water loss. Ferns also finding in Indonesia, moreover, most of ferns like in the wet tropics(Sari, 2022).

Ferns are a group of plants with corms, meaning that their bodies can be divided into three main parts, namely roots, stems, and leaves (Salamah et al., 2020). Considered to be the earliest land plants and their wealth has been shown to predict wealth species as a whole (Bergeron & Pellerin, 2014). In general, *pteridophytes* are perennial herbs that have rhizomes that spread on the ground and dominate the vegetation of a certain area so that they form broad roots and suppress other plants(Yusal & Toni, 2021). Pteridophyta is grouped into 4 classes, namely class *Psilophtinae*, class *Lycopadiinae*, class *Equesetinae*, class *Filicinae* (Yunita et al., 2022). Their place of life is in moist areas, at the base of plants, in the mountains, or on the banks of rivers (Karim et al., 2022).

The advantage ferns other hand, for humans, these plants have the ability as a source of food, raw material for handicrafts, ornamental plants, and medicines, especially as a planting medium in plant cultivation (Syukur, 2019). As it constrains ecosystem services such as biological productivity, capacity water retention and carbon storage (Ohler et al., 2023). This is especially the

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case with ferns *Cyathea Sp* which has a very large role in the balance of forest ecosystems, including as a prevention of erosion(Wiranto et al.,2021). The existence of *Pteridophyta* as one of the components of the ecosystem can indicate whether the area supports the life of an organism or not because it has reciprocal bonds and interdependence with its environment (Kurniawati et al., 2016). Because, According A'tourrohman et al., (2020) availability of basic information regarding community composition and structure constituents are very important in conservation efforts. *Pteridophytes* are independent of pollen and seed vectors their habitat and other environmental factors such as the type of land cover and anthropogenic disturbance (Abotsi et al., 2020). Agrees with Sarkki et al., (2023) in research, which is about the question of how much and how we should protect nature to avoid sacrificing human well-being now and in the future. According to research from Oseguera-Olalde et al., (2022) Ferns and *lycophytes* (hereinafter referred to as ferns for simplicity) is a useful study group for assessing patterns of diversity biodiversity due to their global distribution.

The characteristics of the Kemumu tourism zone are waterfalls, rocks, stairs, cold places, slippery paths, and tracking and adventure tourism activities (Utama et al., 2022). Most of the area has a plain and hilly topography According to Yolla et al. (2022), the diversity of ferns is currently under-recognized when compared to other plant groups. Agree with this opinion, according to Khine & Schneider, (2020) conservation of *pteridophytes* has received comparably less attention than the other plant groups including in the IUCN Red List for the first time in 2003, although *pteridophytes* including ferns and lycophytes are the second most species rich group of vascular plants composing of ca.11,936 species globally.

Information ferns in this area have the potential to support science learning in junior high schools (SMP) with the subject matter of Classification of Living Things. According to Anggriani et al., (2019) environmental-based educational activities are an educational approach that takes advantage of the close environment as a learning resource to increase the learning capacity of students.

Not much is known about the diversity of fern species in the Palak Siring Kemumu Waterfall Nature Tourism Area. This research aims to analyze the terrestrial fern diversity in Palak Siring Waterfall. Information about the diversity of ferns can be used as support in science learning.

Method

The research was carried out in the Palak Siring Waterfall Area which is located in the Kemumu Village, Armajaya District, North Bengkulu Regency, Bengkulu Province. This research was conducted on March 30-April 5 2023. The research method used was the transect method. The tools used include 1 meter (2 pieces) stakes, wooden stakes, raffia rope, stationery, a camera, a tape measure, a hygrometer, a soil tester, an identity book, a lux meter, and a clinometer. The material used is a diversity of fern species found in plots. This study used the transect method by dividing the plots into 5 plots based on the land's slope, namely flat, sloping, rather steep, steep, and very steep areas. The map of the slope of the land in The Siring Kemumu Waterfall Natural Tourism Area is shown in Figure 1.

