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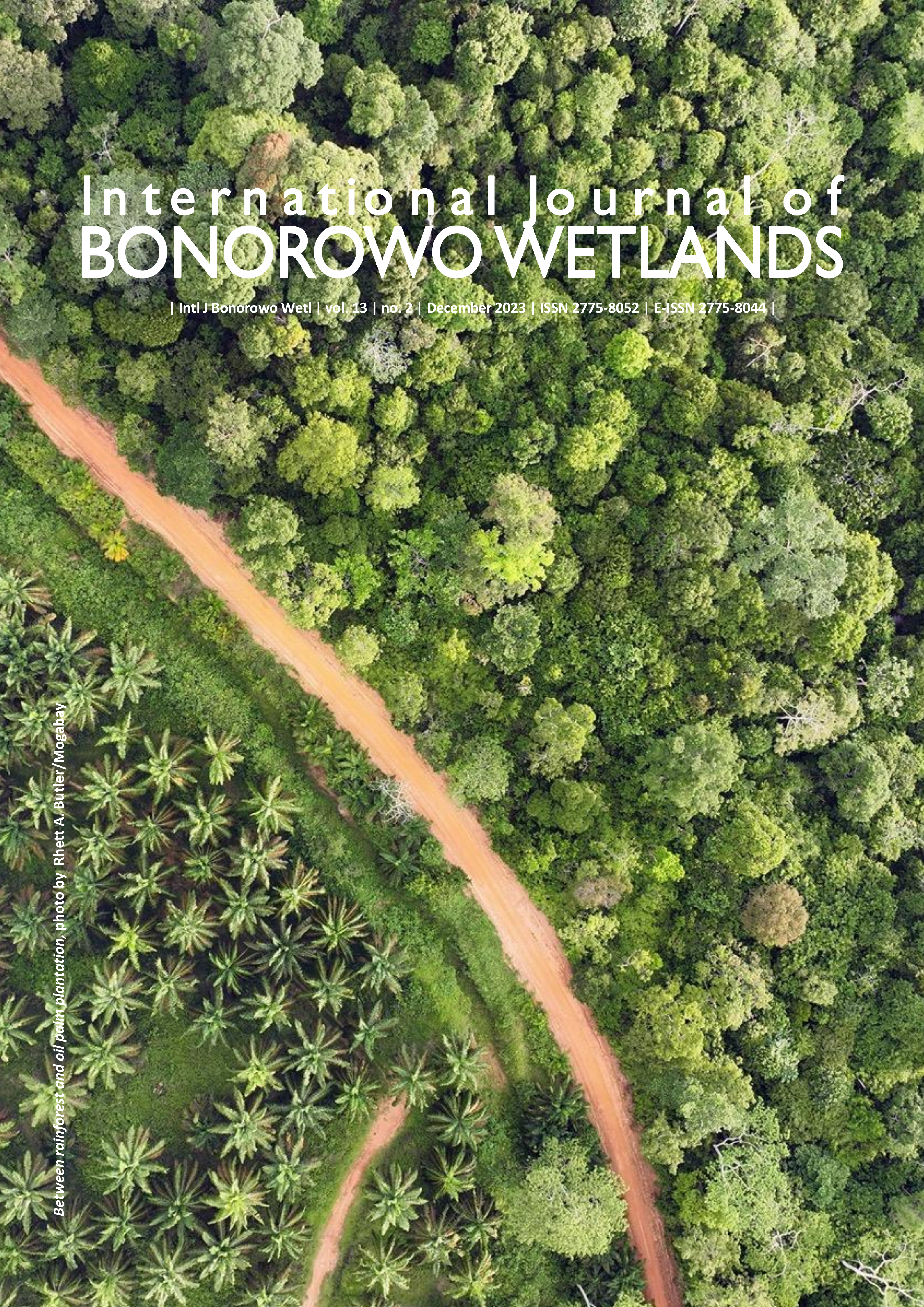

Between rainforest and oil palm plantation, photo by Rhett A. Butler/Mogabay

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The title of the article should be written in compact, clear, and informative sentence, preferably not more than 20 words. Name of author(s) should be completely written, especially for the first and the last name. **Name and institution** address should also be completely written with street name and number (location), postal code, telephone number, facsimile number, and email address. We choose local names in Bahasa Indonesia for universities in Indonesia. The mention of "strata" program, should be avoided. Manuscript written by a group, author for correspondence along with address is required (marked with "♥"). **The title page** (first page) should include title of the article, full name(s), institution(s) and address(es) of the author(s); the corresponding authors detailed postage and e-mail addresses (P), and phone (O) and fax numbers (O).

Abstract A concise abstract is required (about 200 words). The abstract should be informative and state briefly the aim of the research, the principal results and major conclusions. An abstract is often presented separately from the article, thus it must be able to stand alone (completely self-explanatory). References should not be cited, but if essential, then cite the author(s) and year(s). Abbreviations should be avoided, but if essential, they must be defined at their first mention. **Keywords** are about five words, covering scientific and local name (if any), research themes, and special methods used; and sorted from A to Z. **Abbreviations** (if any): All important abbreviations must be defined at their first mention there. **Running title** is about five words.

Introduction is about 600 words, covering the aims of the research and provide an adequate background, avoiding a detailed literature survey or a summary of the results. **Materials and Methods** should emphasize on the procedures and data analysis. **Results and Discussion** should be written as a series of connecting sentences, however, for a manuscript with long discussion should be divided into subtitles. Thorough discussion represents the causal effect mainly explains why and how the results of the research were taken place, and do not only re-express the mentioned results in the form of sentences. **Concluding** sentence should be given at the end of the discussion. **Acknowledgements** are expressed in a brief; all sources of institutional, private and corporate financial support for the work must be fully acknowledged, and any potential conflicts of interest are noted.

Figures and Tables of a maximum of three pages should be clearly presented. The title of a picture is written down below the picture, while the title of a table is written above the table. Colored figures can only be accepted if the information in the manuscript can lose without those images; the chart is preferred to use black and white images. The author could consign any picture or photo for the front cover, although it does not print in the manuscript. All images property of others should be mentioned the source. Author is suggested referring to Wikipedia for international boundaries and Google Earth for satellite imagery. If not specifically mentioned, it is assumed to refer to these sources. **There is no appendix**, all data or data analysis is incorporated into Results and Discussions. For broad data, it can be displayed on the website as a supplement.

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Journal:

Saharjo BH, Nurhayati AD. 2006. Domination and composition structure change at hemic peat natural regeneration following burning; a case study in Pelalawan, Riau Province. Biodiversitas 7: 154-158. DOI: 10.13057/biodiv/d070213.

The usage of "et al." in long author lists will also be accepted:

Smith J, Jones M Jr, Houghton L et al. 1999. Future of health insurance. N Engl J Med 965: 325-329. DOI: 10.10007/s002149800025.

Book:

Rai MK, Carpinella C. 2006. Naturally Occurring Bioactive Compounds. Elsevier, Amsterdam.

Chapter in the book:

Webb CO, Cannon CH, Davies SJ. 2008. Ecological organization, biogeography, and the phylogenetic structure of rainforest tree communities. In: Carson W, Schnitzer S (eds.). Tropical Forest Community Ecology. Wiley-Blackwell, New York.

Abstract:

Assaeed AM. 2007. Seed production and dispersal of *Rhazya stricta*. 50th annual symposium of the International Association for Vegetation Science, Swansea, UK, 23-27 July 2007.

Proceeding:

Alikodra HS. 2000. Biodiversity for development of local autonomous government. In: Setyawan AD, Sutarno (eds.). Toward Mount Lawu National Park; Proceeding of National Seminary and Workshop on Biodiversity Conservation to Protect and Save Germplasm in Java Island. Universitas Sebelas Maret, Surakarta, 17-20 July 2000. [Indonesian]

Thesis, Dissertation:

Sugiyarto. 2004. Soil Macro-invertebrates Diversity and Inter-Cropping Plants Productivity in Agroforestry System based on Sengon. [Dissertation]. Universitas Brawijaya, Malang. [Indonesian]

Information from the internet:

Balagadde FK, Song H, Ozaki J, Collins CH, Barnet M, Arnold FH, Quake SR, You L. 2008. A synthetic *Escherichia coli* predator-prey ecosystem. Mol Syst Biol 4: 187. DOI: 10.1038/msb.2008.24. www.molecularsystembiology.com.

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Analysis of riparian vegetation in the Siwaluh River, Karanganyar District, Central Java, Indonesia

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Abstract. *Pramadaningtyas PS, Chandrasari N, Izdihar RS, Iqbal WM, Cahyaningsih AP, Setyawan AD. 2023. Analysis of riparian vegetation in the Siwaluh River, Karanganyar District, Central Java, Indonesia. Intl J Bonorowo Wetlands 13: 45-56.* This research was conducted in the Siwaluh River Basin region, Karanganyar District, Central Java, Indonesia. Land conversion into residential areas has lowered infiltration capacity, particularly in the Siwaluh River riparian vegetation, in the form of reduced or even lost vegetation that should serve as a water catchment area and habitat for riparian plants. The research was done to analyze riparian vegetation in the Siwaluh River to collect data for the conservation of the riparian zone, which plays a vital role in ecology and the ecosystem. Calculating the maximum IVI value and the existence of plant species from the diversity of riparian vegetation could determine the dominant vegetation type in a given area. The quadratic plot method employed was used; square plots of 20mx20m for trees, 10mx10m for poles, 5mx5m for saplings, and 2mx2m for seedlings were established at each sampling location. After that, the vegetation investigation comprised density, dominance, frequency, Shannon-Wiener diversity index, and IVI. The survey identified 209 plant species; *Kigelia africana* dominated the highest IVI value in tree habitus. Practically, in each upstream, middle, and downstream location, *Bambusa* sp. dominated the highest IVI in the pole habitus, *Manihot esculenta* controlled the highest IVI in the sapling habitus, and *Ageratum conyzoides* dominated the seedling habitus. Variations in the diversity index (H') of tree, pole, sapling, and seedling habitus result from reduced or even disappearing vegetation due to land changes. Therefore, it changes the distribution pattern of riparian vegetation.

Keywords: Riparian, Siwaluh River, vegetation analysis

INTRODUCTION

A river naturally flows freshwater from a high place to the lower; it has an estuary in a bigger sea, lake, or river bordered on the right and left by boundaries (Pane and Suhelmi 2021). Upstream river currents are typically swifter than downstream. While the watershed is the flow of rainwater catchments limited by mountain ridges that will flow into the main river, these catchments are limited by mountain ridges. The watershed is vital for the river and its tributaries, according to Government Regulation No. 37 concerning Watershed Management. The watershed collects, stores, and channels rainwater to the oceans, lakes, and natural reservoirs. In addition, riparian is the transition zone between river habitats and terrestrial ecosystems. This riparian ecosystem is essential since it protects the river's surrounding living (Siahaan and Ai 2014). The riparian also comprises places inhabited by organisms that influence or are influenced by water bodies.

In the riparian zone, an assortment of plants grows. Moreover, riparian vegetation has unique morphological, physiological, and reproductive properties, making it easily adaptable to damp conditions and even capable of adjusting to flooding, settling, and abrasion (Naiman et al. 2005). Riparian vegetation ecosystems serve multiple purposes, including erosion control, as a sediment device to protect the surface of the environment, particularly to prevent rising water temperatures, aiding groundwater supplies, as a habitat for flora and fauna, as a development site, and as an aesthetic boundary for human settlements. Riparian vegetation has the function of regulating the flow of energy and nutrients. Riparian vegetation serves as a river defense against pollutants and a microclimate regulator. The existence of riparian vegetation influences the evolution of a river ecosystem (Ainy et al. 2018). Riparian vegetation also serves as a supporting ecosystem that plays a part in the carbon, oxygen, nitrogen, and water cycles. In addition, riparian vegetation can indicate environmental quality and contribute to preserving the cliffs' structural integrity (Mulyadi 2001).

Indonesia, after all, is experiencing a rise in population and development, leading to a heightened level of land use alteration (Handayani et al. 2020). As a result of this phenomenon, there is a decrease in the riparian zone's width, which subsequently reduces the riparian vegetation. Alterations in land use are anticipated to impact the caliber of riparian flora and water quality in rivers (Liu et al. 2019). The alteration in question has implications for riparian ecosystems, given their role in safeguarding and maintaining the riverine milieu (Kudubun et al. 2020).

Oktaviani and Yanuwiadi (2016) stated that riparian areas serve crucial functions and provide numerous benefits. However, these areas are increasingly vulnerable to threats from human activities that exploit them. Disposing of the household waste directly into aquatic systems can escalate the concentration of contaminants (Susanti 2015). The diminution of riparian vegetation is expected to affect ecological functions and riparian ecosystems' stability negatively (Singh et al. 2021). The reduction of riparian zones through the implementation of river streamlining, shortcuts, and embankment construction can lead to a decrease in riparian vegetation (Bando et al. 2016). Introducing invasive species poses several obstacles to eliminating or restricting riparian areas (Jones et al. 2022).

The Siwaluh River traverses Karanganyar District and is considered one of the lengthiest rivers in this area. The Siwaluh River exhibits a physical cross-sectional profile that deviates from its width and depth. The Siwaluh River, located in Karanganyar District, Indonesia, has been identified as a river that has been contaminated due to improper waste disposal practices. The river above spans roughly 37 kilometers, traversing six districts. Research on the riparian diversity of the Siwaluh River has not been previously conducted. Therefore, it is imperative to study the vegetation types to understand the formation of the vegetation community structure. The study aimed to examine the riparian vegetation in the Siwaluh River region, intending to gather data to support the conservation of the riparian zone in the Siwaluh River. This zone is known to have significant ecological and ecosystem. The study of vegetation was carried out by analyzing the growth rate of various trees, saplings, poles, and seedlings types. The parameters to be assessed are the Important Value Index (IVI) and the Species Diversity Index (H').

MATERIALS AND METHODS

Study area

The Siwaluh River, situated in the Karanganyar District of Central Java, Indonesia, is a hydrological unit that drains water and other resources from its surrounding areas. The river spans roughly 37 kilometers and traverses six sub-districts, specifically Karangpandan, Matesih, Karanganyar, Tasikmadu, Jaten, and Kebakkramat. The Siwaluh River's upstream region is in the Karangpandan Sub-district of the Karanganyar District, while its downstream region is in the Bengawan Solo River. The study was conducted at three locations within the Siwaluh River, specifically the upstream, middle, and downstream regions. The initial station, the upstream region, is in Gerdu Village (750 m asl) at geographical coordinates 07°38'24.4"S 111°05'59.8"E. Next, the second station, the central area, is situated in Bejen Village (185 m asl.) at geographical coordinates 7°35'39.9"S 110°57'10.2"E. Finally, the third station, the downstream area, is situated in Sroyo Village (80 m asl.) at geographical coordinates 7°31'16.2"S 110°52'57.0"E. The study was carried out in May 2022 (Figure 1).

Sampling technique

The study employed a purposive sampling technique, whereby participants were selected based on various factors to ensure they represented the entire population. Research data were collected at three stations, specifically the upstream, middle, and downstream areas. Subsequently, five observation plots were established at each station. Furthermore, abiotic variables were also measured, including altitude, light intensity, water pH, air humidity, air temperature, soil pH, and water temperature. Each plot consists of an area of 20 meters by 20 meters, divided into three sub-plots measuring 10 meters by 10 meters, 5 meters by 5 meters, and 2 meters by 2 meters, respectively. The study employs plots of varying sizes to collect vegetation samples. Specifically, tree vegetation samples are collected using plots measuring 20mx20m, and pole vegetation samples using 10mx10m plots. Then, sapling vegetation samples using 5mx5m plots and seedling vegetation samples using 2mx2m plots. The configuration of the applied vegetation analysis plot is depicted in Figure 2.

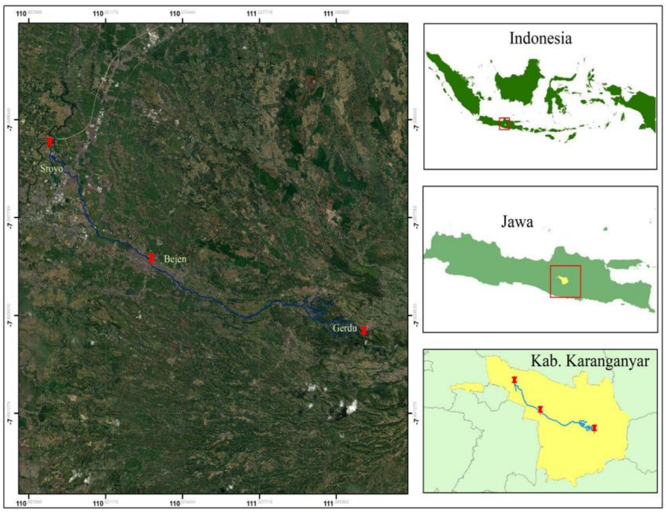

Figure 1. Map of the Siwaluh River research location, Karanganyar, Central Java, Indonesia

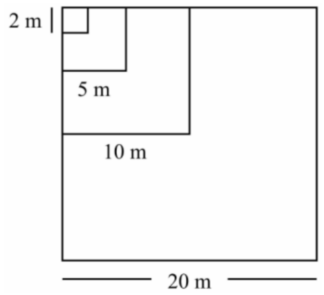

Figure 2. Vegetation analysis plot design

Data analysis

Identification data on tree species, poles, saplings, seedlings, and their number are recorded on a tally sheet. This study involved an analysis of the data about species density, frequency, dominance, Important Value Index (IVI), and Diversity Index (H'). Magurran (1988) stated that the Shannon-Wiener Index is suitable for measuring diversity due to its widespread usage and established conceptual framework. The level of species diversity in an ecosystem can be determined by the value of H', where a classification of low species diversity is assigned when H'<1, moderate species diversity is assigned when 1≤H'≤3, and high species diversity is assigned when H'>3.

$$H' = \sum_{i=1}^{s} (Pi)\ x\ (LnPi)$$

Where:
Pi : Σni/N
H': Shannon-Wiener Diversity Index
Pi : The number of individuals of a species / the total number of all species
Ni : The number of individuals of the i-th species
N : Total number of individuals

The formula developed by Soerianegara and Indrawan (1988) was utilized to calculate the species density, frequency, dominance, and Important Value Index (IVI). Fachrul (2007) has proposed a categorization scheme for IVI values, wherein values greater than 42.66 are classified as high, values ranging from 21.96 to 42.66 are classified as moderate, and values less than 21.96 are classified as low. The equations above encompass the following expressions:

(i) Density

$$Density\ (K) = \frac{\sum \text{Individual}}{\text{Sample plot area}}$$

$$Relative\ Type\ Density\ (KR) = \frac{\text{K of a type}}{\text{K of all type}} \text{x}100\%$$

(ii) Frequency

$$Frequency\ (F) = \frac{\sum \text{subplot where type found}}{\sum \text{subplot of all sample type}}$$

$$Relative\ Frequency\ (FR) = \frac{\text{F of a type}}{\text{F of all type}} \text{x}100\%$$

(iii) Dominance

$$Dominance\ (D) = \frac{\text{Base area of a type}}{\text{Sample plot area}}$$

$$Relative\ Dominance\ (RD) = \frac{\text{D of a type}}{\text{D of all type}} \text{x}100\%$$

(iv) Important Value Index
IVI of tree and pole: KR + FR + DR
IVI of sapling and seedling: KR + FR

RESULTS AND DISCUSSION

Species found

A total of 209 species of riparian vegetation were identified. The occurrence of a particular plant species within a given geographical region indicates its capacity to acclimate to the local ecosystem and withstand various ecological stress. A botanical survey in the Siwaluh River catchment area revealed various plant species exhibiting different growth forms, such as trees, poles, saplings, and seedlings. The study revealed that the number of species in the upstream area was 77, while the middle area exhibited a species composition of 86. A total of 99 species were identified in the downstream area based on the species composition analysis. The study revealed that the tree habitus comprised 15 species, while the pole habitus had 15. The sapling habitus exhibited a species composition of 25, while the seedling habitus displayed a species composition of 179.

