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Diversity and ecology of Pteridophytes in Cendil heath forest and Gurok Beraye tropical rainforest, Belitung, Indonesia

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Abstract. *Priambudi AS, Chikmawati T, Sulistijorini, Fakhrurrozi Y. 2022. Diversity and ecology of Pteridophytes in Cendil heath forest and Gurok Beraye tropical rainforest, Belitung, Indonesia. Biodiversitas 23: 4775-4782.* The tropical heath forest is a unique ecosystem type characterized by sandy and acidic soils with poor nutrients and water availability, making this ecosystem very vulnerable to disturbances. Yet, knowledge regarding the diversity and ecology of the biological elements of heath forests is still very limited, moreover, information on lesser-known plant groups, such as pteridophytes. Pteridophytes can be used as indicators of the quality of a forest ecosystem since they are cosmopolitan and have an excellent adaptation to various habitats. Belitung Island, Indonesia, is a region with a large proportion of tropical heath forest and small areas of tropical rainforest. There are only a few studies on comparison of the flora of the two ecosystem types on Belitung Island. This research aimed to compare the diversity and the ecology of pteridophytes that grow in the Cendil heath forest and the Gurok Beraye tropical rainforest, Belitung Island. The study used the cruise and the purposive sampling methods to record all pteridophytes within the sampling plots measuring 5 x 5 m alternately located on the right and left of line transects with a length of 50 meters each transect. Ecological data were calculated using the Important Value Index (IVI), Shannon-Wiener diversity index, Margalef richness index, Evenness index, Sorensen similarity index, Morisita distribution index, and Canonical Correspondence Analysis. The results showed that as many as 31 species of pteridophytes belonged to 14 families in the Cendil heath forest and Gurok Beraye tropical rainforest. The pteridophytes found in the Gurok Beraye tropical rainforest were higher (30 species) than that in the Cendil heath forest (9 species). There was high dominance of a few species in the Cendil heath forest due to the presence of three species with high IVI, namely *Dicranopteris linearis*, *Palhinhaea cernua* and *Dicranopteris splendida*. In contrast, pteridophytes in the Gurok Beraye tropical rainforest were evenly distributed with no high dominance species. Environmental parameters that affected the diversity and abundance of pteridophytes included temperature, light intensity, humidity, and altitude.

Keywords: Canonical Correspondence Analysis, environmental factors, Important Value Index, inventory, pteridophyta

INTRODUCTION

Pteridophytes are a group of vascular plants that reproduce with micro-sized spores that are light and easily carried by the wind, making them one of the plant groups with wide geographical distribution (Boch et al. 2016; Hervías-Parejo et al. 2019; Qian et al. 2022). They occur from lowlands to highlands and can grow on the surface of soil, rocks, and swamps and even on the surface of trees. Based on their habitat, pteridophytes can be classified into terrestrial, epiphytic, and aquatic pteridophytes.

Indonesia has a high diversity of pteridophytes, with about 3,000 species (Widyatmoko and Irawati 2019) from about 11,000 pteridophytes species globally (PPG I 2016). The high abundance of pteridophytes in Indonesia is caused by the favorable climatic conditions for the growth and distribution of pteridophytes. Pteridophytes are often found in tropical rainforests that have sufficient light intensity and high humidity (Nettesheim et al. 2014). In addition, other climatic and edaphic factors such as nutrients, temperature, wind velocity, and altitude also affect the growth and distribution of pteridophytes in an area (Khine et al. 2019). The distribution of a pteridophytes species is also indirectly influenced by the interaction between vegetation and environmental factors, resulting in suitable environmental conditions and microhabitats for many species with varying degrees of adaptation (Patil et al. 2016; Hasanah et al. 2021).

Pteridophytes have many uses. Several types of pteridophytes can be used as food, traditional medicines, handicrafts, and ornamental plants (Suryana et al. 2018). In forest ecosystems, pteridophytes play a role in protecting the soil from erosion, maintaining moisture of the understory vegetation layer, being a litter mixer for the formation of soil nutrients, producers in the food chain, and habitat for some animals (Ridianingsih et al. 2017; Satriawan et al. 2021). Pteridophytes can also be used as indicators of ecosystem quality and environmental changes (Silva et al. 2018) since they have cosmopolitan nature, good adaptation to various environments, and can grow in any area without being introduced or cultivated.