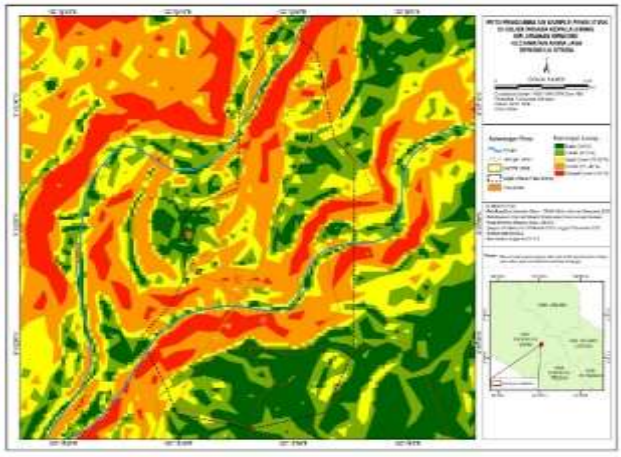

Figure 1. Land Slope of the Palak Siring Area

Result and Discussion

Analysis of Fern Diversity

Based on the Table 1 that shows the abiotic condition were supported environmental in the area. Pramudita et al. (2021) stated that ferns in their growth are influenced by abiotic aspects. Abiotic aspects that affect the development of ferns include soil Ph, soil moisture, air temperature, light intensity, air humidity and land slope. According to Rizky et al., (2019), Temperature is a significant aspect because it determines the speed of reactions and chemical activity in life processes.The high level of Temperature and humidity in this area is based on the canopy of shady trees, which dominate quite densely, so that the incoming intensity is not-too-big. This also affects the slope factor of the land, which is found with the higher the area, the lower the temperature level in the area.

Table 1. Environmental Conditions in the Palak Siring Kemumu Waterfall Nature Tourism Area in each Plot.

Location	Environmental factor					
	Soil Humidity	Temperature (C)	Soil pH	Light intensity	Air Humidity (%)	Land Slope
Plot 1 (Very Steep)	6.8	27.4°	2	423	94	54°
Plot 2 (Steep)	6.6	30.5°	1.2	1410	79	38°
Plot 3 (Rather Steep)	6.9	27.6°	1.2	976	84	25°
Plot 4 (Flat)	6.7	27.2°	1.2	402	94	8°
Plot 5 (Sloving)	6.2	28.8°	3	762	92	14°

Ferns in the forest are generally that like shaded areas (Rizky et al., 2019), The ferns in the forest are protected from heat and strong winds so that the light intensity is less and the humidity is high. The lowest intensity is found in Plot 4 (flat area). The high content of soil organic matter through (C-organic), which comes from the decomposition of fallen leaves (litter) (Nursanti et al., 2022). Temperature can affect plant morphogenesis, such as accelerated flowering with a long time cold treatment period, and promotion of seed germination, stem growth, and plant growthand development, which is called thermomorphogenesis (Jung et al., 2023) and for soil moisture, 6.2-6.9. According to Jayadi (2015), stated that under conditions of high humidity, the growth and development of soil microorganisms become more optimal, so the decomposition process seems faster (Nursanti et al., 2022).Meanwhile according to (Liang et al., 2022) soil moisture can change soil aeration and have an impact on N transformation and migration, including mineralization, nitrification, and processes denitrification. In analyzing the condition of the abiotic environment in an area, one must look at other important factors, such as soil pH. The high content of soil organic matter through (C-organic) which comes from the decomposition of fallen leaves (litter) (Nursanti et al., 2022). And for soil moisture 6.2-6.9. According to Jayadi (2015), stated that under conditions of high humidity, the growth and development of soil microorganisms become more optimal, so the decomposition process seems faster (Nursanti et al., 2022).

Table 2. Diversity of Ferns (*Pteridophyta*) in the Palak Siring Kemumu Waterfall

Species Name	Family
Polypodiaceae	Phymatosorus nigrescens,Goniophelebium subauriculatum, Goniophlebium persicifolium, Drynaria sp
Selaginella	Selaginella waliichi, Selaginella wildenowii, Selaginella intermedia, Selaginella sp 1, Selaginella doederleinii
Cyatheaeceae	Cyathea contaminans, Cyathea latebrosa
Thelypteridaceae	Christella dentata , Christella parasitica
Aspidiaceae	Heterogonium pinnatum
Blechnaceae	Blechnum vestitum
Dennstaedtiaceae	Microlepia spelunca
Osmundaceae	Osmunda javanica
Gleicheniaceae	Dicranopteris linearis
Athyriceae	Diplazium sp
Marattiaceae	Angipteris evecta
Cyathea	Cyathea moluccana
Nephrolepidaceae	Nephrolepis cordifolia

