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Ferns Species Diversity in the Sekar Pudak Sari Waterfall Tourism Area, Wonosalam District, Jombang Regency, East Java, Indonesia

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ABSTRACT

Ferns are significantly dominant in Indonesia. The waterfall area is one of the ferns habitats. This study aims to determine the diversity index of ferns species in the Tourism Area of Sekar Pudak Sari Waterfall Wonosalam District, Jombang Regency, East Java. This research was exploratory, descriptive. Data collection uses a single plot measuring 20x20 m at 500 masl, 700 masl, and 900 masl. Each observation plot has a sub-plot with a size of 2x2 m. Data analysis used the Shannon-Wiener diversity index (H'), the taxonomic diversity index (Δ), and dominance (Δ*). The exploration results found 28 species from 11 families, 6 epiphytes, and the rest terrestrial. The taxonomic diversity index in plot 1 was 23.36 (low category), while plots 2 and 3 were 30.58 and 31.66 (medium category). This shows that the environment in the three plots is classified as stable, as indicated by the presence of ferns at various taxonomic levels. The highest dominance diversity index (Δ*) was 2.8 in Plot 2, while Plots 1 and 3 were 2.7 (low category). The total number of individual ferns found influenced the difference in the diversity index. The ferns found in the three plots were relatively few, indicating that the environment was classified as less stable. The Shannon-Wiener diversity index (H') in the three plots was 2.9 (medium category), indicating that the distribution pattern of ferns in the environment was balanced. The Sekar Pudak Sari Waterfall Tourism Area is a suitable habitat for the growth of ferns, so conservation efforts need to be made to maintain a balance of species and stabilize the ecosystem.

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INTRODUCTION

Indonesia is a country with abundant biodiversity. This is indicated by the presence of various plant species that were found. According to Leksono (2010), Indonesia has 37,000 species and is ranked third in terms of plant species richness in the world. The plants that dominate in Indonesia after seed plants are ferns. Indonesia has 3,000 to 10,000 ferns worldwide (Efendi *et al.*, 2013). The distribution of ferns in Java/NTB/NTT is around 500 species (Kusmana & Hikmat, 2015). According to Suryana et al. (2020), the total number of ferns on Java Island is 515.

Research conducted by Suryana et al. (2020) found as many as 83 species of ferns from 25 families in five different mountains located in West Java, including Mount Patuha, Papandayan, Tangkuban Perahu, Pangrango, and Guntur. Another research was conducted by Sianturi et al. (2021) in three plains located in Central Java which found 15 species of ferns from 8 families in the lowlands, specifically in the Pagerwunung Nature Reserve. The second zone is the temperate plains in the Penggaron forest, where as many as 23 species of ferns from 3 families were found. In the highlands, as many as 32 species of ferns from 18 families were found in the forests of Mount Ungaran and Mount Lawu. The fern's distribution was found in East Java, where 143 species from 21 families were found (Efendi & Iswahyudi, 2019).

Morphological characters are significant in taxonomic studies to distinguish each species found

(Sofiyanti et al., 2020). Differences in morphological characters can also be used for species identification. The characteristics of ferns include being able to grow and develop in a shady and moist place, having true leaves, young leaves being coiled, pinnately compound, and having a sorus on the underside of the leaves (Pranita et al., 2016).

Fern's species diversity is influenced by abiotic environmental factors, including soil pH, air temperature and humidity, and light intensity (Andayaningsih et al., 2013). The ideal temperature suitable for the growth of ferns ranges from 21-27°C (Kurniasih, 2019). This species likes a place that is shaded by sunlight with an intensity ranging from 117-1603 lux (Sandy et al., 2016). Fern's growth is strongly influenced by air humidity, which is 60-80% (Imaniar, 2017), and soil pH between 6.5-7.5 is also needed to help the ferns growth process (Zakiyyah, 2020).

Species diversity is an environmental condition that considers two aspects of the community: the abundance and balance of species in an area (Hamilton, 2005). Fern's species diversity index can be related to taxonomic diversity regarding taxonomic levels, including classes, orders, families, and genera (Darajati et al., 2016). The more species with various taxonomic levels, the higher the taxonomic diversity index. Which indicates that the environment is stable (Hamilton, 2005).