Diversity index value (H')

The Importance Value Index (IVI) and the Diversity Index (H') characterize vegetation distribution across the upstream, middle, and downstream areas. The Shannon-Wiener diversity index, denoted as H', is a commonly employed metric for examining the level of diversity present within plant communities' local flora (Sun and Ren 2021). The present study reports on the diversity index of the Siwaluh river area, specifically for the upstream (3.78), middle (4.05), and downstream regions. (3.92). The findings for the middle region indicate a higher diversity index value of 4.05 (high category) compared to the upstream and downstream regions. The Siwaluh River Basin exhibits a notable diversity level owing to land use alterations within the middle region, situated in Bejen Village. The Siwaluh River Basin region is geographically significant due to its proximity to inhabited localities. The preservation of riverbanks by the local community is achieved through the avoidance of construction activities along the riverbanks and the implementation of vegetation planting measures in the surrounding areas. Cultivating Bamboo in the central region and adjacent riverbanks is a commendable measure in mitigating the potential flooding hazards. Bamboo trees can retain water during periods of high-intensity precipitation (Sholikhati et al. 2020).

Numerous species of *Ageratum conyzoides*, and *Synedrella nodiflora* are present in the upstream region. The local populace commonly considers them weeds due to their significant prevalence. In addition, the Siwaluh River's upstream region is in Gerdu Village, on Mount Lawu. The inherent beauty of the natural environment presents diverse tourist destinations capable of attracting visitors. Additionally, the pleasant climate contributes to the allure of these destinations, thereby generating specific desires and motivations, such as the desire to establish a permanent residence (settlement). Moreover, there is a growing demand for land to be utilized for agricultural purposes, as evidenced by the expanding rice fields and plantations located in the upstream region of the Siwaluh River Basin. The conversion of natural vegetation to agricultural land in the upstream region displaces the former by-crops such as rice, vegetables, and fruits. Sholikhati et al. (2020) suggest that the upstream area is a conservation zone. Therefore, it is recommended that individuals residing in this area prioritize planting trees with ecological benefits, such as bamboo trees, over other species. Revitalizing the upstream region is imperative, as any harm inflicted could adversely affect the downstream area. Noverma (2017) clarifies that bamboo is a plant that exhibits water conservation properties due to its capillary nature. Specifically, Bamboo stems can absorb water during flooding and retain water for extended periods during dry seasons.

The field inventory findings indicate that communities downstream prefer cultivation more than conservation plants to mitigate the likelihood of landslides and floods. The cultivated flora comprises *Carica papaya*, *Musa* sp., and *Leucaena leucocephala*, whereas the conservation vegetation in the lower region solely consists of *Bambusa* sp. and *Tectona grandis*. The prevalence of *palawija* crops (annual crops on dry land) and shrubbery characterizes in most terrain. Winandar (2015) stated that the Siwaluh River Basin is subject to water pollution from human land use activities. The current Water Pollution Control measures prioritize the industrial sector but fail to sufficiently identify pollution loads and analyze the capacity to manage such loads; as a result, the downstream portion of the Siwaluh River remains contaminated. As per Winandar's (2015) findings, the Maximum Daily Load (DTBP) value in the lower regions of the Siwaluh River surpasses the Pollution Load Carrying Capacity value for all parameters, with recorded values of 22.59 (TSS), 28.73 (BOD), and 68.16 (COD). The diversity of habitats in the upstream and downstream sectors is greater than in the middle. The downstream regions underwent significant land-use alterations, including manufacturing facilities and communal gardens. These changes led to a reduction or complete loss of vegetation, with only several species remaining, specifically *Colacasia* sp., *Manihot esculenta*, and *Albizia chinensis*, exhibiting the highest levels of presence. The river's lower region is a hydrological basin that receives water from the upper and middle reaches. As a result, the probability of landslides and floods is significantly elevated, particularly in periods of heavy precipitation (Say et al. 2021). The downstream region's riparian zones underwent notable land use alterations, surpassing those observed in the upstream and midstream regions. The Siwaluh River's downstream regions are utilized for several industrial products. For example, soap and ethyl alcohol factories and plantation land use; also serve as a final disposal site for the nearby community.

Table 1 shows the values of the H' examination for the three sites at high. In contrast, land utilization in the lower region is comparatively higher. As per the findings of Aswin et al. (2019), the uniformity of habitat conditions across the upstream, middle, and downstream station areas has resulted in the similarity of diversity index categories. The stable ecosystem of the Siwaluh River is indicated by the high diversity index observed in the three locations. This study was consistent with Ismaini et al.'s (2015) assertion a greater diversity index corresponds to increased ecosystem stability.

Important Value Index (IVI)

Tree-level Important Value Index (IVI)

The IVI metric demonstrates the significance of a given plant species and its contribution to the surrounding ecosystem. This IVI value is achieved by calculating the cumulative value of Relative Type Density (KR), Relative Frequency (RF), and Relative Dominance(RD) across the various stages of vegetation growth, including tree, pole, sapling, and seedling. The concept of relative density pertains to the quantification of the population of a plant community within a designated study area. On the other hand, relative frequency refers to the proportion of a particular species' absolute frequency to the overall frequency of all species present in the entirety of the study area. The frequency of occurrence of a particular species in its habitat can be inferred from its presence. According to the Important Value Index (IVI) analysis conducted in the Siwaluh River Basin area, it has been determined that *Kigelia africana* exhibits the highest IVI (135.63). The *K. africana* is an autochthonous plant species that thrive in the Siwaluh River region. The *K. africana* is known to thrive in habitats characterized by fertile soils that exhibit a high proportion of clay content. The *K. africana* exhibits remarkable resilience to arid conditions and can thrive across a range of elevations spanning from 50 meters above sea level to 800 meters above sea level. The diversity index of the upstream area is 1.010, indicating a moderate level of diversity. It is attributed to the prevalence of *K. africana* among the plant species in the area, as it is more frequently present than other tree species. The *K. africana* exhibits potential utilization value in the field of health medicine. As per the findings of Fauzan et al. (2020), the *K. africana* fruit comprises active constituents, including flavonoids, coumarins, naphthoquinones, and iridoids. Furthermore, the conservation value of riparian vegetation for the environment is noteworthy. Mukhlison (2015) reported that *Tectona grandis* exhibits an IVI value of 134.83 and possesses the capacity to sequester carbon dioxide (CO_2), while *Terminalia catappa* demonstrates a high IVI value of 74.83 and is capable of effectively absorbing lead (Pb). The plants can manage atmospheric contamination efficiently, particularly lead (Pb) and carbon dioxide (CO_2) particles that typically emanate from vehicular exhaust emissions. The *T. grandis* can thrive in regions characterized by a relatively brief dry spell and a considerable amount of solar radiation throughout the year. The litterfall process, wherein branches and broad leaves fall to the ground, gradually decomposes the soil, impeding other plant species' growth. The Important Value Index (IVI) calculation outcomes for tree species within the Siwaluh River Basin Area are sown in the following (Table 2).

Pole-level Important Value Index (IVI)

The pole vegetation in the River Basin is dominated by *Bambusa* sp., with an IVI of 173.72. Due to their roots, bamboo plants can maintain environmental balance from their ecological (Rathour et al. 2022). Bamboo's deep, wide, and robust roots help reinforce soil structure and prevent erosion (Huzaemah et al. 2016; Mentari et al. 2018). Riparian vegetation plays a crucial role in preserving the rivers' hydro morphology; however, it has been widely overlooked in most hydro morphological assessment methods (Tánago et al. 2021). Riparian ecosystems provide vital habitats for several species, but it is not easy to assess vegetation status over a vast region and extended period (Assal et al. 2021). The findings of calculating the Important Value Index (IVI) for the different types of poles in the Siwaluh River Basin are shown here (Table 3).

Table 1. Diversity index found in the Siwaluh River Basin Area, Karanganyar, Central Java, Indonesia

Station	H'	Category
Upstream	3.78	High
Middle	4.05	High
Downstream	3.92	High

Table 2. Important Value Index of tree species found in the Siwaluh River Basin area, Karanganyar, Central Java, Indonesia

Name	Family	Station	KR	FR	RD	IVI
Artocarpus heterophyllus	Moreceae	Upstream	25	25	30.15	80.15
Bourbon coffee	Rubiciae	Upstream	25	25	34.22	84.22
Kigelia africana	Bignoniaceae	Upstream	50	50	35.63	135.63
Artocarpus heterophyllus	Moreceae	Middle	7.69	7.69	11.86	27.25
Carica papaya	Caricaeae	Middle	7.69	7.69	7.68	23.07
Leucaena leucocephala	Fabaceae	Middle	7.69	7.69	8.00	23.38
Muntingia calabura	Muntingiaceae	Middle	15.38	15.38	10.74	41.51
Naphelium lappacum	Sapindaeae	Middle	7.69	7.69	11.67	27.05
Samanea saman	Fabaceae	Middle	7.69	7.69	7.53	22.91
Tectona grandis	Terminaliaceae	Middle	46.15	46.15	42.52	134.83
Catalpa bignonioides	Bignoniaceae	Downstream	22.22	22.22	18.98	63.42
Ceiba pentandra	Malvaceae	Downstream	11.11	11.11	6.17	28.39
Commiphora mukul	Burseraceae	Downstream	22.22	22.22	37.61	82.06
Otoba novogranatensis	Myristicaceae	Downstream	11.11	11.11	14.02	36.24
Tectona grandis	Terminaliaceae	Downstream	11.11	11.11	11.82	34.04
Terminalia catappa	Terminaliaceae	Downstream	22.22	22.22	30.38	74.83

Notes: KR: Relative Type Density, FR: Relative Frequency, RD: Relative Dominance, IVI: Important Value Index

Table 3. Important value index of the types of poles found in the Siwaluh River Basin area, Karanganyar, Central Java, Indonesia

Name	Family	Station	KR	FR	RD	IVI
Archidendron pauciflorum	Fabaceae	Upstream	7.14	7.14	6.97	21.25
Artocarpus heterophyllus	Moraceae	Upstream	14.29	14.29	19.60	48.17
Bambusa sp.	Poaceae	Upstream	17.86	17.86	11.05	46.76
Carica papaya	Caricaceae	Upstream	3.57	3.57	1.51	8.65
Cedrela montana	Meliceae	Upstream	7.14	7.14	19.69	55.40
Ficus sp.	Moraceae	Upstream	7.14	7.14	5.31	12.45
Kigelia africana	Bignoniaceae	Upstream	3.57	3.57	9.25	23.53
Leucaena leucocephala	Fabaceae	Upstream	7.14	7.14	6.24	20.53
Mangifera indica	Anacardiaceae	Upstream	3.57	3.57	5.48	12.63
Tectona grandis	Terminaliaceae	Upstream	14.29	14.29	13.31	41.88
Zanthoxylum ailanthoides	Poaceae	Upstream	3.57	3.57	1.60	8.75
Bambusa sp.	Poaceae	Middle	15.79	15.79	13.62	45.20
Carica papaya	Caricaceae	Middle	15.79	15.79	15.21	46.78
Leucaena leucocephala	Fabaceae	Middle	10.53	10.53	9.04	30.09
Samanea saman	Fabaceae	Middle	10.53	10.53	10.50	31.56
Tectona grandis	Terminaliaceae	Middle	47.37	47.37	51.63	146.37
Albizia chinensis	Fabaceae	Downstream	11.76	11.76	16.06	39.59
Bambusa sp.	Poaceae	Downstream	58.82	58.82	56.07	173.72
Leucaena leucocephala	Fabaceae	Downstream	23.53	23.53	20.55	67.60
Samanea saman	Fabaceae	Downstream	5.88	5.88	7.33	19.09

Notes: KR: Relative Type Density, FR: Relative Frequency, RD: Relative Dominance, IVI: Important Value Index

Sapling level Important Value Index (IVI)

The vegetation distribution at the sapling level in the upper, middle, and lower sections of the Siwaluh River, the proportion of KR (%) and FR (%), and the dominant sapling level vegetation were dominated by *Manihot esculenta*, *A. chinensis,* and *Colacasia* sp. These three species have relatively high-density ratings because they have the greatest number of individuals per unit area in a research location. Their presence at each research station is nearly identical, with the corresponding IVIs of the three species being 107.14, 70.97, and 68.97. The plant with the highest IVI is *M. esculenta* (107.14), which can be used as a vegetable ingredient with a high protein content or for others such as medicinal ingredients (Anwar et al. 2018); thus, many are planted purposely by locals and grow naturally near river flows and villages. The findings of calculating the Important Value Index (IVI) for saplings in the Siwaluh River Basin are displayed in (Table 4).

Seedling level Important Value Index (IVI).

The vegetation distribution at the seedling level in the upper, middle, and lower sections of the Siwaluh River river revealed that *A. conyzoides*, *S. halepense*, and cleavers had the largest percentages of KR, FR, and IVI, respectively. These three species have high IVI values because they have the greatest number of individuals per unit of research site area. The IVIs of the three species were, respectively, 21.48, 14.51, and 10.54. Changes in land use pose a grave threat to riparian vegetation, necessitating land use management to alter riparian vegetation for biodiversity conservation (Borisade et al. 2021). Increasing habitat heterogeneity through vegetation restoration can improve the diversity of riparian vegetation (Saulino et al. 2021). Riparian vegetation is influenced by river size, with variations depending on the flow system (Shahimi et al. 2019). The result of the Important Value Index (IVI) for seedling kinds in the Siwaluh River Basin is displayed in (Table 5)

Abiotic factor

Furthermore, the observations on abiotic measured the following environmental factors: altitude, light intensity, water pH, humidity, air temperature, soil pH, and water temperature. Table 6 displays the results of measuring environmental factors.