Forest ecosystems on the mainland of Belitung Island, Indonesia, are dominated by heath forests. It is a distinctive and easily recognizable ecosystem in all lowland rainforest formations. The heath forest grows on podzolic soil characterized by white sandy soil, poor in nutrients, low pH (Oktavia et al. 2015), low N and P concentrations (Aoyagi and Kitayama 2016), and high phenolic and tannin content (Dent et al. 2006). Most of the vegetation in heath forest have low stature with a uniform, small and thin appearance and a small number of tree-level vegetation. The canopy cover is relatively open, making sunlight easily penetrates the forest floor and the leaves of the top canopy turn reddish-brown. Once cleared, the vegetation of the heath forests is very difficult to recover, which might lead to the emergence of arid savanna (MacKinnon et al. 1996; Oktavia et al. 2021). In addition, heath forests are very vulnerable to drought and fires because the soil is sandy and porous so it cannot hold water well, resulting in water stress for plants during the dry season (Jambul et al. 2020).

Despite the uniqueness of heath forests, there is limited information regarding the ecology and diversity of the vegetation, especially for lesser-known plant groups such as pteridophytes. Also, it would be interesting to understand the differences in vegetation between heath forests and other forest types. Therefore, this study aimed to investigate the diversity and ecology of pteridophytes in a heath forest in Cendil, Belitung and to compare them with pteridophytes in a tropical rainforest forest in Gurok Beraye on the same island. While the heath forest in Cendil is the typical forest in Belitung, tropical rainforest such as in Gurok Beraye is not very common. The location of Gurok Beraye tropical rainforest is close to a waterfall source, resulting in a wetter and humid environmental condition. This condition makes the rainforest a suitable habitat for the growth of pteridophytes. The difference in the ecosystem between Cendil and Gurok Beraye allows for differences in species and diversity of pteridophytes in the two locations, as well as differences in environmental factors that can affect their abundance.

MATERIALS AND METHODS

Study area and period

Pteridophyte specimen collections and the microclimate measurement were carried out in the Cendil heath forest and Gurok Beraye tropical rain forest, Belitung from September to October 2021 (Figure 1). The Cendil forest was located in the Cendil Village, Kelapa Kampit Sub-district (S02º 40' 38.5"-E107º 56' 10.9"); while the Gurok Beraye tropical rain forest was located in the Gunung Tajam, Kacang Butor Village, Badau Sub-district (S02º 45' 43.8"-E107º 50' 48.3"), Belitung District, Kepulauan Bangka-Belitung Province, Indonesia. The herbarium preparation and the identification of pteridophytes were carried out at the Laboratory of Plant Resources and Ecology, Department of Biology, IPB University, Bogor, Indonesia.

Data collection procedure

Sampling locations in both forest types were determined by the cruising method. Specimen collections and ecological data retrieval were determined by the purposive sampling method. The structure and composition of pteridophyte vegetation were determined by making a transect line as long as 50 meters and establishing a plot measuring 5 x 5 m^2 alternately on the right and left of the transect. The number of plots in the Cendil heath forest was 20 plots, while in the tropical rainforest was 36 plots. Each recorded species of pteridophyte was photographed before being collected and prepared for the herbarium and identification.