Based on the conservation status of the IUCN Red List (2022), 3,532 species of ferns are recorded as conservation plants, 1,497 of which receive little attention, and 289 species are endangered. The low index of species diversity also indicates that environmental conditions in an area have decreased (Adi, 2013). It happens due to environmental pressure factors and the influence of human activities, giving rise to a need for conservation efforts in an area (Cahyanto & Kuraesin, 2013).

Conservation of the fern's species diversity is significant in providing information regarding the balance of species and environmental conditions in an area (Saptasari, 2013). This species also still receives less public attention, so several ferns are threatened with extinction (Suraida et al., 2013). It is what causes the need for conservation efforts to preserve and minimize the extinction of ferns in an area.

One of the suitable habitats for ferns is the waterfall area. The waterfall is one of the green open areas with natural bioecology that are ideal and suitable for plants to grow and develop (Steenis, 2010). Sekar Pudak Sari is a waterfall tourism area in Wonosalam District, Jombang Regency. This waterfall has humid environmental conditions and is shaded by sunlight. Not only functioning as a tourist spot, this waterfall can also be used as a conservation area to protect the growth of ferns.

The Sekar Pudak Sari Waterfall Tourism Area has the potential to become a habitat for the growth and development of ferns. However, until now, there has not been any information regarding ferns species diversity because they are considered useless to the community. Based on this, it is necessary to conduct scientific research on the fern's species diversity in the Sekar Pudak Sari Waterfall Tourism Area, which can be developed and conserved to determine growth patterns and species balance in their natural habitat and prevent extinction.

MATERIALS AND METHODS

The object of this research was the ferns, both terrestrial and epiphytic. This research was descriptive exploratory research that aimed to collect data on ferns species diversity through observations in the Sekar Pudak Sari Waterfall Tourism Area, Wonosalam District, Jombang Regency, East Java, Indonesia (coordinates 7°40'48" S and 112 °22'25" E) (Figure 1). The research was carried out in December 2022 and January 2023.

The research procedure went through several stages: initial observation, determination of plots, exploration and collection of specimens, observation of morphological characteristics, identification of species, and determination of the species diversity index. Preliminary observations were carried out to determine the research path's route and the surrounding environment's condition. Determination of species observation plots using the single plot method (Figure 2) with a size of 20x20 m in three plots based on the height of the location (Darma et al., 2015). Plot 1 was at an altitude of 500 masl, plot 2 was at an altitude of 700 masl, and plot 3 was at an altitude of 900 masl (Riyanto *et al.*, 2019). Each observation plot had a sub-plot with a size of 2x2 m (Darma *et al.*, 2015). This method was used because it was more effective and facilitates sampling, so that the data obtained in the field was more accurate (Yuliastuti et al., 2014).

Specimens of terrestrial and epiphytic ferns were collected by taking the rhizomes and leaves of ferns, curing them with alcohol, and sticking them on cardboard. The dried herbarium was tagged with a hanging label and a description of the fern species. The collection of specimens using an herbarium

aims to facilitate the identification of fern species (Sofiyanti at al., 2020). Fern specimens were also collected by documenting the stature, leaves, and sorus using the Vivo Y15S 720 x 1600pixel (HD+) cell phone camera. The total number of individuals of each species was recorded in each observation plot. Individual fern species of herbaceous stature were counted based on one clump on the same root. In contrast, the total number of individuals in long rhizome species was recorded by measuring each leaf lamina of the species found (Wanma, 2021).

Observation of morphological characteristics, including stature, leaves, and sorus, to identify and determine the species scientific name. Species identification using Flora of Malaya (Holtum, 1968), and Keanekaragaman Tumbuhan Paku di Jawa Timur (Efendi & Iswahyudi, 2019).

Diversity data analysis used the Shannon-Wiener diversity index (1) (Odum, 1993), the taxonomic diversity index (2), and the dominance diversity index (3) (Clarke & Warwick, 1998).
Shannon-Wiener (H') diversity index (Odum, 1993)
Dominance diversity index (Δ*) (Clarke & Warwick, 1998).