The table shows ferns in the area, 22 species of ferns with various characteristics of each. Several specieses of ferns found, the most numerous were 5 species from the *Selaginella* family. This is according to Arianto, et al (2019) at Palak Siring, showing that there are 75 species of seedlings. The most dominant seedling vegetation is *Selaginella plana*, and the *Selaginella* group belongs to ferns. So many *Selaginella* groups are found in the area. The following is an explanation of the description of fern species:

Phymatosorus nigrescens

Ferns belonging to the *Polypodiaceae* family are epiphytic or terrestrial ferns. This type of plant has the shape of a long creeping rhizome, with round stalks and smooth shiny brown color and the color of the leaf bones is blackish brown—green pinnate leaf shape with ovate leaf blade shape with wavy leaf edges. According to Kurniawati et al., (2016), one of the uses of the *Phymatosorus nigrecens* type fern is as an ornamental plant. *Phymatosorus nigrecens*, creeping, scaly rhizome, stalk rounded, smooth, shiny, green, single enthale, shared pinnate, smooth, ovate leaves, wavy edges,

pinnate venation with forked tips. Many species prefer everwet forests at low to middle elevation,but some are also found in monsoon seasonal vegetation and drier habitats(Zhang et al., 2021) .These characteristics can make this species different from other species.The pictures of the species *Phymatosorus nigrecens* are shown in Figure 2.

(a) (b) (c)

Figure 2. *Phymatosorus nigrecens* : a). Reseacher documentation; b), (Piggot, 1988) and c. Dita (2018)

Nephrolepis cordifolia

This type of fern belongs to the *Nephrolepidaceae* family. This fern, known as the local name of this fern, has a fibrous root system that is brown with a cylindrical, spreading rhizome. It has a brownish-green stem with fine hairs along the stem with a height of ± 40 cm. Has pinnate compound leaf type, leaflets opposite each other with flat leaf edges and pointed leaf tips, when young leaves are rolled green in color with fine hairs covering them, leaflets ± 3 cm long. According to Ayatusa'adah & Dewi, (2018), sorus in *Nephrolepis cordifolia* ferns can be found in the leaf veins on the edges and in the middle which are round. The benefits of the *Nephrolepis cordifolia* plant species are as a potential contraceptive drug, overcoming menstrual disorders, and wounds, antibacterial, antifungal, anticancer, antimalarial, antioxidant, antitumor, anti-UV radiation, treating coughs, diarrhea, enteritis, jaundice with using parts of rhizomes, leaves, tubers from plants (Renjana et al., 2021). The pictures of the species *Nephrolepis cordifolia* are shown in Figure 3.

(a) (b) (c)

Figure 3. *Nephrolepis cordifolia* : a). Researcher documentation; b). (Piggot, 1988) and c). Ayatusa'adah & Dewi (2017)

Microlepia spelunca

This type of fern belongs to the *Dennstaedtiaceae* family which has an upright rhizome shape and dark brown scales with fine thorns on the rhizome. Stem round cylindrical green and hard with a length of ± 50 cm. The leaves of the venation type are perforated with the distance between the leaflets which are tenuous and arranged alternately between the leaflets, the length of the leaves is ± 8cm. The sori are brownish below the submarginal leaflets. This is according to the explanation According to Renjana et al. (2021) Sorus are on the abaxial leaves, several 1-2 on each pinula and form a cup-shaped indusium(Kurniawati et al., 2016). The pictures of the species *Microlepia Spelunca* are shown in Figure 4.

(a) (b) (c)

Figure 4. *Microlepia Spelunca* : a). Researcher documentation; b) Piggot (1988) and c) Renjana et al., (2021)

Goniophelebium subauriculatum

A fern that belongs to the Polypodiaceae family which can live in epiphytic and terrestrial habitats. According to Piggot (1988) when sori ripen, bright yellow spores are released. Sterile, 68 cm long, in wet rock. The fertile pinnae are 1.3 cm wide, showing two distinct series of areoles. Part of tertile lamina, 3 mm wide. This fern species is found in plains with a soil pH of 6.7 and humidity of 94%. The pictures of the species *Goniophelebium subauriculatum* are shown in Figure 5.