Table 4. Important value index of sapling species found in the Siwaluh River Area, Karanganyar, Central Java, Indonesia

Name	Family	Station	KR	FR	IVI
Calliandra sp.	Fabaceae	Upstream	1.72	1.72	3.45
Carica papaya	Caricaceae	Upstream	1.72	1.72	3.45
Colacasia sp.	Araceae	Upstream	34.48	34.48	68.97
Cordyline fruticosa	Asparagaceae	Upstream	1.72	1.72	3.45
Cupaniopsis anacarioides	Sapindaceae	Upstream	5.17	5.17	10.34
Dryopteris cristata	Dryiopteridaceae	Upstream	1.72	1.72	3.45
Garnicia mangostana	Clusiaceae	Upstream	1.72	1.72	3.45
Leucaena leucocephala	Fabaceae	Upstream	17.24	17.24	34.48
Mangifera indica	Anacardiaceae	Upstream	1.72	1.72	3.45
Garciniamangostana	Clusiaceae	Upstream	1.72	1.72	3.45
Morinda citrifolia	Rubiaceae	Upstream	1.72	1.72	3.45
Musa sp.	Musaceae	Upstream	17.24	17.24	34.48
Peperomia pellucida	Piperaceae	Upstream	6.90	6.90	13.79
Sterculia carviflora	Passifloraceae	Upstream	1.72	1.72	3.45
Tectona grandis	Terminaliaceae	Upstream	3.45	3.45	6.90
Amaranthus sp.	Amaranthaceae	Middle	2.38	2.38	4.76
Annona squamosa	Annonaceae	Middle	1.19	1.19	2.38
Carica papaya	Caricaceae	Middle	4.76	4.76	9.52
Leucaena leucocephala	Fabaceae	Middle	5.95	5.95	11.90
Manihot esculenta	Euphorbiaceae	Middle	53.57	53.57	107.14
Morinda citrifolia	Rubiaceae	Middle	7.14	7.14	14.29
Albizia chinensis	Fabaceae	Downstream	35.48	35.48	70.97
Citrus maxima	Rutaceae	Downstream	12.90	12.90	25.81
Leucaena leucocephala	Fabaceae	Downstream	9.68	9.68	19.35
Manihot esculenta	Euphorbiaceae	Downstream	9.68	9.68	19.35
Solanum carolines	Solanaceae	Downstream	16.13	16.13	32.26
Solanum melongena	Solanaceae	Downstream	16.13	16.13	32.26

Notes: KR: Relative Type Density, FR: Relative Frequency, RD: Relative Dominance, IVI: Important Value Index

Table 5. Important Value Index for the types of seedlings found in the Siwaluh River Area, Karanganyar, Central Java, Indonesia

Name	Family	Station	KR	FR	IVI
Ageratina riparia	Asteraceae	Upstream	1.45	1.45	2.90
Ageratum conyzoides	Asteraceae	Upstream	10.74	10.74	21.48
Ageratum houstonium	Asteraceae	Upstream	2.18	2.18	4.35
Antirrhinum sp.	Plantangiaceae	Upstream	4.35	4.35	8.71
Arenga undulatifolia	Arecaceae	Upstream	1.60	1.60	3.19
Artemisia dracunculus	Asteraceae	Upstream	1.31	1.31	2.61
Artemisia verlotiorum lamotte	Asteraceae	Upstream	2.18	2.18	4.35
Asarum caudatum	Moraceae	Upstream	0.44	0.44	0.87
Asperlum onopteris	Aspleniaceae	Upstream	0.44	0.44	0.87
Asystasia gangetica	Aspleniaceae	Upstream	0.44	0.44	0.87
Basella alba	Basellaceae	Upstream	3.92	3.92	7.84
Caladium sp.	Araceae	Upstream	1.74	1.74	3.48
Cantella asiatica	Araceae	Upstream	4.35	4.35	8.71
Celtis australis	Cannabaceae	Upstream	1.45	1.45	2.90
Ceropegia papillata	Asclepiadaceae	Upstream	2.18	2.18	4.35
Cherry manila	Rosaceae	Upstream	0.44	0.44	0.87
Circaea alpina	Onagraceae	Upstream	5.08	5.08	10.16
Clidemia hirta	Melastomataceae	Upstream	2.18	2.18	4.35
Coccinia grandis	Cucurbitaceae	Upstream	0.15	0.15	0.29
Cordyline fruticosa	Asparagaceae	Upstream	2.47	2.47	4.93
Curcuma petiolata	Zingiberaceae	Upstream	0.15	0.15	0.29
Cyperus rotundus	Cyperaceae	Upstream	2.18	2.18	4.35
Desmanthus sp.	Fabaceae	Upstream	0.58	0.58	1.16
Dichrocephala integrifolia	Asteraceae	Upstream	1.60	1.60	3.19
Dryopteris cristata	Dryopteridaceae	Upstream	0.44	0.44	0.87
Dsarum caudalum	Aristolochiaceae	Upstream	2.03	2.03	4.06
Duruta repens	Verbenaceae	Upstream	2.47	2.47	4.93
Elusine indica	Poaceae	Upstream	0.15	0.15	0.29
Euphorbia hirta	Euphorbiaceae	Upstream	0.58	0.58	1.16
Galeopsis sp.	Lamiaceae	Upstream	1.45	1.45	2.90
Galinsonga quadruradiata	Asteraceae	Upstream	0.29	0.29	0.58
Gymnocarpium dryteris	Cystopteridaceae	Upstream	1.45	1.45	2.90
Gynura crepidioides	Asteraceae	Upstream	1.45	1.45	2.90
Hyptis capitata	Lamiaceae	Upstream	2.18	2.18	4.35
Ipomea turbinata	Convolvulaceae	Upstream	0.87	0.87	1.74
Manihot esculenta	Euphorbiaceae	Upstream	0.15	0.15	0.29
Marsilea crenata	Marsileaceae	Upstream	2.61	2.61	5.22
Miconia crenata	Melastomataceae	Upstream	1.31	1.31	2.61
Mimosa pudica	Fabaceae	Upstream	4.93	4.93	9.87
Naphelium nappaceum	Sapindaceae	Upstream	2.18	2.18	4.35
Otoba sp.	Myristicaceae	Upstream	0.29	0.29	0.58
Oxalis barrelieri	Oxalidaceae	Upstream	0.15	0.15	0.29
Pennisetum purpureum	Poaceae	Upstream	0.58	0.58	1.16
Physalis angulata	Solanaceae	Upstream	0.87	0.87	1.74
Pilea microphylla	Urticaceae	Upstream	0,44	0,44	0,87
Polygala senega	Polygalaceae	Upstream	0.44	0.44	0.87
Sorghum halepense	Poaceae	Upstream	7.26	7.26	14.51
Sphagneticola trilobata	Asteraceae	Upstream	3.05	3.05	6.10
Synedrella nodiflora	Asteraceae	Upstream	5.66	5.66	11.32
Xanthosoma violaceum	Araceae	Upstream	0.29	0.29	0.58
Xantosoma panduriforme	Araceae	Upstream	2.90	2.90	5.81
Acalypha australis	Euphorbiaceae	Middle	1.22	1.22	2.45
Adenostema sp.	Asteraceae	Middle	1.53	1.53	3.06
Ageratum conyzoides	Asteraceae	Middle	1.84	1.84	3.67
Alternanthera sessils	Fabaceae	Middle	1.22	1.22	2.45
Amaranthus sp.	Amaranthaceae	Middle	0.80	0.80	1.59
Amarantus viridis	Amaranthaceae	Middle	0.61	0.61	1.22
Asystasia gangetica	Acanthaceae	Middle	3.67	3.67	7.34
Biophytum petersianum	Celastraceae	Middle	2.75	2.75	5.51
Brachiara mutica	Poaceae	Middle	2.14	2.14	4.28
Callisia fragrans	Commelinaceae	Middle	0.31	0.31	0.61
Calyptocarpus sp.	Asteraceae	Middle	1.22	1.22	2.45
Catharanthus roseus	Apocynaceae	Middle	0.12	0.12	0.24

Name	Family	Station	KR	FR	IVI
Christella normalis	Thelypteridaceae	Middle	0.61	0.61	1.22
Chromolaena odorata	Asteraceae	Middle	4.28	4.28	8.57
Cleome rutidosperma	Cleomaceae	Middle	0.61	0.61	1.22
Cleome viscosa	Cleomaceae	Middle	0.06	0.06	0.12
Clitoria ternatea	Fabaceae	Middle	0.31	0.31	0.61
Colocasia esculenta	Araceae	Middle	2.26	2.26	4.53
Cornus sessils	Cornaceae	Middle	1.22	1.22	2.45
Cynoglossum lanieolatum	Boraginaceae	Middle	0.92	0.92	1.84
Cyperus esculenthus	Cyperaceae	Middle	0.12	0.12	0.24
Cyperus kyllingia	Cyperaceae	Middle	1.53	1.53	3.06
Cyperus odoratus	Cyperaceae	Middle	0.06	0.06	0.12
Cyperus rotundus	Cyperaceae	Middle	1.53	1.53	3.06
Dacty liandra	Cucurbitaceae	Middle	0.61	0.61	1.22
Delphinium sp.	Ranunculaceae	Middle	2.14	2.14	4.28
Digitania sanguinalis	Poaceae	Middle	0.61	0.61	1.22
Digitari uliaris	Poaceae	Middle	0.31	0.31	0.61
Digitaria milaryiana	Poaceae	Middle	0.92	0.92	1.84
Dioscorea hispida	Dioscoreaceae	Middle	0.61	0.61	1.22
Distichlis sp.	Poaceae	Middle	1.22	1.22	2.45
Dryopteris cristata	Dryopteridaceae	Middle	1.22	1.22	2.45
Echinochloa sp.	Poaceae	Middle	1.84	1.84	3.67
Euphorbia celastroides	Euphorbiaceae	Middle	1.22	1.22	3.30
Euphorbia heterophylla	Euphorbiaceae	Middle	1.65	1.65	1.22
Galium aparine	Rubiaceae	Middle	6.12	6.12	12.24
Gomphrena globosa	Amaranthaceae	Middle	1.16	1.16	2.33
Graptophyllum pictum	Acanthaceae	Middle	2.45	2.45	4.90
Holosteum umbellatum	Caryophyllaceae	Middle	0.61	0.61	1.22
Homalomena	Araceae	Middle	0.37	0.37	0.73
Hyptis capitata	Lamiaceae	Middle	1.41	1.41	2.82
Isotoma longiflora	Campanulaceae	Middle	0.06	0.06	0.12
Koeleria macrantha	Poaceae	Middle	1.22	1.22	2.45
Leucaena leucocephala	Fabaceae	Middle	0.31	0.31	0.61
Lommelina diffusz	Commelinaceae	Middle	1.84	1.84	3.67
Lygodium japonicum	Lygodiaceae	Tengah	0,12	0,12	0,24
Macadamia	Proteaceae	Middle	0.06	0.06	0.12
Melothria	Cucurbitaceae	Middle	0.06	0.06	0.12
Mimosa pudica	Fabaceae	Middle	2.08	2.08	4.16
Morinda citrifolia	Rubiaceae	Middle	0.06	0.06	0.12
Muhlenbergia sp.	Poaceae	Middle	0.92	0.92	1.84
Neprolephis cordifolia	Lomariopsidaceae	Middle	3.06	3.06	6.12
Nesgetis sp.	Aspleniaceae	Middle	0.18	0.18	0.37
Oldenlandia corymbosa	Rubiaceae	Middle	4.90	4.90	9.79
Oxalis barrelieri	Oxalidaceae	Middle	2.20	2.20	4.41
Panicium repens	Poaceae	Middle	1.84	1.84	3.67
Passiflora foetida	Passifloraceae	Middle	0.61	0.61	1.22
Pavetta abyssinisa	Rubiaceae	Middle	0.61	0.61	1.22
Pechonochloa colona	Poaceae	Middle	1.22	1.22	2.45
Peperomia pellucida	Piperaceae	Middle	0.06	0.06	0.12
Perilla shiso	Lamiaceae	Middle	0.61	0.61	1.22
Phylanthus urinaria	Phyllanthaceae	Middle	3.73	3.73	7.47
Phyllantus reticulatus	Phyllanthaceae	Middle	1.84	1.84	3.67
Ruellia tuberosa	Acanthaceae	Middle	2.02	2.02	4.04
Salium parisiense	Rubiaceae	Middle	0.61	0.61	1.22
Scutellaria orata	Commelinaceae	Middle	0.61	0.61	1.22
Solenostemo monostachhyus	Lamiaceae	Middle	1.53	1.53	3.06
Spermacole sp.	Rubiaceae	Middle	1.22	1.22	2.45
Sphagnetocola trilobata	Asteraceae	Middle	1.04	1.04	2.08
Synedrella nodiflora	Asteraceae	Middle	5.08	5.08	10.16
Tectona grandis	Terminaliaceae	Middle	0.37	0.37	0.73
Tridax procumbens	Asteraceae	Middle	3.24	3.24	6.49
Yerba porosa	Asteraceae	Middle	1.22	1.22	2.45
Achyranthes aspera	Amaranthaceae	Downstream	3.77	3.77	7.53
Acmella oleracea	Asteraceae	Downstream	1.00	1.00	2.01
Ageratina riparia	Asteraceae	Downstream	0.40	0.40	0.80
Alternanthera sessilis	Amaranthaceae	Downstream	3.01	3.01	6.03

Name	Family	Station	KR	FR	IVI
Althenanthera reineckii	Amaranthaceae	Downstream	0.20	0.20	0.40
Amaranthus sp.	Amaranthaceae	Downstream	0.40	0.40	0.20
Amarantus palmeri	Amaranthaceae	Downstream	3.01	3.01	0.80
Ambrosia sp.	Asteraceae	Downstream	0,25	0,25	0,50
Ashwagandha withania	Solanaceae	Downstream	0.20	0.20	0.20
Asystasia gangetica	Acanthaceae	Downstream	0.10	0.10	8.24
Atenanthera neineckii	Amaranthaceae	Downstream	0.35	0.35	0.70
Barleria Prionitis	Acanthaceae	Downstream	0.50	0.50	1.00
Beckmania sizygachne	Poaceae	Downstream	1.00	1.00	2.01
Brichiaria mutica	Poaceae	Downstream	0.25	0.25	0.50
Chamaecostus cuspidatus	Costaceae	Downstream	0.90	0.90	1.81
Cleistanthus collinus	Phyllanthaceae	Downstream	1.86	1.86	3.72
Cleome rutidosperma	Cleomaceae	Downstream	1.91	1.91	3.82
Colocasia esculenta	Araceae	Downstream	1.00	1.00	2.01
Commelina communis	Commelinaceae	Downstream	2.16	2.16	4.32
Croton tirtus litter	Euphorbiaceae	Downstream	1.00	1.00	2.01
Curcuma sp.	Zingiberaceae	Downstream	0.50	0.50	1.00
Cynosunus echinatus	Poaceae	Downstream	1.00	1.00	2.01
Cyperus esculentus	Cyperaceae	Downstream	0.70	0.50	1.41
Cyperus rotundus	Cyperaceae	Downstream	15.07	15.07	30.14
Cyrtococum patens	Poaceae	Downstream	5.02	5.02	10.05
Cyrtococum patin	Poaceae	Downstream	0.75	0.75	1.51
Dichrocephala	Asteraceae	Downstream	0.05	0.05	0.10
Echinochloa crussgalli	Poaceae	Downstream	1.26	1.26	2.51
Eleusine indica	Poaceae	Downstream	0.50	0.50	1.00
Epidendrum stamfordianum alba	Orchidaceae	Downstream	0.60	0.60	1.21
Erhanta erecta	Poaceae	Downstream	0.75	0.75	1.51
Euphorbia heterophylla	Euphorbiaceae	Downstream	0.15	0.15	0.30
Flacourtia sp.	Rosaceae	Downstream	0,05	0,05	0,10
Hedyotis corymbosa lamk	Rubiaceae	Downstream	2.01	2.01	4.02
Hyptis capitata	Lamiaceae	Downstream	0.55	0.55	1.10
Impatiens irvingi	Balsaminaceae	Downstream	0.30	0.30	0.60
Ipomeae gangetica	Convolvulaceae	Downstream	1.66	1.66	3.31
Ipomoea aquatica	Convolvulaceae	Downstream	0.45	0.45	0.90
Ipomoea triloba	Convolvulaceae	Downstream	2.01	2.01	4.02
Isodon sp.	Lamiaceae	Downstream	0.50	0.50	1.00
Laportea aestuans	Urticaceae	Downstream	1.26	1.26	2.51
Laportea interrupta	Urticaceae	Downstream	1.51	1.51	3.01
Lepidium draba	Brassicaceae	Downstream	0.35	0.35	0.70
Leucaena leucocephala	Fabaceae	Downstream	0.20	0.20	0.40
Lolium multiflorum	Poaceae	Downstream	1.51	1.51	3.01
Ludwigra decurrens	Onagraceae	Downstream	1.00	1.00	2.01
Luygourd cucurbitaceae	Cucurbitaceae	Downstream	2.26	2.26	4.52
Malvaviscus arboboreus	Malvaceae	Downstream	0.90	0.90	1.81
Manihot esculenta	Euphorbiaceae	Downstream	1.31	1.31	2.61
Melastoma sp.	Melastomataceae	Downstream	0.35	0.35	0.70
Melothria pendula	Melastomataceae	Downstream	1.00	1.00	2.01
Mimosa pudica	Fabaceae	Downstream	3.42	3.42	6.83
Oplismenus hirtellus	Poaceae	Downstream	1.00	1.00	2.01
Orthosiphon aristatus	Lamiaceae	Downstream	0.35	0.35	0.70
Ottochola nodosa	Poaceae	Downstream	0.40	0.40	4.02
Oxalis barrelieri	Oxalidaceae	Downstream	0.40	0.40	0.80
Pandanus amaryllifolius	Pandanaceae	Downstream	0.40	0.40	0.80
Panicum dichotomiflorum	Poaceae	Downstream	2,51	2,51	5,02
Passiflora foetida	Passifloraceae	Downstream	0,75	0,75	1,51
Pennisetum purpureum	Poaceae	Downstream	0.50	0.50	1.00
Peperomia pellucida	Piperaceae	Downstream	0.15	0.15	0.30
Phylanthus urinaria	Phyllanthaceae	Downstream	1.51	1.51	3.01
Polypodium aquatie	Polypodiaceae	Downstream	0.25	0.25	0.50
Ptelea trifoliata	Rutaceae	Downstream	0.75	0.75	1.51
Rhinacanthus acanthaceae	Acanthaceae	Downstream	1.51	1.51	3.01
Richardia brasiliensis	Rubiaceae	Downstream	0.30	0.30	0.60
Richardia scabra	Rubiaceae	Downstream	0.40	0.40	0.80
Ricinus communis	Euphorbiaceae	Downstream	0.05	0.05	0.10
Robinia neomexicana	Fabaceae	Downstream	0.30	0.30	0.60

Name	Family	Station	KR	FR	IVI
Ruellia tuberosa	Acanthaceae	Downstream	0.20	0.20	0.40
Sconnelina communis	Commelinaceae	Downstream	0.35	0.35	0.70
Scutelaria ovata	Commelinaceae	Downstream	0.10	0.10	0.20
Senna obtusiflora	Fabaceae	Downstream	2.76	2.76	5.52
Sida rhombifolia	Malvaceae	Downstream	0.35	0.35	0.70
Solanum carolinense	Solanaceae	Downstream	0.85	0.85	1.71
Solanum diphyllum	Solanaceae	Downstream	0.50	0.50	1.00
Solanum torvum	Solanaceae	Downstream	0.25	0.25	0.50
Sphagneticola trilobata	Asteraceae	Downstream	0.75	0.75	1.51
Stachytapheta urtilofolia	Verbenaceae	Downstream	0.10	0.10	0.20
Synedrella nodiflora	Asteraceae	Downstream	4.02	4.02	8.04
Tragia durbanensis	Asteraceae	Downstream	0.10	0.10	0.20
Triumfetta rhombiodea	Malvaceae	Downstream	0.75	0.75	1.51
Urtica sp.	Urticaceae	Downstream	0.35	0.35	0.70
Zoysia matrella	Poaceae	Downstream	0.50	0.50	1.00

Notes: KR: Relative Type Density, FR: Relative Frequency, RD: Relative Dominance, IVI: Important Value Index

Table 6. Abiotic factors in the Siwaluh River Basin area, Karanganyar, Central Java, Indonesia

Parameter	Station 1 (Upstraem)	Station 2 (Midstream)	Station 3 (Downstream)
Altitude (m dpl)	740	154	103
Light intensity (lux)	10830	28200	54100
Humidity (%)	79	65	35
Air temperature (Fahrenhait)	85	97.5	120
Soil pH	7.1	7.1	7
Water pH	6.7	7.8	8
Water temperature (°Celcius)	22	25	28

Therefore, the observation station's altitude is a factor that can influence its riparian vegetation; various altitudes cause various ambient temperatures. It was also observed that the ambient temperature tended to increase with decreasing height (Hastiana 2014). Furthermore, air humidity is related to river water and plant evaporation and is regulated by air temperature factors. According to Haryono (2011), air humidity will decrease as the air temperature rises, and conversely, air humidity will increase while the air temperature falls. The presence of trees in a region will prevent direct sunlight from reaching the soil's surface, influencing the local temperature. According to Sanger et al. (2016), tall plants and ample space will mitigate the warming effect. It is because tree leaves may intercept, reflect, absorb, and transmit sunlight. The tree cover at the study site can influence the intensity of light. The greater the number of trees, the lower the intensity of incoming sunlight. According to Putri et al. (2018), the length of daylight in a region will impact the light intensity in that region. Tree canopy cover is an additional factor that impacts light intensity. The density of the tree canopy reduces the amount of light that reaches the ground. Due to the number of tree crowns and the humidity that causes fog to gather in the area, Station 1 has a lower light intensity.