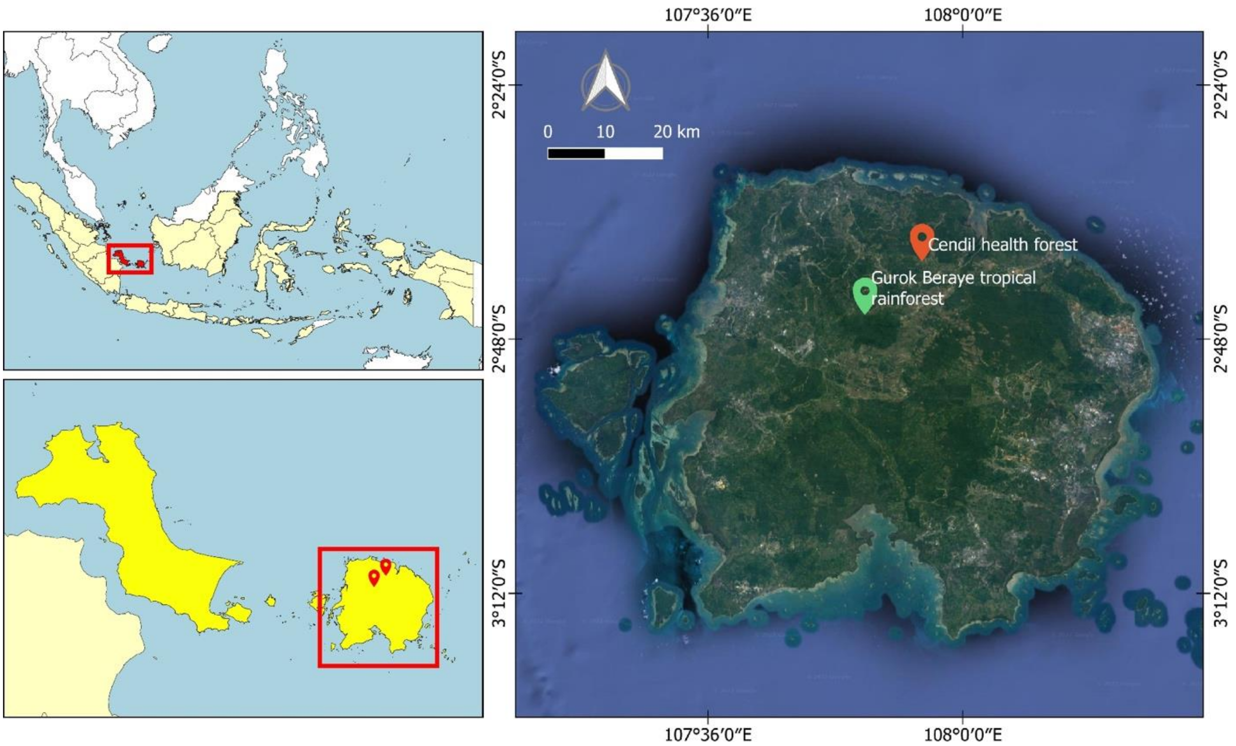

Figure 1. Map of study sites in the Cendil heath forest and the Gurok Beraye tropical rainforest in Belitung Island, Indonesia

Morphological study and identification

The detailed morphological observation of generative and vegetative organs was carried out for each species identified. Identification of pteridophytes referred to the fern of Malaya (Holttum 1966), the flora of Malesiana series Pteridophyta (van Steenis 1982), and the fern of Malaysia in color (Piggot 1988), as well as several websites. Scientific names were verified with two websites, namely the Global online sites Biodiversity Information Facility (GBIF) (https://www.gbif.org/) and plant of the world (https://powo.science.kew.org/).

Data analysis

The composition of pteridophyte species was analyzed based on the Important Value Index (IVI). Biodiversity indicators of pteridophytes were assessed using the Shannon-Wiener diversity index (H'), Margalef richness index (R) and Evenness index (E). The comparison of the uniformity of pteridophyte communities in different habitats was assessed by calculating the Sorensen similarity index (IS). The distribution pattern of the pteridophyte population in each forest type was analyzed using the Morisita distribution index (Id). Correlation data of environmental factors on the presence of pteridophyte species were analyzed with the Canonical Correspondence Analysis (CCA) using R Studio software version 4.0.2.

Important Value Index (IVI) = Relative Density (RD) + Relative Frequency (RF)

Shannon-Wiener diversity index (H') = $\sum^{S}_{i=1} (pi \ln pi)$
pi = total number of species in a habitat
i = number of individuals in a habitat

Margalef richness index (R) = (S-1) / (Ln (N))
S = total number of species in a habitat
N = number of individuals in a habitat

Evenness index (E) = H' / (Log S)
H' = Shannon-Wiener diversity index
S = number of species

Sorensen similarity index (IS) = 2C / (A + B) x 100%
C = the lowest number of IVI's of the same species found in both communities
A = total IVI in the community A
B = total IVI in the community B

Morisita distribution index (Id) = $n(\sum_{xi}2)-n$ / N (N-1)
N = total number of individuals in total n
n = total number of sampling plots
$\sum_{xi}2$ = Square of the number of pteridophytes per plot for a total of n plots

RESULT AND DISCUSSION

Diversity of pteridophytes

In total, the pteridophytes found in the Cendil heath forest and the Gurok Beraye tropical rainforest were 31 species belonging to 14 families (Figure 2). The families that had the most species were Polypodiaceae and Pteridaceae, each with four species. The number of pteridophyte species found in the Gurok Beraye tropical rainforest was higher (30 species) than that in the Cendil heath forest (9 species) (Table 1). This result is in accordance with the characteristics of the habitat and environmental conditions, as well as the existence of ecological pressures biotically and abiotically in the two locations (Azizah et al. 2020). Similar results were also found in the study by Maimunah et al. (2019), who found that the diversity and abundance of plant species that grow in tropical rain forests have a higher level compared to heath forests and Dipterocarp forests.