(a) (b) (c)

Figure 5. *Goniophelebium subauriculatum*: a). Researcher documentation; b).Piggot (1988) and c). ATH(2022)

Heterogonium pinnatum

A fern that belongs to the *Aspidiaceae* family. This type of fern is found in very steep areas, namely at a slope of 54°. Rooted in brown fibers, rhizome forms (rhizome) that spreads dark brown covered with hairs that coat it in the soil. The stems are round brown, grow upright with a slightly curved, dichotomous branch, with a stem height of ± 15 cm. The leaves are elongated, the edges of the leaves are coarsely serrated and the tip of the leaf base is tapered, the type of compound leaf is ± 6cm long. According to Krisnawati & Wardiyanti (2020), The species *Heterogonium pinnatum* has pinnate leaf sheaths, with three pairs of pinnate leaves that are

free, fused, and attached to the topmost leaf blade, with deep grooves. The pictures of the species *Heterogonium pinnatum* are shown in Figure 6.

(a) (b)

Figure 6. *Heterogonium pinnatum*: a). Researcher documentation; b).Piggot (1988)

Blechnum vestitum

A fern that belongs to the *Blechnaceae* family has long, shiny leaves. This type of plant has a terrestrial habitat. It has a brown root system with dark brown rhizomes and is covered with hairs that coat it. It has the shape of elongated leaves that are shiny green in color, with loose spacing between leaves and alternately arranged between leaves with a length of ± 12 cm. Stem is a brown round tube curved downwards, stem length ± 30 cm. At maturity it ruptures, revealing sporangia that almost cover the undersurface of the pinna (Piggot, 1988). The pictures of the species *Blechnum vestitum* are shown in Figure 7.

(a) (b)

Figure 7. *Blechnum vestitum*: a). Researcher documentation; b).Piggot (1988)

Christella dentata

One of the fern plants that are easy to find because of its habitat can survive in terrestrial, epiphytic, and lithophytic areas. This type of plant belongs to the *Thelypteridaceae* family. It has a brown fibrous root system. with upright rhizomes and creeping scaly dark brown. The shape of the venation leaves is interspersed, and the arrangement of the leaves is alternate, with a wide gap between the leaves. Leaf length ± 8 cm. The shape of the petiole is greenish brown, and the length of the stem is ± 35 cm. Sorus is kidney-shaped on the abaxial leaf, located supra-medial on the leaf, the sorus is arranged into two rows on each leaf bend consisting of 2-4 sorus in each row (Agatha et al., 2019). The pictures of the species *Christella dentata* are shown in Figure 8.

(a) (b) (c)

Figure 8. *Christella dentata*: a) Researcher documentation; b) Piggot (1988) and c) Agatha et al. (2019)

Christella parasitica

A fern that belongs to the *Thelypteridaceae* family, can be found in open areas. This type of plant is often found in steep areas with a soil pH of 6.6 and humidity of 79%. It has a fibrous root system with brown color with long vines of dark-colored rhizomes. The shape of the leaf venation is a fork, with very close spacing between the leaves, the length of the leaves is ± 7cm. The shape of the upright leaf stalk is green with a stalk length of ± 30cm. The sorus is located abaxial to the leaf. According to (Agatha et al., 2019) who conveyed the Distinguishing Characteristics of *Cyclosorus* and *Christella*: the distance between the leaflets is very tight, the leaves are hairier, and the leaf color is paler (yellowish green). The pictures of the species *Christella parasitica* are shown in Figure 9.

(a) (b) (c)

Figure 9. *Christella parasitica*: a). Researcher documentation; b).Piggot (1988) and c). Agatha et al. (2019)

Osmunda japonica

A fern that belongs to the *Osmundaceae* family, Fibrous root shape with dark, fleshy, and spreading rhizomes. Stems that are elongated and curved downwards are brown with a length of ±60 cm. Monomorphic leaf shape, alternately arranged with loose leaf spacing, leaf edges glossy and leaf tips tapered, leaf length ± 20 cm. According to Flora Of China "*Osmunda japonica Blume*" 1828, pinnae 25-30 pairs, lower pair opposite up to 22 x 2-2.5 cm, upper alternately ascending, 4-5 cm apart, lanceolate, all edges, wavy, or small serrated, thick veins, 2 or 3 times branched. As for the benefits of this species, it has been around for a long time used in TCM to remove heat, stop pathological bleeding, kill parasites, etc. Its biological activities include antiviral, antiherpetic, hemostatic, and pesticide(Bowen et al., 2020). The pictures of the species *Osmunda japonica* are shown in Figure 10.