Based on the measurements taken at the three observation stations, the soil pH ranged between 7 and 7.1, indicating that the soil at the observation site was neutral. Balanced soil pH is optimal for plant nutrient absorption. In addition, the pH value influences the nitrification process in aquatic habitats. The pH level has a solid relationship with the survival of plants and animals (Hastiana 2014). According to Suryatini (2018), the optimal pH for nutrient accessibility and plant growth is close to neutral (6.5-7.5). According to Rachmawati and Retnaningdyah (2014), a low pH indicates a large diversity of shrub and plant species. As a phytoremediation agent, riparian vegetation can reduce heavy metal pollution and lower pH. Due to heavy metals binding OH^-, which was then removed by phytoremediation agents, the pH level could fall. Strong correlations exist between the riparian diversity index and the water's three physical and chemical parameters: water brightness, COD, and DO levels. Meanwhile, ambient temperature, DO levels, and salinity substantially correlate with the pattern of distribution of riparian vegetation (Hastiana 2014). Moreover, DO can originate from aquatic plants' photosynthesis and oxygen diffusion from the air into the water (Nakova et al. 2009). Ecological and ecosystem functions in the riparian zone that are in good condition will be able to support the ecosystem's productivity (Brodie et al. 2018). Therefore, the riparian zone can benefit the surrounding environment due to riparian vegetation providing shade for wild animals and providing leaf litter inputs that support aquatic food webs and fish assemblages. That is true, particularly for wild animal habitats and water catchment areas (Caissie 2006; Santos et al. 2020).

In conclusion, this study discovered 209 distinct species in the upstream, middle, and downstream regions. The high species variety at these three locations results from several environmental, social, and land use factors. The middle region in the Siwaluh River has the highest diversity value of 4. The riparian zone in the central area is quite diversified and complex, with the diversity values in the upstream and downstream regions being 3.78 and 3.92, respectively. Nevertheless, these three regions are categorized as having high values for species richness. The Important Value Index of Trees in the Siwaluh River Basin indicates that *K. africana* has the highest IVI (135.63). Furthermore, the vegetation near the poles is dominated by *Bambusa* sp. (IVI=173.72). In addition, the plant with the greatest IVI in the sapling habit was *M. esculenta* (107.14). At the same time, the plants with the greatest IVI in the seedling habitus were *A. conyzoides* (21.48). *Bambusa* sp., *M. esculenta*, and *A. conyzoides* have high IVI values, based on their habitus, due to having the greatest number of individuals in a research site. Therefore, many efforts can be arranged with diverse plants to protect natural riparian habitats.

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Composition and feeding guilds bird community in tropical peatland of Orang Kayo Hitam Forest Park buffer area, Jambi, Indonesia

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Abstract. *Pangestu PG, Iswandaru D, Wulandari C, Novriyanti, Prasetia H. 2023. Composition and feeding guilds bird community in tropical peatland of Orang Kayo Hitam Forest Park buffer area, Jambi, Indonesia. Intl J Bonorowo Wetlands 13: 57-65.* Tropical peat ecosystems are vulnerable to fire damage and conversion, including in the Orang Kayo Hitam (OKH) Forest Park buffer villages, Jambi Province, Indonesia. The peat ecosystem is a habitat for various birds. In the ecosystem, birds act as seed dispersers, pest controllers, and pollinators, so their presence can be used as bioindicators of environmental quality. This study aims to analyze the composition and feed guilds of the bird community. The line transect method is used to explore the path in bird watching. The data were then analyzed using descriptively and qualitatively. In total, 29 species from 18 families comprised five species of waterbirds and 25 species of land birds. The families with the highest number of species were Alcedinidae, with a percentage of 13.79% each (4 species). At the same time, the lowest were Apodidae, Bucerotidae, Hirundinidae, Laniidae, Meropidae, Psittacidae, Rallidae, Cisticolidae, Turnicidae, Ploceidae, and Passeridae, with only one species (3.45%) identified per family. Based on the feed guild, there were nine types of guilds, with the highest rate being granivore (24,14%), while the lowest was insectivore on the forest floor (3.45%). The presence of bird species based on the feed guild indicates that shrubs or weeds dominate the land cover of the buffer village around the OKH Forest Park.

Keywords: Bioindicators, bird, foraging ecology, peat ecosystem, wetland

INTRODUCTION

Tropical peat ecosystems are wetland-type marginal areas vulnerable to fire (Karmila et al. 2021). The pressure caused by deforestation and the drying of land makes it experience a decline in quality, making it vulnerable to fires (Usup et al. 2004; Prasetyo et al. 2022). In addition, deforestation and degradation that occurred since 1990 (Miettinen et al. 2016; Wijedasa et al. 2018; Wulandari et al. 2021) resulted in peatland areas in Indonesia decreasing from an initial total of 20.6 million ha to 14 .83 million ha (Wulandari et al. 2021). Orang Kayo Hitam Forest Park (OKH Forest Park) or *Taman Hutan Raya Orang Kayo Hitam*, located on the island of Sumatra, Jambi Province, Indonesia is one of the peat conservation areas. As a conservation area with peatland characteristics, it must overcome these problems. Repeated fires have caused the OKH Forest Park area to experience severe degradation (Tamin et al. 2021). Peat is an accumulation of the remains of organic matter (Setyawati and Suwarsono 2018; Shah et al. 2020) that has been deposited for a very long period (Prayoto et al. 2017), makes it very susceptible to fire when it experiences drought. The damage to peat ecosystems by fires impacts the local environment and buffer areas such as surrounding villages (Anhar et al. 2022).

In addition, fires in peat ecosystems have global-scale impacts on economic, social, and ecological aspects, including burning habitats for endemic plants and animals and increasing extinction threats (Saharjo dan Novita 2022). They impacted decreasing biodiversity (Lee et al. 2017; Harrison and Rieley 2018; Wasis et al. 2019) and influenced global climate change (Syaufina 2016; Kurniasari et al. 2020; Saharjo and Novita 2022). Differences in the peat ecosystem's physical, biological, and chemical characteristics due to damage to the peat ecosystem (Prasetia and Syaufina 2020) will potentially cause various types of animals to lose their habitat, including birds. Birds are wild animals that use the peat ecosystem as a place to live and find food (Pramudianto 2018). Ecologically, birds have an important role in dispersing seeds (Ning et al. 2019) and helping flower pollination (Lindell and Thurston, 2013; Iswandaru et al. 2022) and have a high sensitivity to climate change (Li et al. 2021). Birds are one of the animals with the top position in the food chain, making them sensitive to prey and environmental changes (Egwumah et al. 2017). The presence of birds in an ecosystem is closely related to food availability (Tryjanowski et al. 2018). The distribution of birds that is reasonably wide and easy to observe, as well as their sensitivity to environmental changes, makes the presence of bird composition in an ecosystem can be used as a bioindicator in assessing the condition of the surrounding environment (Adelina et al. 2016; Julyanto et al. 2016; Egwumah et al. 2017; Hutapea et al. 2020).

Bird research has been carried out in OKH Forest Park, especially in the PLN Restoration Block, which recorded 25 species with 418 individuals (Nurfitri et al. 2022). In addition, other studies regarding the composition and community of avifauna in the Leyte Sab-a Basin Peatland, Philippines, and its surroundings found as many as 67 bird species from 37 families recorded (Matutes and Densing, 2022). These studies provide an overview of the value and condition of the land. However, research on family composition and feed guilds in the OKH Forest Park buffer area has yet to be conducted optimally, so this research is considered essential for further study. The birds' composition in an ecosystem reflects the habitat quality; this relates to the relationship of birds to environmental changes and vegetation composition, which will affect their diversity (Kurniawan et al. 2019). Furthermore, grouping species based on food groups can be a way of assessing or knowing the ecosystems' ability to provide for these species' needs. Therefore, a study of bird community feed guilds in the OKH Forest Park buffer area is needed to provide an overview of their environmental conditions through their ability to provide feed. This study aimed to analyze the bird community's species composition and feed guilds in the OKH Forest Park buffer area and describe efforts to restore the peat ecosystem.

MATERIALS AND METHODS

Study area

The research location is one of the supporting villages for OKH Forest Park, namely Jebus Village, Kumpeh Sub-district, and Muaro Jambi District, Jambi Province, Indonesia. Geographically, Jebus Village is between 1º20'38.85" and has a longitude of 104º01'58.90". The area of Jebus Village reaches 23,072.71 Ha, and 94.9% is a peat area; this village is also located in the Batanghari River basin. Furthermore, due to river overflows, Jebus Village is affected by flooding almost yearly. In addition, Jebus Village experienced much loss of flora due to the fire in 2015. The following is a map of the research locations presented in Figure 1.

Procedures

Bird data were collected using the line transect method, sampling in observation line units form (Asrianny et al. 2018). Each transect line is 2 km long and 50 meters wide to the right or left of the bar (Figure 2). Transect 1 (TR 1) is placed on the road that separates agricultural land and swamps, and transect 2 (TR 2) on the road separating residential and plantation areas. Observations were made in the morning from 06.00-09.00 and afternoon from 15.00-18.00 (Asrianny et al. 2018; Lwin 2018; Iswandaru et al. 2020a; Ramadhani et al. 2022). Observers strolled along the transect, and each encounter recorded the type of bird observed (Sabo et al. 2022). In addition, bird species are recorded at each direct encounter. Species identification is based on MacKinnon et al.'s (2010), and species nomenclature refers to the Handbook of the Birds of the Word and BirdLife International (2020). Observations cannot be made during rain because it is difficult to observe, and the dominant birds hide while it rains. Observations were carried out for 10 days by a team of 5 observers.

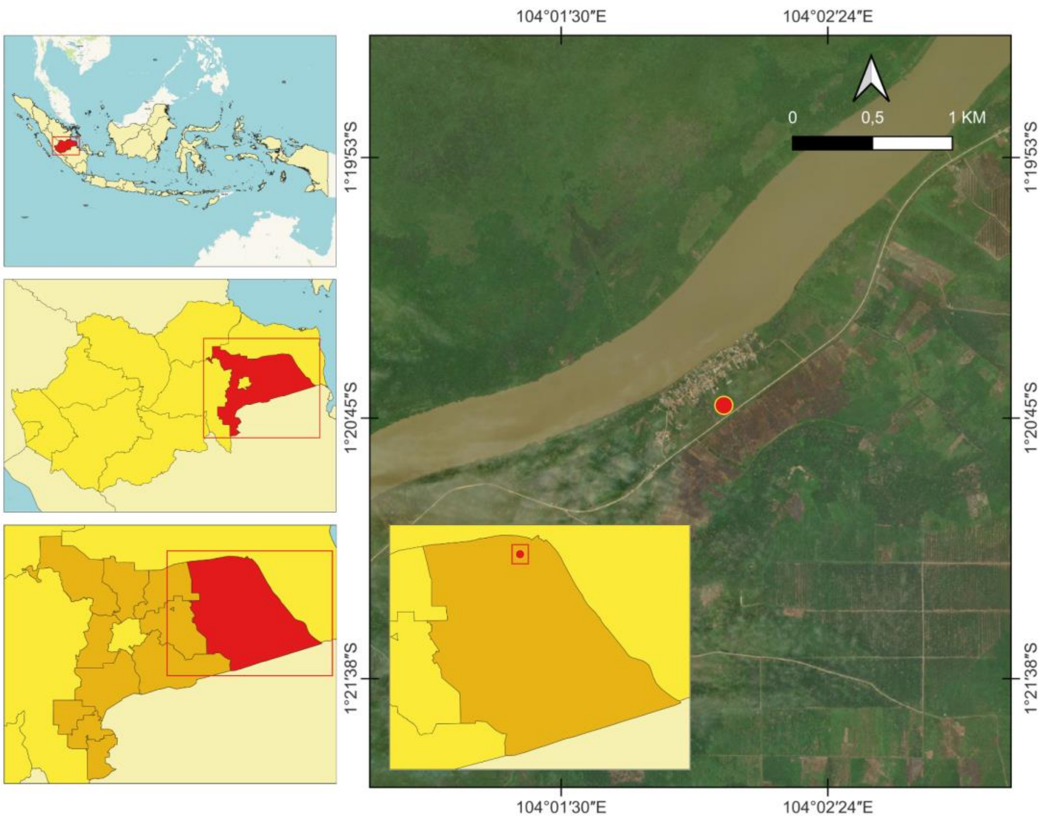

Figure 1. Maps of the research location in Jebus Village, Kumpeh Sub-district, Muaro Jambi District, Jambi Province, Indonesia

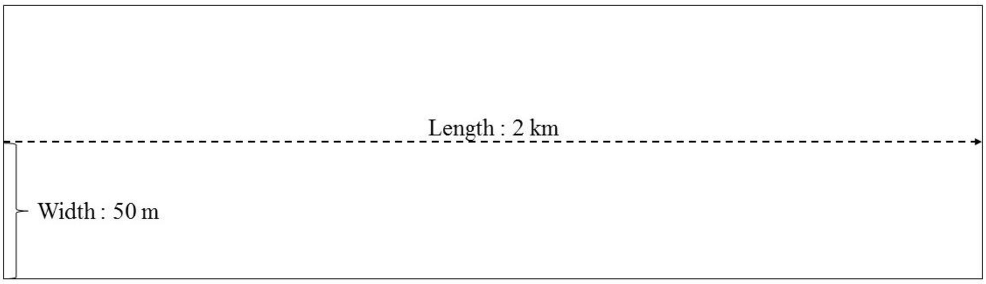

Figure 2. Transect-line methods

Data analysis

The research data were analyzed qualitatively, with the result generated as a description of bird-field conditions. Bird data grouped by habitat (waterbird and landbird) refers to Lee et al. (2018). Landbird is a group of birds whose main activity is in terrestrial habitats (Rich et al. 2004), such as: forests, plantations, agriculture, and agroforestry (Franklin and Steadman 2010; Pyle et al. 2020), while waterbirds are a group of birds who are dependent on wetlands (Prasetya and Anisia 2021) such as peatlands, watersheds, and mangroves (Firdausy et al. 2021; Haider et al. 2022; Nurfitri et al. 2022). Furthermore, birds are grouped by their family based on MacKinnon et al.'s (2010), and feeding guild refers to Iswandaru et al.'s (2020b) (Table 1). Finally, the descriptive analysis provides an overview of the data obtained during this study (Sitanggang et al. 2020).

Data on the number and species of birds were analyzed to predict the species' diversity, richness, and evenness. Species diversity was analyzed using the Shannon-Wiener (H') method (Iswandaru et al. 2020a,b; Zhang et al. 2021), species richness index using the Margalef method (Sina and Zulkarnaen 2019; Pramudita et al. 2023), while evenness uses the Pielou evenness index (Fikriyanti et al. 2018; Iswandaru et al. 2020b). The three index formulas are presented as follows:

$$\mathbf{H'} = -\sum_{i=1}^{S} (\mathbf{pi}) \ln \mathbf{pi}$$

$$R = \frac{(S-1)}{Ln\ N}$$

$$E = \frac{H'}{Ln\ S}$$

Where:
H': Shannon-Wiener diversity index
R: Margalef richness index
E: Pielou evenness index
S: the number of types
pi: the proportion of the number of individuals it-i (ni/N)
N: total number of individuals observed
Ln: natural logarithm

Table 1. Feeding guilds of the bird community (Iswandaru et al. 2020b)

Guilds type
Insectivore
Insectivores while flying (Iw)
Insectivores on branches of the canopy (Ic)
Insectivore on the forest floor (If)
Eating insects by grabbing (E)
Meat eaters
Piscivore (Pc)
Carnivore (Cr)
Granivore (G)
Frugivore (F)
Omnivore (O)

The criteria in the Shannon-Wiener index are: (I) if H'<1.5, then the diversity is low, (II) if 1.5≤ H'≥ 3.5, then the diversity is medium, (III) and if H'>3, 5 then it is said to be high diversity. The criteria for the richness index include (I) if R<2.5, it is defined that the species richness is low, (II) if 2.5>R>4, then the species richness is moderate, (III) whereas if R>4 then the species richness is high. Finally, the evenness index has criteria with a range of 0-1; if the index value is close to 1, it is defined as evenness is high (even) and vice versa.