The pteridophytes in the Cendil heath forest were dominated by *Dicranopteris linearis* (45.87%) followed by *Palhinhaea cernua* (23.46%) and *Dicranopteris splendida* (16.22%) (Table 1). The top three orders were dominated by the Gleicheniaceae family, namely *D. linearis* and *D. splendida*. The Gleicheniaceae tended to grow densely and in groups to form shrubs in open lowland areas. In addition, the genus *Dicranopteris* has a high distribution with stolons that propagate both below and above the soil surface, branches that develop in all directions, and fronds that grow lengthwise, spreading to tree branches so that they can easily dominate the surrounding area (Yang et al. 2021; Liyanage et al. 2021). The study of Beukema et al. (2013) on pteridophytes in relation to habitat quality in Sumatra showed that there were *Dicranopteris* species that can be used as indicators of forest disturbance and ecological restoration. In this regard, *D. linearis* is species identified as an indicator of highly disturbed to moderately disturbed habitats that proceed early successional stage. *Dicranopteris* also has important ecological functions due to the ability of rapid growth to fill gaps after disturbance and facilitate habitat succession, as well as to be able to reduce soil erosion due to rainfall (Yang et al. 2021).

On the other hand, the IVI of pteridophytes in the Gurok Beraye tropical rainforest was relatively more uniform and evenly distributed. *Blechnopsis finlaysoniana* had the highest IVI (10.44%), followed by *D. splendida* (6.36%), and *B. orientale* (5.98%) (Table 1). The dominant pteridophytes belong to the Blechnaceae family, namely *B. finlaysoniana* and *B. orientale*. The *Blechnopsis* genus lives in groups on the ground or attached to rocks by utilizing the available space and can grow up to 1-2 meters with wide and elongated fronds, especially *B. finlaysoniana*. Meanwhile, *Tectaria heracleifolia* of Tectariaceae had the lowest IVI value (1.66%). This species is very few because its habitat is on the forest floor with wet and moist litter and dense trees with a dense canopy. This condition causes the humidity to be very high, so that the microclimate is maintained well (Song et al. 2012).

The pteridophyte species that have the highest IVI are the species that dominate in the surrounding area, especially in optimizing resources and being able to adapt well to their environment. The abundance of a species is influenced by several factors, such as persistence, aggressiveness, ability to regrow, changes in humidity levels, soil fertility, and rainfall (Siappa et al. 2016).

Table 1. Diversity and important value index of pteridophytes in the Cendil heath forest and Gurok Beraye tropical rainforest, Belitung Island, Indonesia

Family	Species	CHF (IVI %)	GBTRF (IVI %)
Adiantaceae	*Adiantum caudatum* L.	-	√ (2.59)
Aspleniaceae	*Asplenium nidus* L.	-	√ (3.32)
Athyriaceae	*Diplazium angustipinna* (Holtt). Holtt.	-	√ (1.85)
	Diplazium donianum (Mett.) Tardieu	-	√ (1.96)
	Diplazium pallidum (BI). Moore.	-	√ (2.15)
Blechnaceae	*Blechnopsis finlaysoniana* (Wall. ex Hook.& Grev.) C. Presl.	-	√ (**10.44**)
	Blechnopsis orientalis (L.) C. Presl.	√ (4.88)	√ (5.98)
Dennstaedtiaceae	*Microlepia todayensis* Christ.	-	√ (3.60)
Gleicheniaceae	*Dicranopteris linearis* (Burm.) Underw.	√ (**45.87**)	√ (4.64)
	Dicranopteris splendida (Hand.-Mazz) Tag.	√ (16.22)	√ (6.36)
Lycopodiaceae	*Palhinhaea cernua* (L.) Vasc. & Franco	√ (28.46)	√ (4.20)
	Lycopodium clavatum L.	√ (2.93)	√ (3.25)
Nephrolepidaceae	*Nephrolepis bisserata* (Sw.) Schott.	√ (0.31)	√ (4.18)
Polypodiaceae	*Aglaomorpha sparsisora* (Desv.) Hovercamp & Linds.	-	√ (2.51)
	Lepisorus excavatus (Bory ex Willd.) Ching.	√ (0.51)	-
	Platycerium coronarium (Koenig) Desv.	-	√ (3.19)
	Pyrrosia piloselloides (L.) M. G. Price.	-	√ (2.13)
Pteridaceae	*Pityrogramma calomelanos* (L.) Link.	√ (0.62)	√ (2.04)
	Pteris biaurita L.	-	√ (2.29)
	Pteris semipinnata L.	-	√ (1.94)
	Pteris vittata L.	-	√ (3.00)
Selaginellaceae	*Selaginella ciliaris* (Retz.) Spring.	-	√ (2.78)
	Selaginella corrugis Mickel & Beitel.	-	√ (2.84)
	Selaginella intermedia (Blume) Spring.	-	√ (2.54)
Taenitidaceae	*Taenitis blechnoides* (Willd.) Sw.	-	√ (1.77)
	Taenitis interrupta Hook. & Grev.	-	√ (2.43)
Tectariaceae	*Pleocnemia irregularis* (C. Presl) Holttum.	-	√ (4.17)
	Tectaria heracleifolia (Willd.) Underw.	-	√ (1.66)
Thelypteridaceae	*Amblovenatum opulentum* (Kaulf.) J.P. Roux..	-	√ (2.24)
	Christella subpubescens (BI.) Holtt.	√ (0.21)	√ (3.06)
	Pronephrium asperum (C. Presl.) Holtt.	-	√ (4.88)