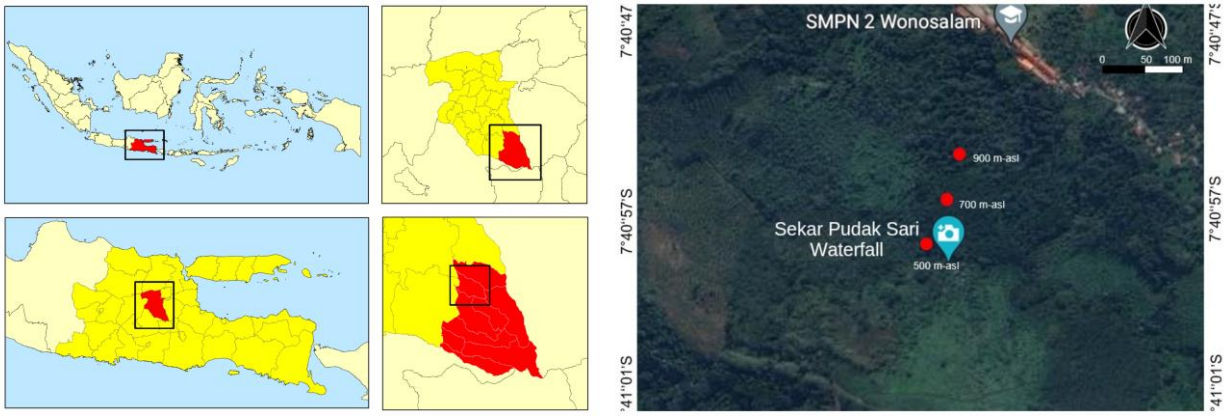

Figure 1. Research Location Area

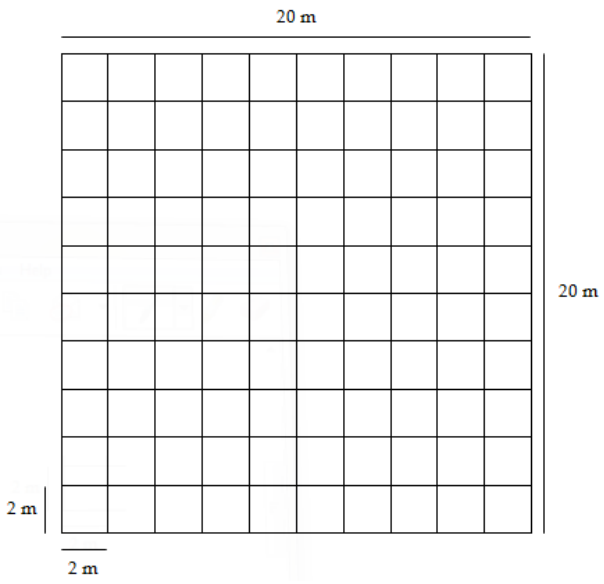

Figure 2. Observation Plot

Shannon-Wiener (H') diversity index (Odum, 1993)

$$H' = -\Sigma \frac{ni}{N} \ln \frac{ni}{N} \quad \ldots\ldots\ldots\ldots\ldots\ldots (1)$$

Information: H' = Shannon-Wiener diversity index
N = Total of all individuals
ni = Total individuals of species-i

ln = Logarithm with base e

The Shannon-Wiener diversity index category is divided into three, namely, low (H' < 1.0); medium (1.0 ≤ H' ≤ 3.322); and high (H' > 3.322) (Odum,1993).

Taxonomic diversity index (Δ) (Clarke & Warwick, 1998)

$$\Delta = \lceil \Sigma_{j=1,\ldots,n} \Sigma_{i<j} \omega_{ij} x_i x_j \rceil / \lceil n(n-1)/2 \rceil \quad \ldots\ldots\ldots\ldots\ldots\ldots (2)$$

Note :
Δ = Taxonomic diversity index
ωij = Representative of the two species
ω1 = Genus with different species
ω2 = Family with different genus
ω4 = Class and order
n = Total of individuals in the sample
xixj = Species abundance indicator

The taxonomic diversity index category is divided into three, namely, low (Δ < 26.06); medium (26.06 ≤ Δ ≤ 69.07); and high (Δ > 69.07) (Clarke & Warwick, 1998).