RESULTS AND DISCUSSIONS

Bird family composition

There were 29 bird species recorded in the Orang Kayo Hitam Tahura buffer area (Table 2). The number of birds found comprised five species of water birds (16.67%) and 25 land birds (83.33%). The 30 bird species found consisted of 18 families, including Alcedinidae, Columbidae, Ardeidae, Caprimulgidae, Cuculidae, Pycnonotidae, Estrildidae, Apodidae, Bucerotidae, Hirundinidae, Laniidae, Meropidae, Psittacidae, Rallidae, Cisticolidae, Turnicidae, Ploceidae, and Passeridae (Figure 3). The dominating family is Alcedinidae, with four species (13.79%). Other families with the highest number of species below them are Ardeidae and Columbidae, with the number of species in each family being three (10.34%). Members of the Alcedinidae family are the Stork-billed Kingfisher (*Pelargopsis capensis*), Small Blue Kingfisher (*Alcedo coerulescens*), White-throated Kingfisher (*Halcyon* *smyrnensis*), and Collared Kingfisher (*Todiramphus chloris*). The Ardeidae family includes Cinnamon Bittern (*Ixobrychus cinnamomeus*), Purple Heron (*Ardea purpurea*), and Cattle Egret (*Bubulcus ibis*). Then the Columbidae Family consists of Pink-necked Green-Pigeon (*Treron vernans*), Zebra-Dove (*Geopelia striata*), and Spotted-Dove (*Spilopelia chinensis*). Some bird species can be seen in Figure 4.

Indices of diversity, richness, and evenness of bird species in the buffer area around OKH Forest Park

Based on the results of observations, it was found that 139 individual birds were recorded from 29 bird species that could be identified. Therefore, bird species diversity, richness, and evenness in the buffer area are moderate, high, and low, respectively. The index of diversity, richness, and evenness of bird species in the OKH Forest Park is presented in Figure 5.

Bird feed guild composition

The composition of the bird feed guilds in OKH Forest Park is quite varied. Five feed guilds can be found: granivore, frugivore, omnivore, raptor, and insectivore. The percentage of feed guilds is presented in Figure 6.

Discussion

This study analyzed birds' composition in the OKH Forest Park buffer area, grouped by family and feeding guild. Three bird families that dominate the study area include Alcedinidae, Columbidae, and Ardeidae. Three families, one of which are water birds, namely Ardeidae (Lee et al. 2018). The presence of water birds in peatlands naturally occurs because peat is a wetland that is an ideal habitat for water birds to live and find food (Prasetya dan Anisia 2021). It is said that 10% of bird species out of the total global number depend on wetlands, and 20% use them to find food, rest, and breed (Rannestad et al. 2015; Kačergytė et al. 2021; Jangral and Vashishat 2022). In a study of bird diversity and populations in the wetlands of the Bangpu Nature Education Center, Thailand, it was recorded that eight families of water birds lived and used the wetlands, including Scolopacidae, Ardeidae, Charadriidae, Laridae, Ciconiidae, Phalacrocoracidae, Recurvirostridae, and Rallidae (Chanate et al. 2020). In China, Luo et al.'s (2019) research in the Dianchi Lake wetlands revealed that 67 of the 182 bird species were water birds. In addition, a similar study conducted in the Taunsa Barrage Ramsar site (wetland) in Punjab, Pakistan, by Haider et al. (2022) found that 150 species of 53 families with the highest number of species were Accipitridae, Ardeidae, and Anatidae, of which two of them belonged to a group of waterbirds.

Table 2. Feeding guild of birds in the buffer area of OKH Forest Park, Muaro Jambi District, Jambi Province, Indonesia

Name	Nama Ilmiah	Family	Feeding guild								
			G	F	O	Pc	Pr	Iw	Ic	If	E
Stork-billed Kingfisher	*Pelargopsis capensis*	Alcedinidae				✓					
Small Blue Kingfisher	*Alcedo coerulescens*	Alcedinidae				✓					
White-throated Kingfisher	*Halcyon smyrnensis*	Alcedinidae					✓				
Collared Kingfisher	*Todiramphus chloris*	Alcedinidae					✓				
Glossy Swiftlet	*Collocalia esculenta*	Apodidae						✓			
Cinnamon Bittern	*Ixobrychus cinnamomeus*	Ardeidae				✓					
Purple Heron	*Ardea purpurea*	Ardeidae				✓					
Cattle Egret	*Bubulcus ibis*	Ardeidae								✓	
Oriental Pied Hornbill	*Anthracoceros albirostris*	Bucerotidae		✓							
Savannah Nightjar	*Caprimulgus affinis*	Caprimulgidae						✓			
Large-tailed Nightjar	*Caprimulgus macrurus*	Caprimulgidae						✓			
Yellow-bellied Prinia	*Prinia flaviventris*	Cisticolidae							✓		
Zebra-Dove	*Geopelia striata*	Columbidae	✓								
Spotted-Dove	*Spilopelia chinensis*	Columbidae	✓								
Pink-necked Green-Pigeon	*Treron vernans*	Columbidae		✓							
Lesser Coucal	*Centropus bengalensis*	Cuculidae							✓		
Plaintive Cuckoo	*Cacomantis merulinus*	Cuculidae							✓		
White-headed Munia	*Lonchura maja*	Estrildidae	✓								
Black-headed Munia	*Lonchura atricapilla*	Estrildidae	✓								
Pacific Swallow	*Hirundo tahitica*	Hirundinidae						✓			
Long-tailed Shrike	*Lanius schach*	Laniidae									✓
Blue-tailed Bee-eater	*Merops philippinus*	Meropidae									✓
Eurasian Tree Sparrow	*Passer montanus*	Passeridae	✓								
Baya Weaver	*Ploceus philippinus*	Ploceidae	✓								
Long-tailed Parakeet	*Belocercus longicaudus*	Psittacidae	✓								
Sooty-headed Bulbul	*Pycnonotus aurigaster*	Pycnonotidae		✓							
Yellow-vented Bulbul	*Pycnonotus goiavier*	Pycnonotidae		✓							
White-breasted Waterhen	*Amaurornis phoenicurus*	Rallidae			✓						
Barred Buttonquail	*Turnix suscitator*	Turnicidae			✓						

Note: G: Granivore, F: Frugivore, O: Omnivore, Pc: Piscivore, Cr: Carnivore, Iw: Insectivore while flying, Ic: Insectivore on branches of canopy, If: Insectivore on the forest floor, E: Eating insects by grabbing

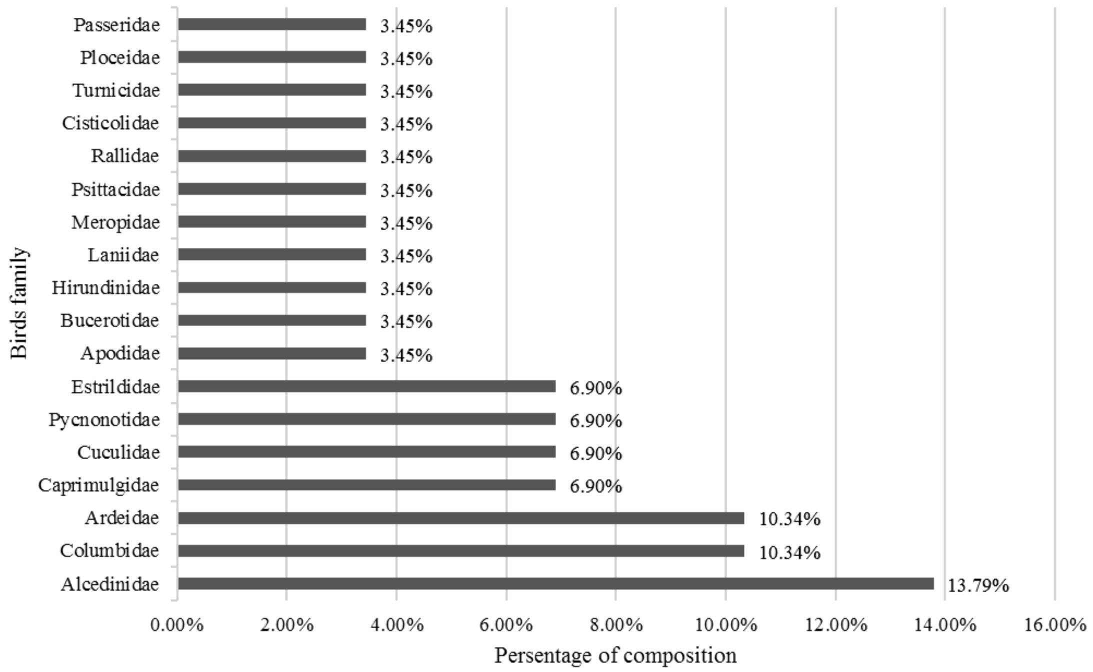

Figure 3. Composition of bird families in the buffer area around OKH Forest Park, Muaro Jambi District, Jambi Province, Indonesia

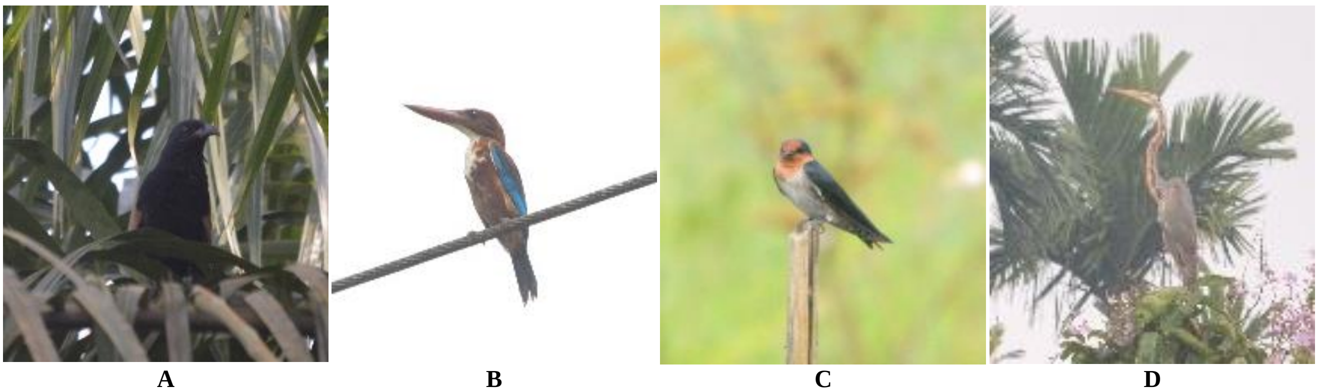

Figure 4. Several bird species exist in the buffer area of Orang Kayo Hitam Forest Park, Muaro Jambi District, Jambi Province, Indonesia: A. Lesser Coucal (*Centropus bengalensis*), B. White-throated Kingfisher (*Halcyon smyrnensis*), C. Pacific Swallow (*Hirundo tahitica)*, D. Purple Heron (*Ardea purpurea*)

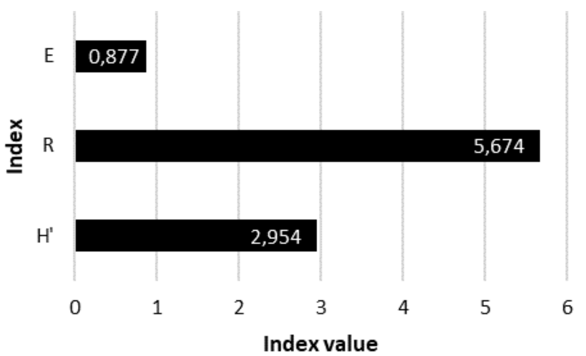

Figure 5. Diversity index (H'), Richness (R), and Evenness (E) bird species in the buffer area around OKH Forest Park, Muaro Jambi District, Jambi Province, Indonesia

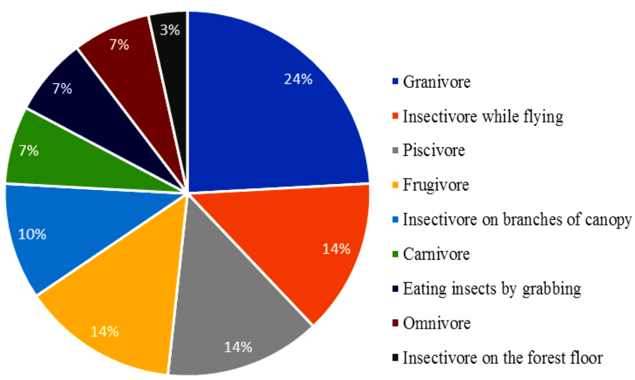

Figure 6. Percentage of feed guilds by species in OKH Forest Park, Muaro Jambi District, Jambi Province, Indonesia

Alcedinidae is a group of birds with long, solid beaks with bright colors, generally metallic blue (MacKinnon et al. 2010). The shape of the long and robust beak is intended to make it easier to find and catch its prey. The leading food of the Alcedinidae bird group is insects and several types of fish (Anugrah et al. 2017). The existence of Alcedinidae in the area around peat is based on the needs of this group of birds. Although not classified as a water bird, the family Alcedinidae depends on wetlands (Etayeb et al. 2015). Therefore, Ardeidae is part of a group of water birds dependent on wetlands (Hidayat and Dewi 2017). This dependence is based on their need to eat, rest, and reproduce (Miranda-García et al. 2021). In addition, Ardeidae has characteristics on the body, namely a long neck and characteristic long and straight beaks (MacKinnon et al. 2010; Nisa and Setyoko 2021). The characteristics of the long and straight beak are intended for taking prey such as fish, vertebrates, and small invertebrates.

Columbidae is a family of pigeons with short and robust beaks (MacKinnon et al. 2010). This type of beak supports the searching and taking food activity. Columbidae's leading food is generally fruits and seeds. These birds are scattered in various habitats, including lowland forests, highland forests, swamp forests, grasslands, deserts, and rural to urban areas (Sawitri and Garsetiasih, 2015). Environmental conditions and food availability influence the dominance of Columbidae around Orang Kayo Hitam Forest Park. OKH Forest Park is mostly dominated by pioneer plants with relatively fast-growing power, such as *Macaranga* sp., *Gluta rengas*, and *Tetrameristra glabra*. *Macaranga* sp. is a type of tree with small fruit that is easy for birds to eat (Pradwinata et al. 2020), so it is suspected to be a source of bird feed. According to Nurfitri et al. (2022), the OKH Forest Park area is widely planted with *Alstonia pneumatophora*, *Dyera lowii*, *Melaleuca leucadendra*, *Ficus* sp., *Melastoma candidum,* and *Scleria sumatrensis;* these plants which allow them to become birds' food sources.

Meanwhile, observing the types of feed guilds, the species found during the observation were dominated by G, followed by Iw, Pc, and F (Figure 6). This study found that the bird species from guild G habitually foraged on the ground. It indicates that most Jebus villages are open, and some are overgrown with shrubs. Changes in a habitat will affect birds' diversity, structure, and composition (Ntongani and Andrew, 2013). The fire in the peat area in 2015 changed this habitat. The fire caused Jebus Village, one of the buffer areas of OKH Forest Park, to experience much flora loss. Significant environmental changes by leaving grasses, herbs, and shrubs producing seeds and small fruit will cause a response to the granivore group (Putri et al. 2017). The granivore bird group prefers open areas with low vegetation density (Rofiq et al. 2021). In addition, it is observed that the granivore group has a response to increasing the number of groups after logging or loss of trees in a habitat and decreases while there is regrowth during the recovery period to a more complex forest (Burivalova et al. 2015; Nasruddin-Roshidi et al. 2021). Therefore, the presence of high G guilds in a specific area can indicate that the area has a low density of high-level vegetation.

Insectivore is the most varied guild type, including Iw, Ic, E, and If. If the total variations are added, it will be even higher than the G type alone. The total number of insectivore guild types is ten species or 34.48% of the total species found. The division of the insectivore into several guild sub-types is based on the variation of birds in finding and preying on insects. Differences in finding or catching prey can be based on their need for the same food type; these birds use their strategies to avoid competition between species (Norazlimi and Ramli 2015). A high enough insectivore exists in an area based on environmental conditions or the habitat itself; each guild has a detailed response to a particular type of environment (Rumblat et al. 2016). Insectivore is generally found in grassy areas habitats (Bowler et al. 2019). In addition, research by Kerekes and Végvári (2016) revealed that the insectivore guild type has the highest abundance in swamp and grassland habitats. It aligns with the conditions in the OKH Forest Park buffer area, mainly dominated by shrubs and grassy areas due to the peat forest fires several years ago.

On the other hand, many groups of birds with guild types Iw, F, and Pc are also found in the OKH Forest Park buffer area. Insectivores can adapt to their environment, as evidenced by their existence, which can be found in various habitats (Bowler et al. 2019). In addition, the diversity of bird species is directly proportional to the diversity and abundance of insects (Beskardes et al. 2018; Bowler et al. 2019). Insects ideally live in open habitats such as grasslands and shrubs (Hopwood et al. 2016). The condition of the peat ecosystem around the OKH Forest Park is dominated by shrubs or grassland, a habitat that many insects prefer. The abundance of these resources responds to groups of insectivorous birds, including the Iw type. In addition, this condition also responds to small fruit-eating birds, such as *Pycnonotus aurigaster* are usually active in bush habitats to find food. In addition, the presence of these birds is also vital in the spreading of bush plant seeds (Partasasmita 2015). Even though shrubs dominate it, there are still places with high levels of vegetation; the presence of *Anthracoceros albirostris*, a member of the Bucerotidae family, evidences this. The Bucerotidae family usually lives in large and tall trees, and their leading food is fruit (Kamal et al. 2020). On the other hand, the peat ecosystem, a wetland, is an ideal habitat for water bird species, including the Pc guild type group. Peat ecosystems as wetlands are essential to water bird survival, including nesting, shelter, foraging, stopover during migration, and various other annual life cycles (Bouldjedri and Mayache 2020).