Notes: (√) = Recorded; (-) = Not recorded; CHF = Cendil Heath Forest; GBTRF = Gurok Beraye Tropical Rain Forest; IVI = Important Value Index

The diversity of pteridophytes in the Cendil heath forest was categorized as moderate (H' = 1.32), while in the Gurok Beraye tropical rainforest was high (H' = 3.01) (Figure 3A). The relatively moderate diversity index value is mostly caused by the presence of dominant species in the area, while the higher values tend to be due to a wide sampling area and more species found (Strong 2016). The species richness of pteridophytes in the Cendil heath forest was low (R = 1.29), while in the Gurok Beraye tropical rainforest was in the moderate category (R = 3.86) (Figure 3B). The value of species richness of pteridophytes corresponds to the number of species found in each location. The more the number of species found, the higher the value of the richness index, and vice versa. The study of Acebey et al. (2017) reported that pteridophyte species richness has been correlated with the availability of ambient water and energy, as well as with the complex topography, and particularly in the highlands, with high humidity and moderate temperatures.

The distribution of pteridophytes in the Cendil heath forest showed an uneven distribution (E = 0.49), while the distribution of species in the Gurok Beraye tropical rainforest showed an even distribution (E = 0.92 or close to 1) (Figure 3C). According to Rahmad and Akomolafe (2018), the low evenness value is caused by a species being dominant while others are not dominant or the density is lower. In contrast, the higher the evenness value shows that the species is distributed evenly in each plot. The distribution pattern of the fern population in the Cendil heath forest is 6.59, but that in the Gurok Beraye tropical rainforest is 1.97, showing a distribution pattern that tended to cluster (Id > 1) (Figure 3D). Siappa et al. (2016) explained the clustered distribution pattern is due to the need for the same environmental factors such as water, soil composition, temperature, and light that are suitable for survival.

Based on the Sorensen Index (IS), the uniformity value of pteridophytes species between the Cendil heath forest and Gurok Beraye tropical rainforest was around 24.15%, indicating both locations had a very low similarity in fern communities (≤ 25%). It is suspected that some environmental factors differed between the two locations, such as habitat characteristics, distance, and altitude. Cendil heath forest tends to be dry, while the Gurok Beraye tropical rainforest is relatively wet and humid (Table 2). Vegetation in the Cendil heath forest was relatively homogeneous. Individuals of the same species will occupy the location because these species naturally have developed adaptation and tolerance mechanisms to their habitat (Anderson 2021).

Figure 2. Morphological appearance of pteridophytes in the Cendil heath forest and Gurok Beraye tropical rainforest: A. *Adiantum caudatum* L.; B. *Asplenium nidus* L.; C. *Diplazium angustipinna* (Holtt). Holtt.; D. *D. donianum* (Mett.) Tardieu..; E. *D. pallidum* (BI). Moore.; F. *Blechnopsis finlaysoniana* (Wall. Ex Hook. & Grev.) C. Presl..; G. *B. orientalis* (L.) C. Presl. ; H. *Microlepia todayensis* Christ.; I. *Dicranopteris linearis* (Burm.) Underw.; J. *D. splendida* (Hand.-Mazz) Tag.; K. *Palhinhaea cernua* (L.) Vasc. & Franco.; L. *Lycopodium clavatum* L.; M. *Nephrolepis bisserata* (Sw.) Schott.; N. *Aglaomorpha sparsisora* (Desv.) Hovenkamp & S. Linds. .; O. *Lepisorus excavatus* (Bory ex Willd.) Ching.; P. *Platycerium coronarium* (Koenig) Desv.; Q. *Pyrrosia piloselloides* (L.) M. G. Price.; R. *Pityrogramma calomelanos* (L.) Link.; S. *Pteris biaurita* L.; T. *P. semipinnata* L.; U. *P. vittata* L.; V. *Selaginella ciliaris* (Retz.) Spring.; W. *S. corrugis* Mickel & Beitel.; X. *S. intermedia* (Blume) Spring.; Y. *Taenitis blechnoides* (Willd.) Sw.; Z. *T. interrupta* Hook. & Grev.; AA. *Pleocnemia irregularis* (C. Presl) Holttum.: AB. *Tectaria heracleifolia* (Willd.) Underw.; AC. *Amblovenatum opulentum* (Kaulf.) J. P. Roux.; AD. *Christella subpubescens* (BI.) Holtt.; AE. *Pronephrium asperum* (Presl.) Holtt. Scale 10 cm