Dominance diversity index (Δ*) (Clarke & Warwick, 1998)

$$\Delta^* = \lceil \Sigma_{j=1,\ldots,n} \Sigma_{i<j} \omega_{ij} x_i x_j \rceil / \lceil \Sigma_{j=1,\ldots,n} \Sigma_{i<j} x_i x_j \rceil \quad \ldots\ldots\ldots\ldots\ldots\ldots (3)$$

Note:
Δ* = Dominance diversity index
ωij = Representative of the two species
ω1 = Genus with different species
ω2 = Family with different genus
ω4 = Class and order
xixj = Species abundance indicator

The dominance diversity index category is divided into three, namely, low (Δ* < 3.0); medium (3.1 ≤ Δ* ≤ 6.0); and high (Δ* > 6.1) (Clarke & Warwick, 1998).

RESULTS AND DISCUSSION

Exploration results for ferns in the Sekar Pudak Sari Waterfall Tourism Area are presented as an inventory table. Ferns found at the study site based on different heights found as many as 28 species from eleven families that grow terrestrially and epiphytically (Table 1). There were 5 species of ferns found in three plots with different heights, including *Pityrogramma calomelanos*, *Pteris biaurita*, *Pteris ensiformis*, *Diplazium asperum*, and *Christella dentata*. The Pteridaceae family was the most common species found in the three plots, with 7 different species.

Pteridaceae is one of the families with the most species in the three observation plots. There were 7 species of Pteridaceae found at the research location, including *A.capillus-veneris*, *A.philippense*, *A.hispidulum*, *Pityrogramma calomelanos*, *Pteris biaurita*, *Pteris ensiformis*, and *Pteris vittata*. Pteridaceae are most commonly found at every altitude with neutral soil pH and can grow in various conditions, such as open, dry, moist, and shaded areas (Muswita et al., 2013).

The most common species in one genus include *Adiantum*, *Pteris*, and *Diplazium*. *Adiantum* and *Pteris* belong to the Pteridaceae family, with species including *A. capillus-veneris*, *A. philippense*, *A. hispidulum*, *P. biaurita*, *P. ensiformis*, and *P. vittata*. In contrast, *Diplazium* belongs to the Athyriaceae family, with species including *D. asperum*, *D.*

Table 1 List of Ferns Inventory in Three Plots with Different Altitudes (1= 500 masl; 2= 700 masl; 3= 900 masl)

No	Species Name	Families	Plot			Total of individuals
			1	2	3	
1	*Adiantum capillus-veneris* L.	Pteridaceae	25	20	-	45
2	*Adiantum philippense* L.		17	8	-	25
3	*Adiantum hispidulum* Sw.		-	-	17	17
4	*Pityrogramma calomelanos* (L.) Link.		68	59	23	150
5	*Pteris biaurita* L.		35	52	41	128
6	*Pteris ensiformis* Burm.		38	21	28	87
7	*Pteris vittata* L.		17	13	-	30
8	*Belvisia revoluta* (Bl.) Copel.	Polypodiaceae	-	-	4	4
9	*Drynaria rigidula* (Sw.) Bedd.		-	-	11	11
10	*Drynaria quercifolia* (L.) J. Sm.		-	6	-	6
11	*Goniophlebium subauriculatum* (Blume.) Presl.		-	-	9	9
12	*Microsorum scolopendria* (Burm. f.)		-	7	-	7
13	*Diplazium asperum* Blume.	Athyriaceae	15	27	47	89
14	*Diplazium esculentum* (Retz.) Sw.		-	19	31	50
15	*Diplazium procumbens* Holttum.		-	28	39	67
16	*Christella dentata* (Forsk.) Brownsey & Jermy.		22	63	42	127
17	*Cyclosorus interruptus* (Willd.) H. Ito.	Thelypteridaceae	23	-	-	23
18	*Sphaerostephanos heterocarpus* (Blume.) Holt.		-	13	-	13
19	*Coryphopteris unidentata* (Bedd.) Holttum.		-	8	21	29
20	*Dryopteris carthusiana* (Vill.) H. P. Fuchs.	Dryopteridaceae	-	-	15	15
21	*Dryopteris sparsa* (D.Don) Kuntze.		-	9	-	9
22	*Polystichum prolificans* v.A.v.R.		-	18	28	46
23	*Lygodium flexuosum* (L.) Sw.	Lygodiaceae	17	-	-	17
24	*Cyclopeltis crenata* (Fee) C. Chr.	Lomariopsidaceae	21	12	-	33
25	*Tectaria multicaudata* (Wall.) Ching.	Tectariaceae	32	26	-	58
26	*Microlepia todayensis* Christ.	Dennstaedtiaceae	18	5	-	23
27	*Davallia solida* (Forst.) Sw.	Davalliaceae	-	-	10	10
28	*Nephrolepis biserrata* (Sw.) Schott	Nephrolepidaceae	-	-	9	9
Total			348	414	375	1.137