The bird species diversity level in the OKH Forest Park buffer area is moderate (H'= 2,954); this index is influenced by vegetation composition (Xu et al. 2022). Scrub or grassland types and young vegetation habitats dominate the area around the OKH Forest Park. The habitat type around the OKH Forest Park could provide the needs of various bird species based on their diversity index value (Praptiwi et al. 2019). That is also supported by the species richness level with a relatively high index value (R= 5.674); the level of species richness shows the number of species in a community. The species richness index positively correlates to the complexity of the ecosystem attributes that compose it (Zhang et al. 2021). The high species richness index indicates that the post-fire peat ecosystem has gradually recovered. This is also supported by the evenness index, which is relatively high or evenly distributed (E = 0.887); the low species diversity index is caused by competition over resource use (Kurniawan et al. 2018; Iswandaru et al. 2020a,b). The evenly distributed bird species show no competition in resource use, so it can be said that the ecosystem could meet bird species' needs quite well.

The OKH Forest Park buffer area has a wealth of abundant birds, indicating that the area can still provide various food sources for various birds. The dominance of waterbird groups in family groupings shows peatlands' vital role as wetlands for waterbirds' sustainability. Post-fire conditions had a significant impact on the composition of the ecosystem. However, there are good recovery processes to support the needs of various birds. The dominance of the G guild group and the insectivore sub-guild illustrates peatlands dominated by shrubs or grassy weeds. The composition of birds in the buffer area around the OKH Forest Park needs to be reviewed and improved to support the peatland restoration.

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Paludicola turfosa (Batrachospermales, Rhodophyta), a new record from Sebangau National Park, Central Kalimantan, Indonesia

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Abstract. *Adam C, Segah H, Kawamura K, Pitoyo D, Adiwijaya S, Damanik Z, Sustiyah, Pidjath C, Rafsanjani MA. 2023.* Paludicola turfosa *(Batrachospermales, Rhodophyta), a new record from Sebangau National Park, Central Kalimantan, Indonesia. Intl J Bonorowo Wetlands 13: 66-72.* *Paludicola* is a genus of red algae that inhabits freshwater environments. Based on initial observations, this genus was found in peat waters associated with the Rasau plant (*Pandanus helicopus* Kurz ex Miq.) in the peat swamp forest, Sebangau National Park. Of the many studies related to biodiversity in Sebangau National Park, none have reported the presence and description of algae, including members of the freshwater red algae *Paludicola*. The current status of red algae diversity in Indonesia has mostly been reported from marine ecosystems with only two species of freshwater red algae known from Indonesia. In this study, we report the preliminary description of the freshwater red algae *Paludicola turfosa* (Bory) M.L.Vis & Necchi, previously known as *Batrachospermum turfosum* Bory de Saint-Vincent from the peat water of Sebangau River, Sebangau National Park, as a new record for Indonesia. The *P. turfosa* was mainly found attached to the leaves of Rasau (*P. helicopus*) forming hair-like tufts representing its filamentous appearance. The descriptions include the recently updated taxonomy, general ecological macroscopic characteristics, and microscopic appearance of this algae.

Keywords**:** *Batrachospermum*, black water, *Paludicola*, peat swamp forest, Rhodophyta, Sebangau National Park

INTRODUCTION

Sebangau National Park is a national park in Central Kalimantan, Indonesia, established in 2004 and administratively located in three regencies/cities: Palangka Raya City, Katingan District, and Pulang Pisau District. The Sebangau area, since being designated a national park has an area of 568,700 hectares but has undergone recent changes; the area was reduced to 537,126 hectares based on a decree from the Minister of Environment and Forestry of the Republic of Indonesia in 2018 (Ditjen KSDAE 2021). Sebangau National Park is great in biodiversity and is protected by the Indonesian government (Sutrisno 2005; Wicaksono et al. 2015; Husson et al. 2018; Maulidi et al. 2020; Lukas et al. 2021). Husson et al. (2018) reported species diversity in the Sebangau tropical peat swamp forest to be consisting of taxa of 215 trees, 92 non-tree flora, 73 ants, 66 butterflies, 297 spiders, 41 dragon/damselflies, 55 fishes, 11 amphibia, 46 reptiles, 172 birds and 65 mammals. Sutrisno (2005) reported moth diversity consisting of 278 species from 19 families in the Busang River secondary rainforest, Sebangau National Park. Herpetofauna diversity in Sebangau National Park has been reported until 2019 based on the results of research in Punggualas as many as 38 species consisting of 22 reptile species and 16 amphibian species (Wicaksono et al. 2015; Maulidi et al. 2020). The conservation status of these herpetofauna species is mostly Least Concern category (Maulidi et al. 2020).

Various conservation efforts have been made to preserve the biodiversity in Sebangau National Park, including providing preliminary data for undescribed species. One major group of organisms in the peat waters of Sebangau National Park that has not been properly accounted for is algae. Algae have an important role in aquatic ecosystems as primary producers, including peat water ecosystems, by forming the energy base of the food web for all aquatic organisms (Lembi 2003). In addition, algae can also be used as bioindicators to assess the condition of the aquatic environment (Omar 2010; Dell'Aglio et al. 2017; Kadam et al. 2020; Stevenson 2022). Therefore, Algae are important elements of aquatic ecosystems and are significant determinants of the "goods and services" rivers provide (Stevenson 2022). Based on observations in the field, a red algae (Rhodophyta) of the genus *Paludicola* Necchi & M.L.Vis was found to be associated with the leaves of the Rasau plant (*Pandanus helicopus* Kurz ex Miq.) in the peat swamp forest of Sebangau National Park. Of the many studies related to the biodiversity in Sebangau National Park, none have yet reported the presence and description of algae, especially freshwater red algae and members of *Paludicola*.

Red algae are predominantly distributed in marine ecosystems with only 3% of the total diversity found in freshwater ecosystems (Sheath and Wehr 2015; Fischer et al. 2020; Guiry and Guiry 2021). Freshwater red algae are also mainly restricted to flowing waters (Dodds 2002; Sheath and Vis 2015; Sheath and Wehr 2015). The status of red algae diversity in Indonesia has been mostly reported from marine ecosystems (Ghazali et al. 2018; Zulpikar et al. 2020; Mushlihah et al. 2021). However, Johnston et al. (2014) reported eight freshwater red algae taxa from the order Batrachospermales distributed in Malaysia and Indonesia, and only two of them have thus far been found in Indonesia; namely, *Kumanoa celebes* E.T.Johnston, N. Buhari & ML. Vis and *Kumanoa gibberosa* (Kumano) Necchi & ML. Vis.

Due to the lack of scientific data regarding red algae in Sebangau National Park, it is critical to conduct this preliminary research to understand the algal biodiversity in this bioregion better. This study reports the presence of and describes the general ecological and morphological characteristics of *Paludicola turfosa* (Bory) M.L.Vis & Necchi (Batrachospermales, Rhodophyta) in Peat Swamp Forest, Sebangau National Park, Indonesia.

MATERIALS AND METHODS

Study area and sample collection

This research was conducted in the conservation area of Sebangau National Park, Central Kalimantan, Indonesia, precisely in the Sebangau River (2°29'10.0"S, 114°02'26.7"E), (Figure 1). When selecting the sample, only *Paludicola* specimens associated with the submerged leaves of the Rasau plant (*P. helicopus*) in the peat waters of the Sebangau River were collected for the samples. Samples were stored in collection bottles for further analysis.

Procedures

Collected specimens were observed microscopically using an Olympus CX21 at the 40× (10× ocular; 4× objective), 100× (10× ocular; 10× objective), 400× (10× ocular; 40× objective) magnifications. Specimens were then photographed for further identification. Therefore, to facilitate specimen identification, the photographed images were processed for color enhancement using Adobe Photoshop CC, and a scale bar was added using ImageJ software version 1.53g (Rasband 2020) to estimate filament length. Scaling with ImageJ uses a cell size estimation method that utilizes the known diameter of the microscope's field of view (Armstrong 2021; Adam 2022).

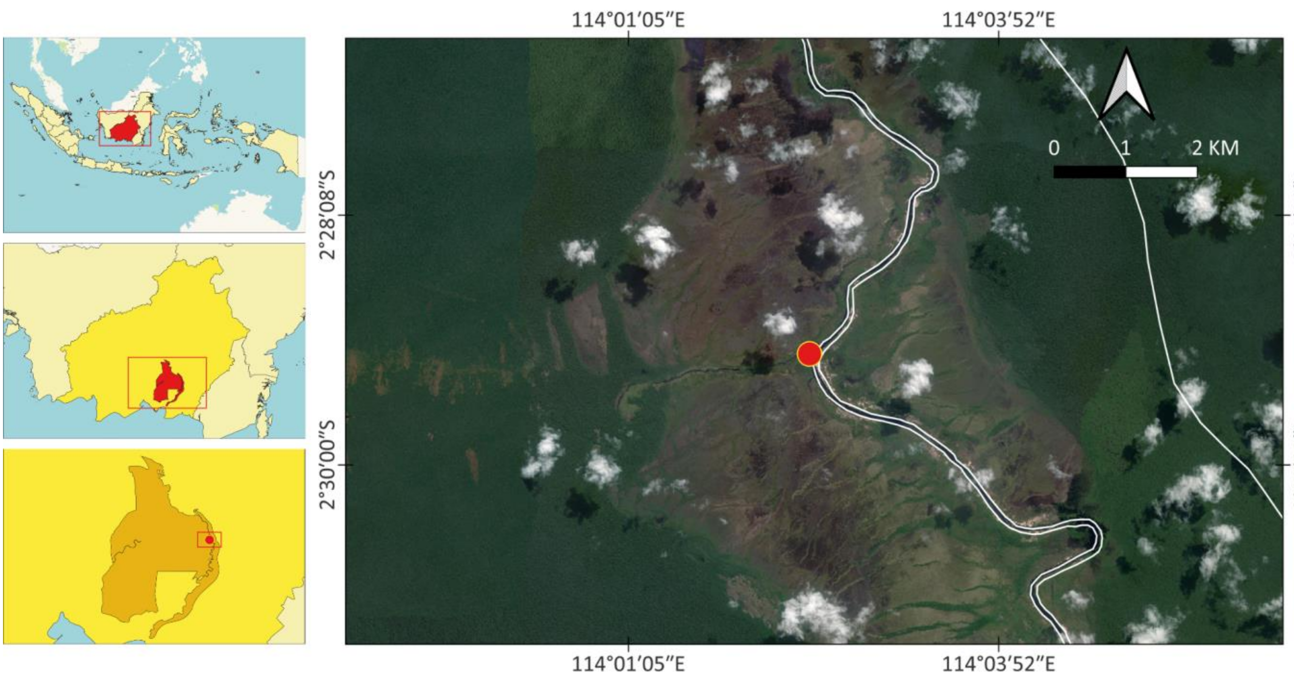

Figure 1. Study area in Sebangau River of Sebangau National Park, Central Kalimantan, Indonesia

Data analysis

This study is a qualitative analysis describing the sampled collections of Paludicola microscopically. The description includes taxonomy, general ecological and morphological characteristics, and the microscopic morphological characteristics (branching pattern, fascicles, carpogonia and spermatangia) using the previously published works of Roeder and Peck (1977), Sheath and Vis (2015), Wehr and Sheath (2015), Vis et al. (2020), Guiry and Guiry (2021), Necchi Jr and Vis (2021).

RESULTS AND DISCUSSION

Taxonomy

The *P. turfosa* has been identified in this study, belonging to Batrachospermales previously known as *Batrachospermum turfosum* Bory de Saint-Vincent. The *B. turfosum* was transferred into a new species *P. turfosa* based on the molecular phylogenetic analysis research using *rbcL* and COI-5P sequences (Vis et al. 2020). Five species of *Paludicola* previously included in the genus *Batrachospermum* and consists of *P. turfosa* (Bory) M.L.Vis & Necchi, *P. keratophyta* (Bory) M.L.Vis & Necchi, *P. orthosticha* (Skuja) Necchi & M.L.Vis, *P. phangiae* (Johnston, Lim & Vis) Vis, Lee, Eloranta, Chapuis, Lam & Necchi, and *P. periploca* (Skuja) Necchi & ML. Vis (Vis et al. 2020). The *P. turfosa* is currently accepted taxonomically and *B. turfosum* is currently regarded as a homotypic synonym (Guiry and Guiry 2021). The taxonomical enumeration in detail is presented below.

Phylum Rhodophyta
Subphylum Eurhodophytina
Class Florideophyceae
Subclass Nemaliophycidae
Order Batrachospermales
Family Batrachospermaceae
Genus *Paludicola* Necchi & ML. Vis, 2020
Species *Paludicola turfosa* (Bory) ML. Vis & Necchi

General ecological and morphological characteristics

The study showed that *P. turfosa* was found in the peat waters of the Sebangau River, Sebangau National Park, and was mainly found in association with the Rasau plant (*P. helicopus*) and was also attached to wooden branches or other macrophytes growing in the water. The *P. helicopus* is a Pandanus species common in peat swamp forests (Keim et al. 2011) and growing in peat waters along the Sebangau River (Figure 2). The *P. turfosa* is one of 3% species of red algae (Rhodophyta) that inhabit freshwater ecosystems such as rivers and streams. It is known that three species of red algae are typical inhabitants of lentic freshwater bodies including *P. turfosa* and two other species, namely *Compsopogon caeruleus* (Balbis ex C.Agardh) Montagne and *Kumanoa mahlacensis* (Kumano et W. A. Bowden-Kerby) M. L. Vis, Necchi, W. B. Chiasson et Entwisle (Sheath and Vis 2015). In addition, *P. turfosa* typically occurs in acid and soft waters (Eloranta and Kwandrans 2007), including peat waters which are similar due to their high acidity levels (Syafalni et al. 2013; Suhendra 2018).

Paludicola turfosa was found attached to the leaves of Rasau (*P. helicopus*) forming a hair-like structure that was filamentous in appearance (Figures 3 and 4). These filaments of *P. turfosa* appear green to blue-green. Red algae generally contain chlorophyll-a and phycobilins as the dominant pigments; thus, the cell and filaments can appear reddish brown, blue-green, or violet (Dodds 2002; Sheath and Vis 2015). In addition, the phycobilin content in red algae is similar to that in Cyanobacteria but in different proportions (Dodds 2002). The types of phycobilins contained in *P. turfosa* are phycoerythrin and phycocyanin (Aigner et al. 2017). According to Schagerl and Donabaum (2003), the pigment composition of *P. turfosa* is dominated by chlorophyll *a* and lutein as well as small amounts of zeaxanthin.

This phycocyanin content is thought to be the main pigment that makes *P. turfosa* filaments look blue-green. Phycocyanin is a blue pigment belonging to phycobiliproteins (Eriksen 2008; Buchweitz 2016; Morançais et al. 2018; Zeece 2020; Tripathi et al. 2021) that can be found in the Cyanophyta, Rhodophyta, and Chrysophyta (Eriksen 2008; Morançais et al. 2018). Phycocyanin increases the efficiency of chlorophyll undergoing photosynthesis to produce oxygen under low light conditions (Zeece 2020). This phycocyanin characteristic correlates with *P. turfosa* also found in peat waters in a closed forest area, Sebangau National Park.

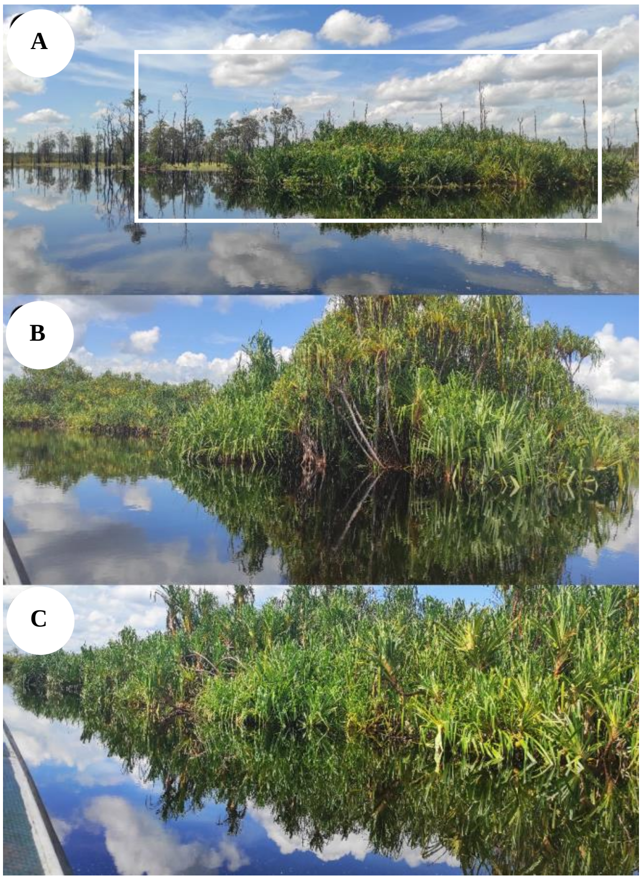

Figure 2. Rasau (*Pandanus helicopus*) (A-C): Plants associated with *Paludicola turfosa*

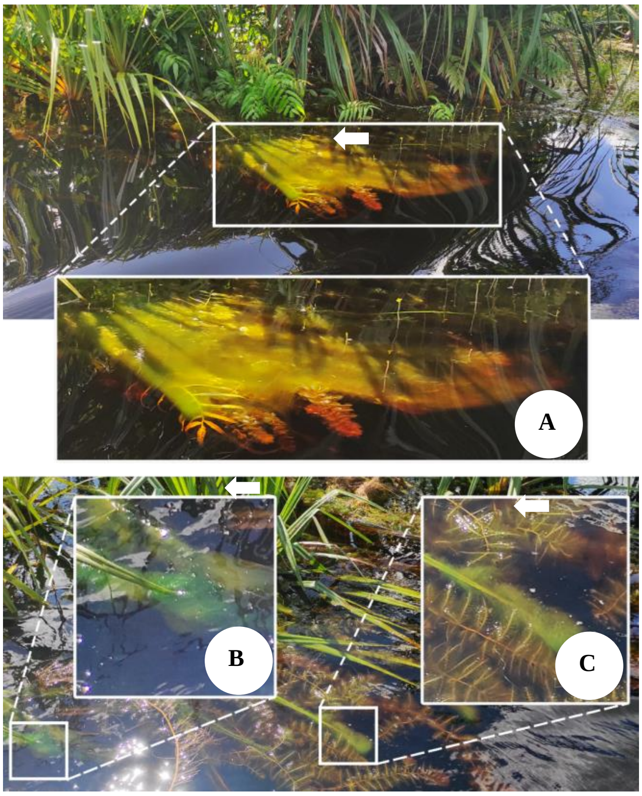

Figure 3. General appearance *Paludicola turfosa* (A-C) attached to the leaves of Rasau (*Pandanus helicopus*)

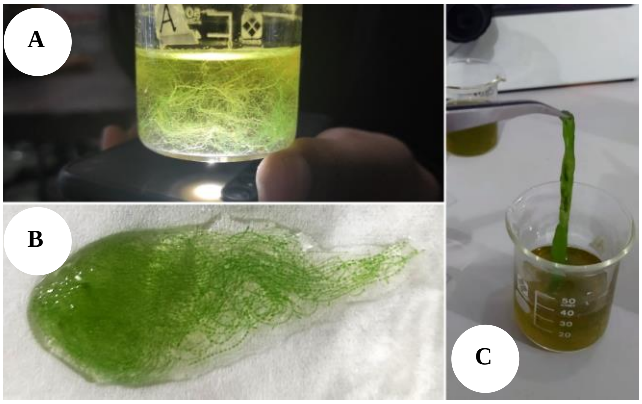

Figure 4. *Paludicola turfosa* filaments: (A, C) in a beaker glass; and (B) on a microscope slide

The filamentous branching pattern is key morphological characteristic of distinguishing red algae species and can be categorized as pseudo-dichotomous or irregular (Vis et al. 2020). Based on morphological observations, our collection of *P. turfosa* generally appears to have a pseudo-dichotomous branching pattern. The bifurcation of thalli was clearly evident, with each branch divided into two derivative branches (Figure 5).