(a) (b)

Figure 10. *Osmunda japonica*: a) Researcher documentation; b) Piggot (1988)

Goniophlebium persicifolium

Belonging to the *Polypodiaceae* family, this type of fern is an epiphytic fern found in very steep areas with a soil pH of 6.9 and 94% humidity. It has the shape of a black creeping rhizome, with brown leaf stalks ± 40 cm long. This fern are compound with wavy edges, green, smooth, long, and glistening 80-100 cm, sori are found between the leaf veins, parallel to yellowish-green when young and brown when old. The pictures of the species *Goniophlebium percifolium* are shown in Figure 11.

(a) (b) (c)

Figure 11. *Goniophlebium percifolium*: a). Researcher documentation; b).Piggot (1988) and c). Tirani (2022)

Dicranopteris linearis

The fern plant is known by the local name Paku resam. It belongs to the *Gleicheniaceae* family. The stems are erect, elongated, hard, and green in color. Meanwhile, according to Yolla et al., (2022) who explained that this type has special branching so that it is easy to distinguish from other types. This type of fern plant is widely used as a handicraft that has high economic value. As well as the leaves can be used as medicine as poultices, injections, and irrigation to relieve fever (Piggot, 1988). This fern is commonly found as a pioneer succession species under critical conditions such as on mountain ridges, precipices and severely disturbed sites such as landslides,road cuttings and degraded forest lands (Mai et al., 2019). According to research by Li et al. (2013), Jally et al. (2021) this fern is a pioneer plant, capable of colonising laterites in the mining areas of Southern China which makes it a suitable candidate for agriculture on IAC tailing. The pictures of the species *Dicranopteris linearis* are shown in Figure 12.

(a) (b) (c)

Figure 12. *Dicranopteris linearis*: a). Researcher documentation; b).Piggot (1988) and c). Yolla, et al. (2022)

Cyathea latebrosa

Plants that belong to the *Cyatheaeceae* family. Paku is known by the local name Paku Siur or Paku Lemputu. A spike that can be tall, upright like a pole, characterized by black and hard roots, there are thorns on the roots to hard blackish-brown stems with black stipes hanging down like messy and scaly skirts. The leaf stalks are colored. brown covered with thorns. Bi- or tripinnate leaf shape that is up to ± 2 m long. This attracts researchers and naturalists because of the extraordinary morphology of this plant species, and wide geographical distribution (Mishra and Sandip, 2023). This fern species is included in the type of fern that can increaseits abundance under disturbance(Oseguera-Olalde et al., 2022). The pictures of the species *Cyathea latebrosa* are shown in Figure 13.

(a) (b) (c)

Figure 13. *Cyathea latebrosa*: a). Researcher documentation; b).Piggot (1988) and c). GBIF "Cyathea latebrosa", accessed on 9 July (2023)

Cyathea contaminants

This fern plant is known by the local name Paku trees because it grows upright like a tree. This fern has the characteristic of long leaves curving downwards making it look like an umbrella. This plant can grow up to ± 7m high. It has a black rhizome root system, rough, tight, and thick covering the stem.According to Atho et al. (2020), the *Cyatheaeceae* family has large leaves (5 m),visible on the apex or surface of the veins, and spores of the deal tetra, trilete,non-perinate, exine smooth or granulose. Tree fern species are typically associated with fertile or semi fertile soils over a range of hydrological conditions, slope, soil stability, forest-type or successional stages (Brock et al., 2016). The pictures of the species *Cyathea contaminants* are shown in Figure 14.