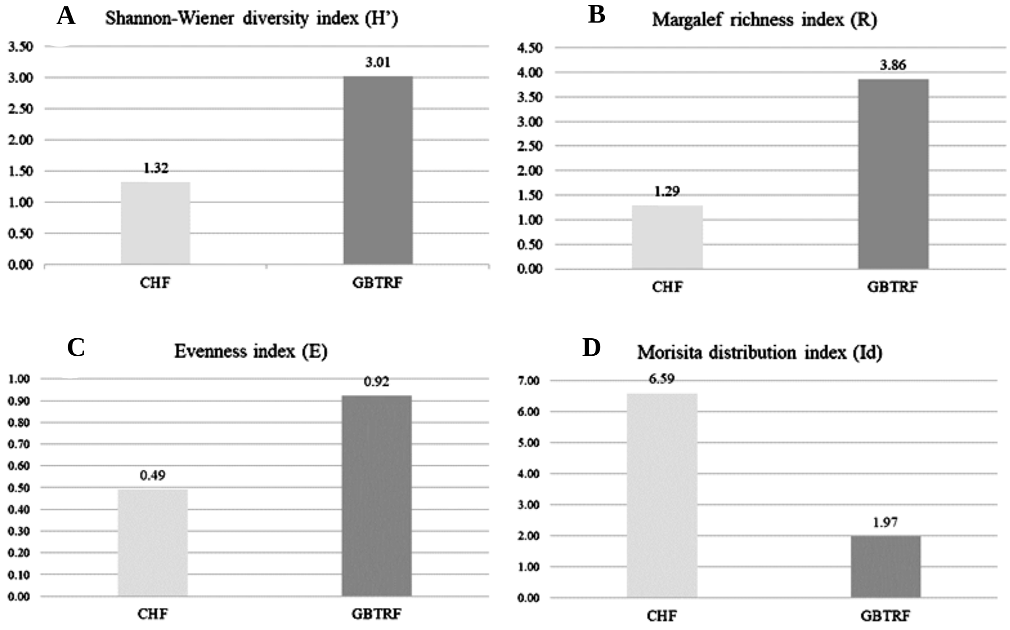

Figure 3. Biodiversity indicators of pteridophytes species in the Cendil heath forest (CHF) and Gurok Beraye tropical rainforest (GBTRF): Shannon-Wiener diversity index (A), Margalef richness index (B), Evenness index (C), and Morisita distribution index (D)

Table 2. Environmental parameters in the Cendil heath forest and Gurok Beraye tropical rainforest, Belitung Island, Indonesia

Site	Temperature (°C)	Light intensity (lux)	Humidity (%)	Wind velocity (m/s)	Altitude (mdpl)
CHF	30.79-39.30	1081-1963	56.50-82.15	0.00-0.50	32-38
GBTRF	28.00-35.15	261-1827	61.30-89.90	0.00-0.10	71-184

Notes: CHF = Cendil Heath Forest; GBTRF = Gurok Beraye Tropical RainForest

In addition, the known distance between the Cendil heath forest and the Gurok Beraye tropical rainforest is 15 km apart. The two locations are also at different elevations. The Cendil heath forest is in the lowlands with an altitude of 32-38 m asl, while the Gurok Beraye tropical rainforest is in the hills with an altitude of 71-184 m asl. These three factors also correlated with the distribution pattern of pteridophytes in particular habitats (Krömer et al. 2013; Salazar et al. 2015).