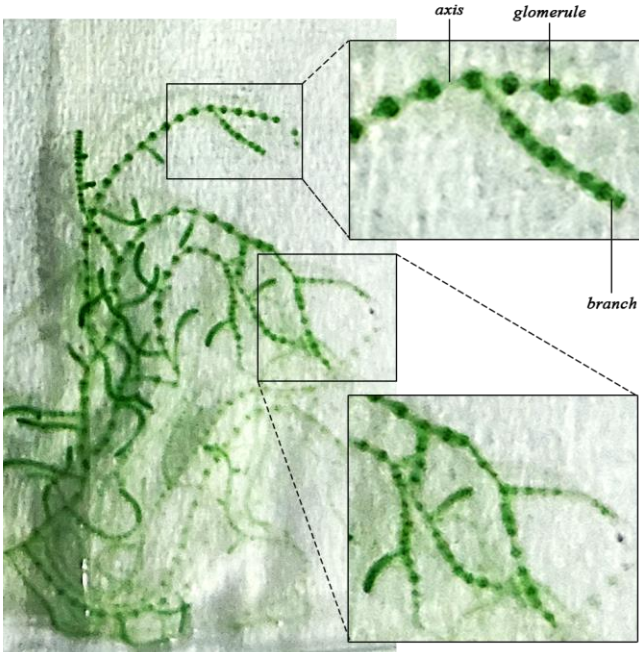

Figure 5. Photograph of *Paludicola turfosa* exhibiting characteristics branching pattern

Microscopic observations

The morphology of *P. turfosa* was also observed at low and higher magnifications (Figures 6, 7 and 8). Figure 6 depicts the crossing filaments, the arrangement of glomerules, and shoot branches of *P. turfosa*. Crossing filaments were clearly visible at 40× magnification (Figures 6.A-C); at this magnification, the *P. turfosa* filaments were often tangled. The arrangement of the glomerules was observed to form different levels of density, ranging from loose to compressed. The densest arrangement of the glomerules is observed in juvenile or newly formed branches. The axis distance (Figure 6.E) between the glomerules was wider away from the branching of the *P. turfosa* filament outgrowths. Shoot branches had a pattern with two derivative branches emerging from each branch known as a pseudo-dichotomous branching pattern (Figures 6.B-C; red arrows).

Vis et al. (2020) recently described the revised morphological description of *P. turfosa* (previously *B. turfosum*) in that this species is pseudodichotomously branched, and the whorls are reduced (238-375 μm diameter), obconic, barrel-shaped, and becoming confluent to indistinct in older parts of the thallus. In addition, Sheath and Vis (2015) described the typical morphological characteristics as follows rhizoid-like cortical filaments typically develop from the lower side of the pericentral cells. Cortical filaments grow downward and ensheath axial cells, often producing secondary fascicle branches. Each fascicle cell contains several, ribbon-like, parietal chloroplasts with no pyrenoid.

Figure 7 shows the microscopic appearance of the apical portions of *P. turfosa* thallus at 100× and 400× magnification. The results indicate two different states of the apical portion of *P. turfosa* thallus, i.e., the apex with dense whorls (Figures 7.A-E) and the apex with loose young whorls (Figures 7.F-H). The apices with dense whorls give the blue-green appearance of the filaments (Figure 3.B), whereas those with loose young whorls give the dominant green appearance of the filaments (Figure 3.C). These conditions indicated that the color of the *P. turfosa* filament depends on pigment concentration resulting from the density of the glomerules which is influenced by the maturation state of the thallus.

The fascicles were microscopically observed at 400× magnification, including the primary and secondary ones (Figure 8). The fascicle is a cluster of filaments or branches with the parts sub-parallel. Figure 8.A shows the microscopic appearance of fascicles at the apical portions of *P. turfosa* thallus; the primary fascicles appear straight. The fascicles are so dense that it is impossible to observe the secondary ones. Vis et al. (2020) describe the fascicles of *P. turfosa* as follows: primary fascicles are straight, cylindrical, ellipsoidal cells becoming obovoidal at tips; secondary fascicles are abundant, covering the entire internode throughout most of the thallus. Figures 8.B-C shows spherical spermatangia at the tips of fascicles with a diameter of about 7 µm. According to Vis et al. (2020), spermatangia of *P. turfosa* is located at the terminal or subterminal on primary and secondary fascicles with a 7-10 µm diameter. The carpogonial filaments were not observed nor were trichogyne due to the limited detail on micrographic images.

Carpogonia and spermatangia are the sexual reproductive organs of *P. turfosa* where carpogonia are female sex organs, and spermatangia are male sex organs. The carpogonium is a club-shaped structure with a lanceolate trichogyn that functions as a receptive organ (Sheath and Vis 2015; Vis et al. 2020). The spermatangium produces a male gamete called spermatium. The spermatium is unicellular, spherical, non-motile, and colorless. In the process of sexual reproduction, when the spermatium is around the carpogonium, it will attach to the trichogyne (Baweja et al. 2016).

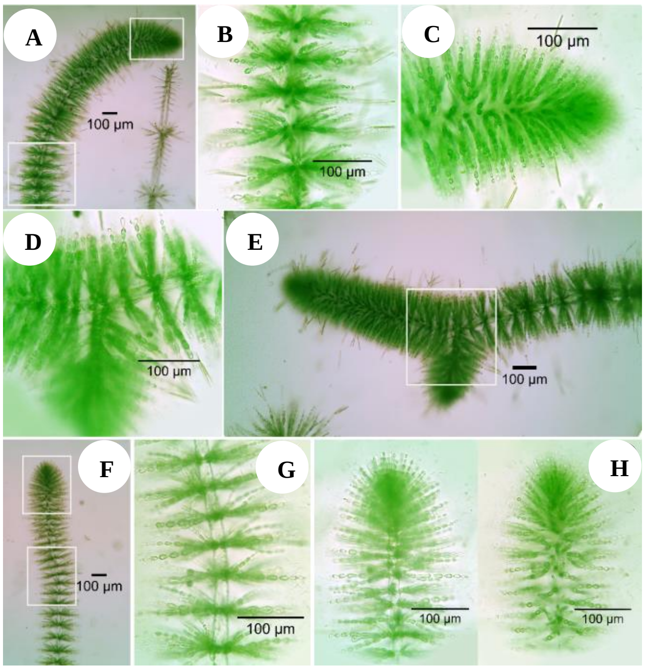

Figure 7. Microphotographs of the apical portions of *Paludicola turfosa* Thallus: (A and E) apex with dense whorls at 100× magnification; (B-D) apex with dense whorls at 400× magnification; (F) apex with loose young whorls at 100× magnification; and (G-H) apex with loose young whorls at 400× magnification

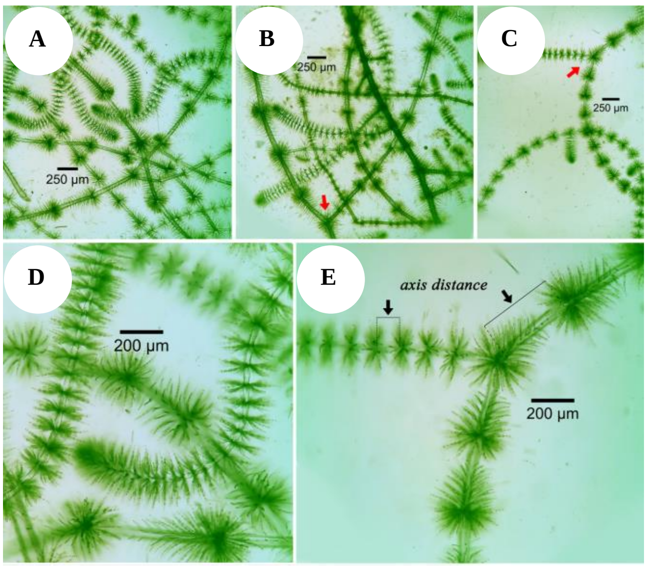

Figure 6. Microscopic appearance of *Paludicola turfosa* at 40× magnification (A-C) and 100× magnification (D-E); Pseudo-dichotomous Branching Pattern (red arrows; B-C); axis distance (black arrows; E)

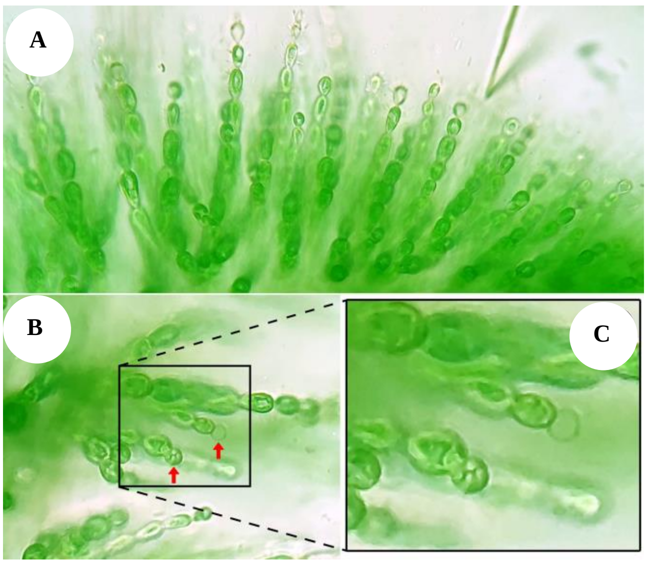

Figure 8. Microphotographs of *Paludicola turfosa* fascicles at 400× magnification (A-C): (A) the fascicles of the apical portions; (B-C) and spermatangia (red arrows)

In this study, we report the preliminary description of the freshwater red algae *P. turfosa*, previously known as *B. turfosum* from the peat waters of Sebangau River, Sebangau National Park, as a new record for Indonesia. The *P. turfosa* was mainly found attached to the leaves of Rasau (*P. helicopus*) forming a hair-like structure representing its filamentous appearance. The *P. turfosa* generally appears to have a pseudo-dichotomous branching pattern. The bifurcation of thalli was clearly observed on the *P. turfosa* filaments, with each branch divided into two derivative branches. The primary fascicles appear straight and so dense that it is impossible to observe the secondary fascicles. The spermatangia at the tips of fascicles were spherical with a diameter of about 7 µm. The carpogonial filaments were not observed nor was the trichogyne due to the limited detail on the microphotographic images.

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Short Communication: First record of Crow-billed Drongo (*Dicrurus annectens* (Hodgson, 1836)) in East Java Province, Indonesia

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Abstract. *Siddiq AM, Kurnianto AS. 2023. Short Communication: First record of Crow-billed Drongo (*Dicrurus annectens *(Hodgson, 1836)) in East Java Province, Indonesia. Intl J Bonorowo Wetlands 13: 73-77.* Crow-billed Drongo (*Dicrurus annectens* (Hodgson, 1836)) is a migratory bird that breeds in the Himalayas and Southern China. It has a range of distributions for migration to Indonesia (Sumatra, Kalimantan, and Java Island). However, on Java Island, this species was only found distributed in West Java. During migration, species *D. annectens* have a stopover habitat in mangrove and coastal forests. This study records *D. annectens* in the mangrove forest of Jatipapak Block, Kucur Resort, Alas Purwo National Park (APNP) on 29 October and 31 October 2020. The species was observed by the using morphology characteristics documentary: the tail is split like a scissor with the ends curved upwards, the body is about 25-30 cm long, has a broad chest, and narrows to the belly direction. In addition, this bird has a thick-sharp bill and a shiny, bluish-black body. The species was observed resting in the crown of the outer side of the mangrove vegetation and then fleeing to other mangrove vegetation (the crown of the outer side). The occurrence of *D. annectens* in the APNP has not previously been reported. Therefore, the encounter of this species in the Jatipapak mangrove forest is the first record in APNP. On the other hand, this report also provides information that *D. annectens* has an extended migration range to the East Java Region.

Keywords: Crow-billed Drongo, East Java, first record

INTRODUCTION

The Crow-billed Drongo (*Dicrurus annectens* (Hodgson, 1836)) is one of the eight Drongo species found in the Greater Sundas, Indonesia (MacKinnon et al. 2010; Eaton et al. 2016; Akbar et al. 2020; Taufiqurrahman et al. 2022). Species *D. annectens* is a migratory bird that breeds in the Himalayas and Southern China, then migrates south to India, Southeast Asia, and the Greater Sundas (Rocamora and Yeatman-Berthelot 2020; Avibase 2023; Birdlife International 2023). The complete migration movement of this species includes spending the non-breeding period in East Bangladesh and adjacent North East India, and from South Myanmar and South Thailand through the Malay Peninsula (mainly on coasts and small islands, rarer inland, uncommon to Singapore) and islands to Sumatra (rare) and Java (occasional in West coastal forest and mangroves) (Rocamora and Yeatman-Berthelot 2020) (Figure 1). Taufiqurrahman et al. (2022) also reported that *D. annectens* in the Greater Sundas is a rare migrant species, and it has only been reported in Sumatra, Kalimantan (especially the western seas), and Java (especially in west Java). So, this species is rarely reported on Java Island and has never been recorded in the East Java Region. However, considering the current environmental conditions that tend to change, whether biotic or abiotic, they could affect species range shifts or expansion (Lenoir et al. 2020; Han et al. 2023). More specifically, Lenoir et al. (2020) revealed that terrestrial species follow the direction of isotherm shifts along elevational gradients but are slower in warm climate areas. In this case, migratory species such as *D. annectens* may also expand geographically.

Like other Drongo species, *D. annectens* is an insectivore (Rocamora and Yeatman-Berthelot 2020). This species often occupies and forages in open habitats, particularly coastal forest areas (Eaton et al. 2016; Taufiqurrahman et al. 2022). The records on *D. annectens* in Indonesia, especially in Java, are minimal (Taufiqurrahman et al. 2022). Therefore, there is only some information about this species' ecology (MacKinnon et al. 2010; Eaton et al. 2016; Taufiqurrahman et al. 2022). In the East Java Region, several forest areas have databases related to the occurrence of Drongo species, such as Alas Purwo National Park with 4 species, i.e., Black Drongo (*Dicrurus macrocercus* Vieillot, 1817), Ashy Drongo (*Dicrurus leucophaeus* Vieillot, 1817), Hair-crested Drongo (*Dicrurus hottentottus* (Linnaeus, 1766)), and Greater Racquet-tailed Drongo (*Dicrurus paradiseus* (Linnaeus, 1766)) (Grantham 2000), Baluran National Park with 4 species, i.e., Black Drongo, Hair-crested Drongo, Greater Racket-tailed Drongo, and Ashy Drongo (Winnasis et al. 2011), Meru Betiri National Park with 2 species, i.e., Ashy Drongo and Greater Racquet-tailed Drongo (Kurnianto et al. 2014), Ijen Highland with 2 species, i.e., Ashy Drongo and Greater Racquet-tailed Drongo

(Mittermeier et al. 2014; Siddiq et al. 2023), Bromo Tengger Semeru National Park with 4 species, i.e., Black Drongo, Ashy Drongo, Lesser Racket-tailed Drongo (*Dicrurus remifer* (Temminck, 1823)), and Greater Racquet-tailed Drongo (Prasetya and Siswoyo 2017; Avibase 2023), and *Erek-Erek* Geoforest of Ijen Geopark with 3 species, i.e., Ashy Drongo, Lesser Racket-tailed Drongo, and Greater Racquet-tailed Drongo (Siddiq et al. 2023). Based on these reports, there are 5 Drongo species in the East Java Region: Black Drongo, Ashy Drongo, Hair-crested Drongo, Greater Racquet-tailed Drongo, and Lesser Racket-tailed Drongo. Therefore, the scientific reports of Crow-billed Drongo in this region have not been reported. Several hypotheses related to species range expansion may occur for this species, such as the shift of migrant habitat to the eastern tip of Java Island.