(a) (b) (c)

Figure 14. *Cyathea contaminants*: a). Researcher documentation; b).Piggot (1988) and c).Ulum and Setyati (2022)

Diplazium sp

This fern belongs to the *Athyriceae* family. This fern is found in rather steep areas with a soil pH of 6.9 and humidity of 84%. Has a compound leaf type, pinnate with serrated leaf edges, with cylindrical leaf stalks, and green pinnate bones arranged in pairs with slightly tenuous spacing between leaves. Composed of 12 pairs of parallel leaflets with a length of 45 cm and a leaf width of 9 cm. Having shallow sori arranged mounted on the sides of the veins or veinlets. This plant is often found in protected river valleys in soils rich in organic matter. It can grow from a height of 350 m-1600 m above sea level(Maulidia et al., 2019). The pictures of the species *Diplazium sp* are shown in Figure 15.

(a) (b) (c)

Figure 15. *Diplazium sp*: a). Researcher documentation; b).Piggot (1988) and c). Maulidia, et al (2019)

Angipteris evecta

This fern plant has the local name Paku Gajah.The shape of the rhizome is upright, large, and fleshy black covered with dark hairs. *Angiopteris evecta* has a sorus which is located in the sub-marginal part of the pinna and is protected by indium which is in the form of a cup or like a cup. *Angiopteris evecta* mostly grows in tropical areas. annual rainfall of 1.054-5.447 mm, and a slope of 0-1.492 m.

(a) (b)

Figure 16. *Angipteris evecta*: a). Researcher documentation; b).Piggot (1988)

Conditions suitable for growth and development are low to medium-moist forests, wet valleys, canyons, and mountain slopes. Young plants can thrive in open or shaded places (Hartini, 2015). The pictures of the species *Angipteris evecta* are shown in Figure 16.

Selaginella wallichii

A fern that belongs to the *Selaginella* family .It has the form of a fibrous root that spreads brown with erect stems in brown color with dichotomous branching patterns. The leaves are green in color, and the microfilm type is arranged alternately. This species most often grows under a canopy and is protected from direct sunlight. Upland ecosystems with a humid and cool climate are the preferred habitat for this type of species(Krisnawati & Wardiyanti, 2020). The pictures of the species *Selaginella wallichii* are shown in Figure 17.

(a) (b)

Figure 17. *Selaginella wallichii*: a). Researcher documentation; b). Krisnawati, et al (2021)

Selaginella wildenowii

It belongs to the *Selaginella* family which is found in steep and somewhat steep areas, both of which are shaded or low-light areas. One of the distinguishing features of this type of fern from other types is the branching of the leaves, which are increasingly conical upwards. On the rhizome, it grows long and creeping, with micropyle leaves, branching alternate leaves, with green thorn-like leaf tips. On the round green stems covered by necrophilous leaves. For the branching pattern of this type of *Selaginella*, it has a regular egg-shaped dichotomous branching pattern (Krisnawati & Wardiyanti, 2020). The pictures of the species *Selaginella wildenowii* are shown in Figure 18.

(a) (b)

Figure 18. *Selaginella wildenowii*: a). Researcher documentation; b). Agatha et al. (2019)

Selaginella intermedia

A fern that has the local name Paku Rane. This type of fern belongs to the *Selaginella* family. It has a fibrous

root type with an axillary rhinophores type which is only found at the bottom of the stem. Stems that grow upright are brown and have a fork branching pattern (dichotomous) oval and dense. Dimorphic leaf shape that is gray to green in color. Lateral leaves do not overlap, are closer together at the top, oblong-shaped, apex pointed to obtuse, base rounded to breech, asymmetric, leaf edge serrated on one side, serrated sometimes very fine, barely visible, leaf veins not visible, leaf surface smooth, berligula (Sartika et al., 2021). The pictures of the species *Selaginella intermedia* are shown in Figure 19.

(a) (b) (c)

Figure 19. *Selaginella intermedia*: a). Researcher documentation; b). Sartika et al. (2021)

Selaginella sp 1

Plants belonging to the *Selaginella* family are plants capable of living in terrestrial, epiphytic, and lithophytic habitats. It has the shape of a spreading rhizome, brown in color, with microfilm leaf types, the leaf branching pattern is alternate, the tip of the leaf is like a thorn which is green in color, and the underside of the leaf is green to make it bluish. Sartika, et al (2021) described a fern species of the type *Selaginella Sp* which has a dichotomous branching pattern (dichotomies), with few dichotomous branches, consisting of 2-3 dichotomous branches on each branch. Lateral leaves are shaped like a triangle (ovate triangular), and the edges of the leaves are sparsely haired.The pictures of the species *Selaginella sp 1* are shown in Figure 20.