Environmental variables of pteridophyte's habitat

Measurement of environmental factors from two different locations showed significantly different results. The temperature and light intensity in the Gurok Beraye tropical rainforest were relatively low, while the humidity was high (Table 2). This is because, in the Gurok Beraye tropical rainforest, there were many trees with a wide and large canopy so that the intensity of sunlight and the temperature tended to be lower. In addition, the forest floor tended to be more humid and wet with litter, causing high humidity. In contrast, in the Cendil heath forest, the temperature and light intensity was relatively higher, while the humidity was lower (Table 2). The relative open tree canopy in the heath forest makes the light easier to enter the forest floor during the day, thereby increasing the ambient temperature and lowering humidity (Azizah et al. 2020).

The wind velocity factor was not too influential because the results obtained from the two locations were not significantly different. Even so, pteridophytes need wind as an intermediary for spore dispersal. On the other hand, altitude was likely to affect the abundance and distribution of pteridophytes. This situation is caused by the higher elevations that allow fog which can cause humidity to increase, and the flow of water plays a role in the dispersion of fern spores (Rose and Dassler 2017).

Habitat characteristics at each location determined the diversity and abundance of pteridophytes. The diversity and abundance of pteridophytes in the tropical rainforest of Gurok Beraye were found to be higher than that of the Cendil heath forest. This is because tropical rainforests have high humidity and rainfall, which is an ideal condition for the fern to grow (Table 2). In addition, these conditions greatly affect the distribution of pteridophytes to be higher and wider. Previous studies also reported that tropical rainforests had a very high diversity and abundance of plants, especially pteridophytes (Baraloto et al. 2013; Haque et al. 2016; Krishnan and Rekha 2021).