esculentum, and *D. procumbens*. Species belonging to these three genera are often found because they can grow in dry, rocky, or humid habitats with sufficient light intensity (Sukarsa et al., 2011).

Families in which only 1 species was found in the research location included Lygodiaceae, Lomariopsidaceae, Tectariaceae, Dennstaedtiaceae, Davalliaceae, and Nephrolepidaceae. Few of these six families were found due to unfavorable environmental abiotic factors, resulting in less-than-optimal growth of the species (Syafrudin et al., 2018). Lygodiaceae and Lomariopsidaceae are only found in plot 1 because they can grow in open areas that are not too tall and in dry environmental conditions (Afriana *et al.*, 2022). Tectariaceae and Dennstaedtiaceae can be found in habitats with humid environmental conditions, open areas, and close to the water (Haque *et al.*, 2016), so species from this family are found in plots 1 and 2. Davalliaceae and Nephrolepidaceae live as epiphytes and are only found overlapping in old trees with damp conditions (Kinho, 2009), so they only found in plot 3.

A total of 13 species from seven families were found in Plot 1, including Pteridaceae, Athyriaceae, Thelypteridaceae, Lygodiaceae, Lomariopsidaceae, Tectariaceae, and Dennstaedtiaceae. A total of 19 species from eight families were found in Plot 2, including Pteridaceae, Polypodiaceae, Athyriaceae, Thelypteridaceae, Dryopteridaceae, Lomariopsidaceae, Tectariaceae, and Dennstaedtiaceae. In plot 3, 16 species were found from seven families, including Pteridaceae, Polypodiaceae, Athyriaceae, Thelypteridaceae,

Dryopteridaceae, Davalliaceae, and Nephrolepidaceae. Each plot has distinct species with its own characteristics (Figure 3). The only species found in plot 1 is *L. flexuosum* because this species is very dependent on low humidity (Andayaningsih et al., 2013). Plot 2 has the characteristics of the species, namely *S. heterocarpus*, because it is usually found on the banks of streams with moist and shady environmental conditions (Piggott, 1988). The characteristics of the species found in plot 3 is *D. solida* because this species grows at moderate to high altitudes and is highly dependent on-air humidity (Sukarya, 2013). Species with other characteristics were also found in *B. revoluta* with a total of 4. It is because *B. revoluta* depends on tree vegetation and air temperature in the environment (Hanjarwani, 2011).

Each plot has species that dominate in different families (Figure 4). The dominant species in plot 1 was *P. calomelanos*, which is 68 individuals. *Christella dentata* is the species that dominates in plot 2, which is 63 individuals. Plot 3 also contains *D. asperum*, whose total dominates at individuals. These three species have high adaptability, making survival easier in an environment with a more dominant total of individuals than other species (Andayaningsih et al., 2013).

Based on Table 2, the taxonomic diversity index (Δ) related to taxonomic levels includes classes, orders, families, and ferns species in the three observation plots. The highest taxonomic diversity index was found in plot 3 which is 31.66, which belongs to the medium category, this indicates that various ferns species were found with various taxonomic levels. While the lowest diversity index was found in plot 1 which is 23.36, belonging to the low category, which indicates that there are various species with less diverse taxonomic levels in that plot. This category is highly dependent on the species found at the research location.