(a) (b) (c)

Figure 20. *Selaginella sp 1*: a). Researcher documentation; b). Krisnawati et al. (2021) and c). Sartika et al. (2021)

Selaginella doederleinii

A plant that belongs to the *Selaginella* family which has a type of brown fibrous root with a round, upright stem shape, with fork branching patterns. The shape of the leaves resembles a chicken claw, making this type of fern called a chicken claw. This type of fern is included in the type of fern that likes shaded areas. According to Krisnawati & Wardiyanti, (2020), *Selaginella doederleinii* will grow in shaded areas with relatively high humidity. The pictures of the species *Selaginella doederleinii* are shown in Figure 21.

(a) (b) (c)

Figure 21. *Selaginella doederleinii*: a). Researcher documentation; b). Krisnawati et al. (2021) and c). Encyclopedia (2008)

Cyathea moluccana

A plant that belongs to the *Cyathea* family which has the main characteristic of having a glossy leaf surface. It has a fibrous root shape with a spreading rhizome and brown color. The shape of the curved stem is brown. It has a monomorphic leaf shape which is shiny green in color with a flat surface and a pointed leaf tip. The glossy dark green surface on the top of the pinnae is 2.4 cm wide. The lower surface of the pinnae is 2 cm wide with sori in two irregular rows on each side of the rib (Piggot, 1988). The pictures of the species *Cyathea moluccana* shown in Figure 22.

(a) (b)

Figure 22. *Cyathea moluccana*: a). Researcher documentation; b).Piggot (1998)

Drynaria sp

It is a fern plant that belongs to the *Polypodiaceae* family. According to Febriani H, (2019), *Drynaria sp* likes damp places and wet environmental conditions with low intensity. An epiphytic plant that has a creeping rhizome, pinnate leaf shape, and smooth and stiff green edges, wide leaf shape with wavy leaf edges.*Drynaria* in the *Polypodiaceae* is a morphologically distinctive genus by having some diagnostic characters, e.g., pinnatifid frond, sori arranged along the primary vein of the pinnae, an unbranched veinlet occasionally occurring in the areole, and monolete spores that are semicircular to bean-shaped with averrucate surface(Huang et al., 2016). The pictures of the species *Drynaria sp* shown in Figure 23.


(a)


(b)

Figure 23. *Drynaria sp*: a). Researcher documentation; b). Kurniawati and Budiwato (2020)

The results of the Fern Diversity Index obtained in the Palak Siring Kemumu Waterfall Nature Tourism Area by showing the number of each species found are shown in Table 3.

Table 3. Results of the Diversity Index of Paku Plants in the Palak Siring Kemumu Waterfall Nature Tourism Area.

Species name	Quantity	Pi (ni/N)	Ln Pi	Pi Ln Pi
Phymatosorus nigrescens	1	0.0014	-6.569	-0.009
Nephrolepis cordifolia	24	0.033	-3.391	-0.114
Goniophelebium subauriculatum	2	0.0028	-5.876	-0.016
Heterogonium pinnatum	25	0.035	-3.350	-0.177
Microlepia spelunca	105	0.147	-1.915	-0.282
Blechnum vestitum	12	0.0168	-4.084	-0.068
Christella dentata	48	0.067	-2.698	-0.181
Christella parasitic	117	0.164	-1.807	-0.296
Osmunda javanica	4	0.0056	-5.183	-0.029
Goniophlebium persicifolium	2	0.0028	-5.876	-0.0164
Dicranopteris linearis	11	0.0154	-4.171	-0.064
Cyathea contaminants	3	0.0042	-5.470	-0.023
Cyathea latebrosa	2	0.0028	-5.876	-0.0164
Diplazium sp	25	0.035	-3.350	-0.117
Angipteris evecta	6	0.0084	-4.777	-0.040
Selaginella waliichi	25	0.035	-3.350	-0.117
Selaginella wildenowii	110	0.154	-1.869	-0.288
Selaginella intermedia	96	0.134	-2.0051	-0.269
Selaginella sp 1	35	0.049	-3.014	-0.147
Selaginella doederleinii	20	0.028	-3.573	-0.100
Cyathea moluccana	37	0.051	-2.958	-0.153
Drynaria sp	3	0.0042	-5.470	-0.023
Total	713	1	-86.642	2.494