A

B

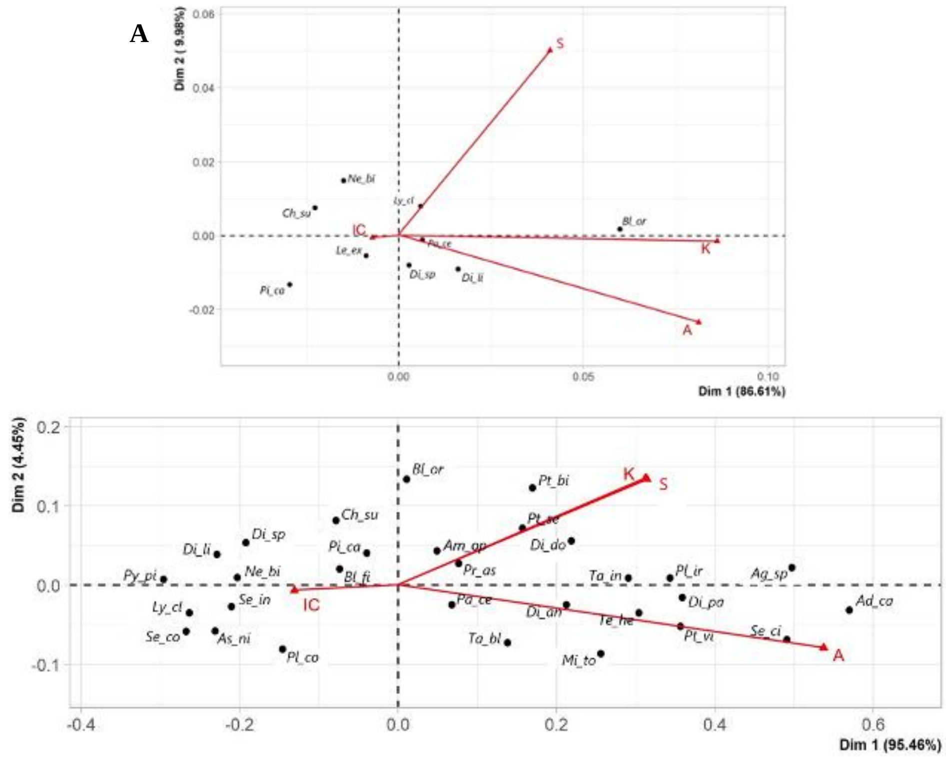

Figure 4. Analysis of the canonical correspondence of pteridophytes in the Cendil heath forest (A) and Gurok Beraye tropical rainforest (B); A = Altitude, IC = light intensity, K = Humidity, S = Temperature; *Adiantum caudatum (Ad_ca), Aglaomorpha sparsisora (Ag_sp), Amblovenatum opulentum (Am_op), Asplenium nidus (As_ni), Blechnopsis finlaysoniana (Bl_fi), Blechnopsis orientalis (Bl_or), Christella subpubescens (Ch_su), Dicranopteris linearis (Di_li), Dicranopteris splendida (Di_sp), Diplazium angustipinna (Di_an), Diplazium donianum (Di_do), Diplazium pallidum (Di_pa), Lepisorus excavatus (Le_ex), Lycopodium clavatum (Ly_cl), Microlepia todayensis (Mi_to), Nephrolepis bisserata (Ne_bi), Palhinhaea cernua (Pa_ce), Pityrogramma calomelanos (Pi_ca), Platycerium coronarium (Pl_co), Pleocnemia irregularis (Pl_ir), Pronephrium asperum (Pr_as), Pteris biaurita (Pt_bi), Pteris semipinnata (Pt_se), Pteris vittata (Pt_vi), Pyrrosia piloselloides (Py_pi), Selaginella ciliaris (Se_ci), Selaginella corrugis (Se_co), Selaginella intermedia (Se_in), Taenitis blechnoides (Ta_bl), Taenitis interrupta (Ta_in), Tectaria heracleifolia (Te_he)*

In contrast, the Cendil heath forest had habitat characteristics that were inversely proportional to the Gurok Beraye tropical rainforest. The heath forest had a forest floor covered by white sandy soil (podsol soil) which is poor in nutrients and generally acidic with a pH of around 3-4 (Oktavia et al. 2015). The low nutrient content in heath forests causes the dominance of seedling and pole vegetation to be higher (Robiansyah et al. 2018). Most heath forests are formed by young trees with small and regular trunk diameters making them difficult to penetrate, such as *Archidendron pauciflorum* (Jering), *Cinnamomum parthenoxylon* (Medang kalong), *Ilex cymose* (Mensira), *Schima wallichi* (Seruk), and *Syzygium lepidocarpa* (Samak) (Oktavia et al. 2021). In addition, the leaves of plants that grow in the heath forest tend to be smaller and thicker to reduce water evaporation and nutrient loss (Din et al. 2015). Ecosystems in the heath forest are easily damaged and difficult to return to their original state if they have been disturbed (Kissinger et al. 2013).

Relationship between environmental variables and pteridophyte diversity

The relationship between environmental factors and the diversity of pteridophytes in each ecosystem is presented in graphical form. The presence of pteridophytes in the Cendil heath forest and Gurok Beraye tropical rainforest show positive correlations to temperature, humidity, and altitude. In the Cendil heath forest, the presence of *Lycopodium clavatum* (Ly_cl) was affected by temperature, while *Palhinhaea cernua* (Ly_ce) was affected by the humidity and altitude (Figure 4A). Meanwhile, in the Gurok Beraye tropical rainforest, the presence of *Pronephrium asperum* (Pr_as) and *Pteris semipinnata* (Pt_se) was affected by air humidity and temperature, while *Diplazium angustipinna* (Di_an), *Palhinhaea cernua* (Ly_ce), *Pteris vittata* (Pt_vi), *Selaginella ciliaris* (Se_ci) and *T. heracleifolia* (Te_he) were affected by altitude (Figure 4B). In general, pteridophytes are relatively more diverse in the highlands with high humidity, low temperature, and high rainfall so that there is continuous availability of water (Nagalingum et al. 2014; Della and Falkenberg 2019).

In conclusion, the diversity of pteridophytes found in the Cendil heath forest and the Gurok Beraye tropical rainforest was 31 species belonging to 14 families. The Polypodiaceae and Pteridaceae families had the most species, each with four species. The diversity of pteridophytes in the Gurok Beraye tropical rainforest was higher in number (30 species) than in the Cendil heath forest (only nine species). The pteridophytes in the Gurok Beraye tropical rainforest were dominated *by B. finlaysoniana*, followed by *D. splendida*, and *B. orientalis*. Meanwhile, in the Cendil heath forest, the most dominant pteridophytes were *D. linearis*, *P. cernua*, and *D. splendida*. Ecological parameters affecting the pteridophyte abundance and distribution included temperature, light intensity, humidity, and altitude. Environmental conditions in the Gurok Beraye tropical rainforest had a low temperature and light intensity, while the humidity was higher than that in the Cendil heath forest. On the other hand, the Cendil heath forest had high light intensity, while the air temperature was lower. Further exploration needs to be carried out more extensively in various ecosystem types where pteridophytes are present to describe the whole flora so that data on the diversity of pteridophytes on Belitung Island is more available and diverse, complete with the ecological data. An assessment of the benefits of pteridophytes on Belitung Island also needs to be carried out to maximize the potential of pteridophytes by local communities. In addition, efforts need to be made to increase local community awareness of the importance of the existence of pteridophytes, especially in particular ecosystems, and various activities such as land clearing and tin clearing that can cause habitat loss and fragmentation on Belitung Island.

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