Figure 3. Species Characteristics in Three Plots, A) *Lygodium flexuosum*, B) *Sphaerostephanos heterocarpus*, and C) *Davallia solida*

Figure 4. Species with the Most Individuals in Three Plots, A) *Pityrogramma calomelanos*, B) *Christella dentata*, and C) *Diplazium asperum*

Table 2 Index of Taxonomic Diversity and Dominance of Ferns in the Sekar Pudak Sari Waterfall Tourism Area (n = 28)

Plot	Taxonomic Diversity Index (Δ)	Category	Dominance Diversity Index (Δ*)	Category
Plot 1 (500 masl)	23.36	Low	2.7	Low
Plot 2 (700 masl)	30.58	Medium	2.8	Low
Plot 3 (900 masl)	31.66	Medium	2.7	Low

Table 3 Environmental Abiotic Factors for Each Plot

Plot	Environmental Abiotic Factors			
	pH	Temperature	Humidity	Light intensity
Plot 1 (500 masl)	6.6	25°C	63%	1.104 lux
Plot 2 (700 masl)	6.8	23°C	68%	1.018 lux
Plot 3 (900 masl)	7.1	22°C	70%	837 lux

Species diversity is essential to ecosystem stability and the species balance in an area. The taxonomic diversity index is also crucial to knowing the existence of various species in an area (Indriyanto, 2017). The taxonomic diversity index is high if various species are evenly distributed in an area with a balanced total of individuals. If an area has a low to medium category, the species found are less diverse or still in the same taxonomic group even though the total number of individuals is abundant (Hutasuhut & Febriani, 2019).

The dominance diversity index (Δ*) in Table 2 shows that all three plots belong to the low category, with the highest score which is 2.8 in plot 2, while the two plots have the same value, which is 2.7. The dominance diversity index was determined by the total number of individuals of each species at the research location.

The dominance diversity index is essential to the distribution pattern of species in an area. The dominance diversity index is determined by the total number of individuals in each species, which is also related to its taxonomic level. The dominance diversity index is influenced by high species productivity and good adaptability to their habitat. The easier species grow and develop, the more individuals there will be in an area (Efendi *et al*., 2013).

The diversity index of ferns species was calculated using the Shannon-Wiener (H'). Fern's species diversity index in the Sekar Pudak Sari Waterfall Tourism Area was obtained at 2.92, classified into the medium category. This diversity index indicates the existence of species and the total of individuals that are balanced and evenly distributed.

The distribution of individuals in each species influences species diversity. The more evenly distributed the individuals of each species are the higher the species diversity (Hutasuhut & Febriani, 2019). The species diversity index in the medium category can be caused by the ability of ferns to adapt to the environment and grow in the shade, resulting in an adequate balance of species in an area (Sari & Mukti, 2019).

Measurement of abiotic environmental factors includes soil pH, air temperature and humidity, and light intensity. Based on Table 3, it can be seen that the highest soil pH is in plot 3, which is 7.1, and the lowest soil pH is in plot 1, which is 6.6. The highest air temperature is in plot 1, which is 25°C, and the lowest is in plot 3, which is 22°C. The highest humidity is in plot 3, which is 70%, and the lowest is 63% in plot 1. The highest light intensity is 1.104 lux in plot 1, and the lowest is in plot 3, at 837 lux.

Fern's species diversity is essential as a constituent of the ecosystem. It is one of the supporting factors for environmental conservation efforts. Based on the conservation status of the IUCN Red List in 2022, the species found in the Sekar Pudak Sari Waterfall Tourism Area are still in the safe category. However, one species, namely *P. vittata*, has been registered with the IUCN with LC (Least Concern) status. According to the statement of Perida et al. (2023), *P. vittata* is a species that has received little attention. Thus, it is necessary to carry out conservation efforts to prevent the extinction of the species.

CONCLUSION

Based on the results of research in the Sekar Pudak Sari Waterfall Tourism Area, it can be concluded that there are 28 species of ferns from eleven families. The index of taxonomic diversity and dominance varies for each plot. Plot 1 shows a low taxonomic diversity index. In contrast, plots 2 and 3 are medium. It indicates stable environmental conditions for species at various taxonomic levels. However, the total number of individuals found is still relatively low, so the dominance diversity index is low and less stable. In contrast, the Shannon-Wiener diversity index is classified as medium, indicating that the ferns distribution pattern in the environment is still balanced.

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