Based on the data analysis, it was found that the diversity index of ferns in the Palak Siring Waterfall obtained the result H' = 2.494 which was classified as in the medium category with a total of 22 species and a total of 713 individuals. According to Sari (2022), the diversity index H' is categorized as moderate because of the ability to adapt and compete with other plants. Meanwhile, according to Odum, (1996) in Handayani, et al (2021) states that the greater the number of species, the greater the diversity. According to Leksono (2017), in Salsabila et al. (2021) species diversity can be used to determine community structure. The more species with the same or nearly the same number of individuals, the higher the level of heterogeneity.

Analysis of Potential Research Results to Support Middle School Science Learning

The results of this research related to the characteristics of the species of ferns (*pteridophyta*) can be implemented to support science learning in junior high schools in several Basic Competencies (KD). The are potential of natural and human resources, geographic, historical and cultural potential (Muldayanti & Kurniawan, 2021). According to Muharam et al. (2019), the environment is a learning resource that can be used by students..

From research (Lamasai, A, & Puadi, 2017: 132) in (FT et al., 2018) with Utilizing the natural environment around this can be used as a source learning that can stimulate students' understanding because they see directly objects that are being studied in science lessons. The potential implementation of research results on the characteristics of fern species in junior high school science learning is shown in Table 4.

According to Mahfuzi (2023), the importance of the environment as a learning resource that can enrich insight and knowledge student. Environments are wide-reaching and varied, and students can draw on resources learn from those environments to increase their understanding of the world around them.

Table 4. Potential Analysis of Fern Diversity to Support Middle School Science Learning

Class	Basic competencies	Achievement Indicator Competency	Learning materials	Learning Activity
VII	3.2 Classify living things and objects based on observed characteristics 4.2 Presenting the results of the Classification of Kingdom Plantae in The Surrounding environment based on the observed characteristics	3.2.2 Classifying right kingdom plantae (plant) 4.2.1Makeobsobservations (Existence practicum plantae in the environment) 4.2.2 Presenting group plantae	- Subject matter: Classification of Kingdom Plantae - Sub Material: Classification of Kingdom Plantae (Division *Pteridophyta*)	- Submission of theory in class - Make observations - Group discussions - Generate reports - Presentation
VIII	3.4 Describe the interrelationships of plant tissue structures and their functions. 4.2 Presenting the results of the analysis of the description of the structure and function of plant parts	3.4.1 Describe structure and function part plants (roots, stems, leaves, flowers, fruit and seed) 4.2.1 Observing structure and function parts plant 4.2.2 Create a report structure and function plant parts 4.2.3 Presenting report Results observation	- Subject matter: Structure and Function of Plants - Sub Material: Structure of Plants (Pak Plants)	- Submission of theory in class - Make observations - Group discussion - Doing report assignments - Present the results of the report assignment in front of the class
IX	3.2 Analyzing the reproductive systems of plants and animals as well as the application of technology to the reproductive systems of plants and animals 4.2 Presents the Results of the analysis of the application of technology to the plant reproductive system	3.2.2 Analyze application technology on reproduction system plant 4.2.1 Do tool observation sexual reproduction on plants 4.2.2 Create a report reproductive organs sexual on plant 4.2.3 Presenting result tool Observation sexualReproduction on plants	- Subject matter: Reproduction in Plants and Animals - Sub Material: Sexual reproduction in plants (ferns)	-Submission of theory in class -Make observations/ Observation -Group discussion -Presenting the report in front of the class

Conclusion

Based on the survey, 22 species in 13 families of terrestrial ferns (Pteridophyta) were found in the Palak Siring Waterfall Nature Tourism Area, Kemumu Village, Armajaya District, North Bengkulu Regency, and Bengkulu Province. The Diversity Index value of ferns belongs to the medium category. This certainly indicates that there is a fern that can adapt to the environment as well as other plants in the Palak Siring Waterfall Area. The research results have the potential to be applied to junior high school science learning through several basic competencies, materials, and forms of learning activities.

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The authors have declared that no competing interests exist.

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