The current exploration of the distribution range of the Crow-billed Drongo in the East Java Region is important. Several potential areas in the East Java Region are used as stopover habitats for this species during migration. Therefore, exploring the new occurrence of *D. annectens* in potential areas in the East Java Region, which may also be a new distribution range along the migration period, is necessary. This paper describes the first Crow-billed Drongo (*D. annectens*) record in the East Java Region, specifically at Alas Purwo National Park (APNP). This National Park is a conservation area located at the eastern tip of Java Island, with a total area of around 43,420 ha. Generally, the forest types of APNP are lowland rainforests, such as coastal forests, mangrove forests, bamboo forests, and tropical lowland forests (Ariyanto et al. 2011). These conditions provide habitat for many bird species. Grantham (2000) reported 227 bird species (with an additional 11 'possible' species) in APNP during observation periods from May 1997 until September 1999. Another report shows that around 285 bird species were reported in APNP (Widodo 2009; Ariyanto et al. 2011). Based on previous reports, a species of Crow-billed Drongo has never been reported in APNP. These studies will add new information on bird species richness in APNP. More specifically, it becomes essential information related to the new expansion of the Crow-billed Drongo on Java Island.

MATERIALS AND METHODS

The study site is located in the mangrove forest of Jatipapak Block, Kucur Resort, APNP (8°32'24.25"S and 114°22'19.28" E), East Java, Indonesia (Figure 2). Administratively, APNP is located in Banyuwangi District, East Java, Indonesia. This conservation area has five management zones, i.e., Core Zone (17,150 ha), Buffer Zone (24,207 ha), Rehabilitation Zone (620 ha), Utilization Zone (660 ha), and Traditional Zone (783 ha). Meanwhile, geographically, APNP is located at the eastern tip of Java Island and directly borders the Indian Ocean, the Bali Strait, and Pangpang Bay. Therefore, this area has a vast coastal ecosystem within the mangrove ecosystem. Ariyanto (2011) revealed that there are around 26 types of mangroves in APNP, and *Rhizophora apiculata* Blume, *Rhizophora mucronata* Lam., *Bruguiera gymnorhyza* (L.) Lam., *Avicennia marina* (Forssk.) Vierh., *Cordia bantamensis* Blume, *Xylocarpun granatum* J.Koenig, *Heritiera littolaris* Dryand. ex Aiton, *Sonneratia alba* Sm., and *Sonneratia caseolaris* (L.) Engl. mostly dominate them.

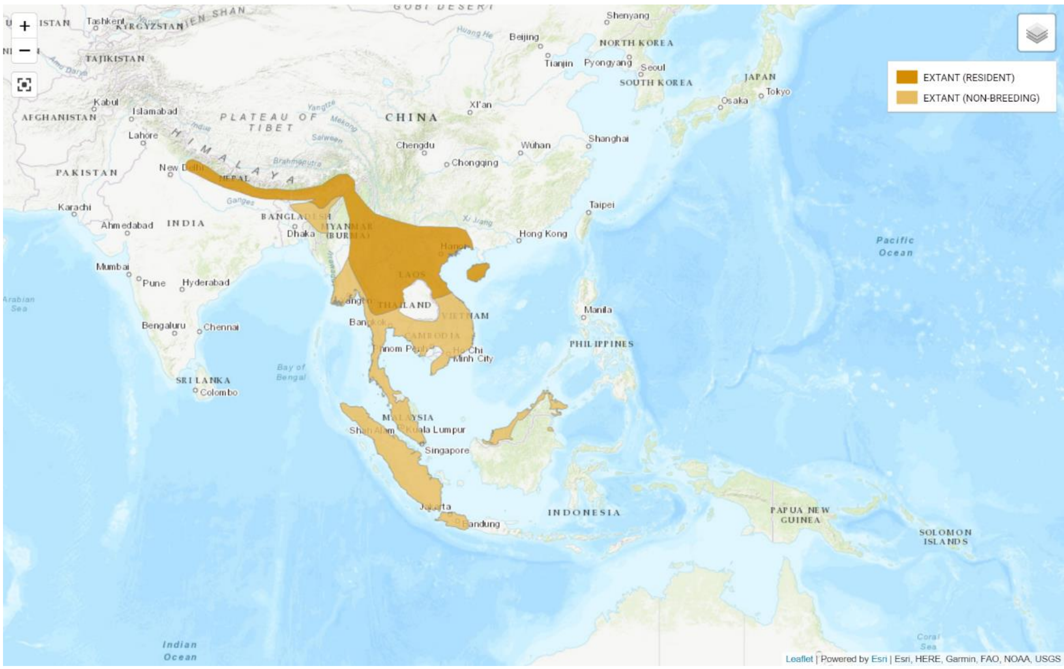

Figure 1. The geographic range of Crow-billed Drongo (Birdlife International 2017)

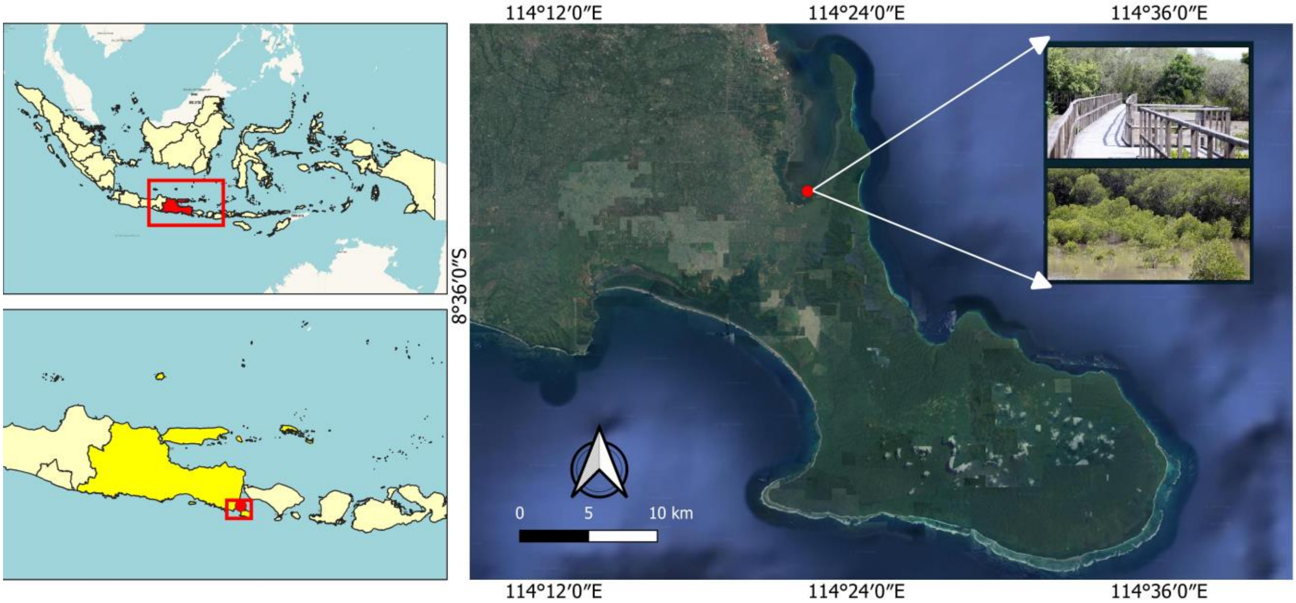

Figure 2. Mangrove forests at Jatipapak Block, Resort of Kucur, APNP, and its position on Java Island, Indonesia

The coastal area in APNP is circular from Cungur, Plengkung, Tanjung Purwo, Tanjung Pasir, Teluk Banyu Biru, Perpat, Klosot, Bringinan, Kayu Aking, Tanjung Sembulungan, and Kucur (Jatipapak Block) (Ariyanto et al. 2011; Tisnawati et al. 2012). Jatipapak block has a mangrove ecosystem with *R. apiculata*, *R. mucronate*, *S. alba*, and *S. caseolaris* species. This block is located on the northern side of APNP and borders the Pangpang Bay area. Data were recorded on 29 October and 31 October 2020 during data collection for research on the valuation of mangrove forests at Jatipapak Block, Kucur Resort, APNP. The author (Arif Mohammad Siddiq: AMS) conducted these observations at the edge of the mangrove ecosystem bordering the coastal forest. The weather was sunny, making it easy to observe bird morphology. Bird observation was done using a Nikon Aculon A211 16x50 binoculars, a Canon EOS 60D, a telephoto lens 75–300mm, and stationary notes. These observations were conducted at 06.00-09.00 AM along the mangrove trails. Observation of morphological characteristics is used for identification, including body size, overall body color, forehead color, chest and belly color, back and rump color, tail shape and length, beak shape, bill color, bill size, and other important characteristics. The identification and verification of species use the guideline book "Birds in Sumatra, Java, Bali, and Kalimantan" by MacKinnon et al. (2010) and Guideline Book of Birds in Sunda Besar (Sumatra, Java, Kalimantan, and Bali) (Taufiqurrahman et al. 2022).

RESULTS AND DISCUSSION

AMS recorded a single individual of Crow-billed Drongo in the mangrove forest of Jatipapak APNP. This species was perched on the crown of a tree around the coastal forest bordering the mangrove (Figure 3). With a Nikon Aculon A211 16x50 binocular, AMS immediately recognized it as a Drongo because of its distinctive morphology: the tail is split like a scissor with the ends curved upwards, the body is about 25-30 cm long, with a broad chest, and narrows to belly direction. However, this bird has a thick-sharp bill and a shiny, bluish-black body. These characteristics distinguish it markedly from the sister species, Black Drongo (*D. macrocercus*), which is also recorded at that location (see Figure 3 for more comparison). This description aligns with MacKinnon et al. (2010) and Ebird (2023), where the Crow-billed Drongo is distinguished from the Black Drongo by its larger body size, dark-shiny color, and thick bill. There were no vocal records during the observation. Considering that it is an aggressive bird, it will potentially affect the foraging behavior of native species, particularly Black Drongo. However, further research is needed to prove these allegations. On the other hand, Ashy Drongo and Lesser Racquet-tailed Drongo in Gunung Gede-Pangrango National Park were observed in mixed flocks with other bird insectivores. Even though this case is quite rare, more of these two species form separate flocks (Putra et al. 2020).

The species was observed resting for 5-7 minutes and then flew to the inner mangrove vegetation. Furthermore, on 31 October 2020, AMS again recorded a single individual Crow-billed Drongo perched in the crown of the outer side of the mangrove vegetation (Figure 3). The species was observed resting for 3-4 minutes and then flew to other mangrove vegetation (crown of the outer side). This is thought to be due to catching prey (it is unclear which prey was caught). This species tends to catch insects for feed (including ants: Formicidae and termites: Isoptera) (Eaton et al. 2016; Rocamora and Yeatman-Berthelot 2020). This species still hunts from shaded perch, capturing prey at ground level in open areas, clearings, and forest paths.

Furthermore, Crow-billed Drongo takes aerial insects by sallying from hidden perch or, less often, by more prolonged hawking (Rocamora and Yeatman-Berthelot 2020). It is a territorial and aggressive bird, especially during the breeding season, frequently mobbing raptors or corvids with all its might (Ebird 2023). AMS documents these birds with a Canon EOS 60D and telephoto lens of 75-300 mm at each observation.

The existence of a Crow-billed Drongo in the APNP has not previously been reported. Therefore, the encounter of Crow-billed Drongo in the Jatipapak mangrove forest is the first record in APNP. Grantham (2000) only discovered four Drongo species, i.e., Black Drongo (a common category in APNP), Ashy Drongo (a rare category in APNP), Hair-crested Drongo (an uncommon category in APNP), and Greater Racquet-tailed Drongo (a common category in APNP). Moreover, Widodo (2009) reported that 4 species of Drongo were found in each habitat type in APNP, such as natural forest (1 species: Greater-racquet Drongo), teak forest (4 species: Black Drongo, Ashy Drongo, Hair-crested Drongo, and Greater Racquet-tailed Drongo), coastal forest (2 species: Black Drongo and Greater Racquet-tailed Drongo), artificial savannah (1 species: Black Drongo). While, Widodo (2016) did not rediscover 2 species, i.e., Ashy Drongo and Hair-crested Drongo. It is possibly due to a movement of both species to the northern part of the national park (Sembulungan and its surroundings). This means that the distribution of Drongo species in APNP is still unclear, so comprehensive research is needed for each species.

On the other hand, this report also provides information that *D. annectens* has an extended migration range to the East Java Region. Akbar et al. (2020) and Taufiqurrahman et al. (2022) reported that this species had restricted distribution in the West Java Region, especially in mangrove and coastal forests. This species was also reported on Sumatra, Java, and North Kalimantan from September to November (during their migration periods), and it was found to inhabit coastal and mangrove forests (Eaton et al. 2016; Taufiqurrahman et al. 2022). Therefore, compared with these results, *D. annectens* prefers coastal and mangrove forests during the migration season. Recently, information regarding the *D. annectens* population has been limited. Based on The International Union for Conservation of Nature (IUCN) Red List of Threatened Species, *D. annectens* has the least concern status. Information regarding threats from this species has also never been reported before. However, wetland areas, particularly mangrove and coastal forests, tend to change over time, possibly impacting this species ecologically, especially on Java Island.

The condition of Java Island, where anthropogenic activities have fragmented, is one of the challenges and threats facing the bird species. According to the Ministry of Forestry data, forest loss between 2000 and 2005 in Java was about 800,000 hectares (Prasetyo et al. 2009). This is due to the sharp increase in human population growth, and the population on this island is more than 60% of the total population of Indonesia (Prasetyo et al. 2009; Tsujino et al. 2016). In the period 2005-2020, there is likely to be increased forest degradation (Tsujino et al. 2016).

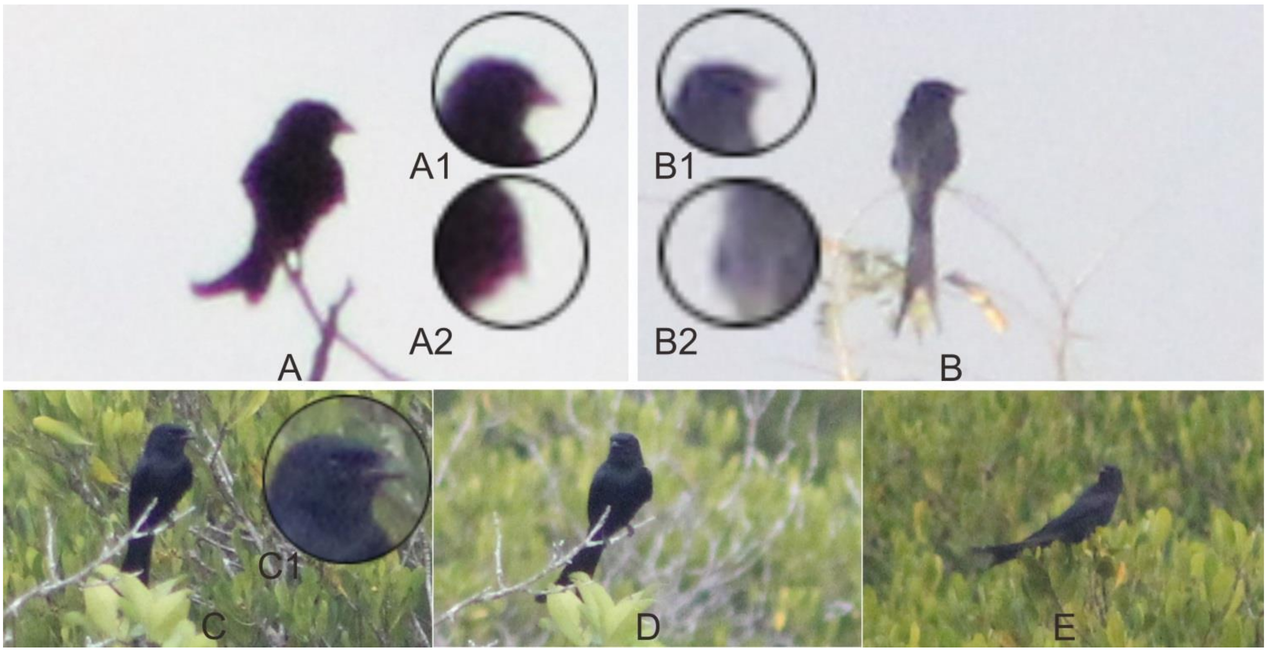

Figure 3. Single individuals of A. Crow-billed Drongo and B. Black Drongo were recorded on 29 October 2020, with the comparison of A1. and B1. heads and A2. and B2. body colors, and C-E. A Crow-billed Drongo was recorded on 31 October 2020 with the insert of the head (C1)

With the remaining forest, it becomes an essential corridor for bird species. Species *D. annectens*, which prefers habitats near the coast, are thought to have chosen coastal forest and mangrove forest areas as migration routes. Environmental changes, especially in coastal ecosystems, could be potential drivers of the range expansion of this species. Thus, the distribution dynamics of this species will be interesting to study. Furthermore, the existence of conservation areas on Java Island is also a critical stopover habitat for this species. Apart from that, non-conservation area forests are also an important part of the corridor for the movement of this species.

Finally, based on this short report, there is expected to be further research going forward for data collection or monitoring of this species in APNP, especially in coastal areas of Sembulungan, Payaman, Perpat, Segoro Anak, and Bedul. Several locations have similar characteristics of habitat type as Jatipapak, with coastal and mangrove forests inside; its characteristics are the preferred habitat of the Crow-billed Drongo. Observations can be made periodically or every month, especially during the migration season (September-November). A study of this species' local distribution, habitat characteristics, population, and behavior is also significant for research. Bilal et al. (2020) conducted a feeding ecology, behavior, and habitat utilization of black Drongo in Pothwar Plateau, Pakistan. Similar research can also be carried out at APNP with Drongo species as the objects, particularly Crow-billed Drongo. So, it is supposed that the ecological information related to this species will be more comprehensive in APNP.

The conclusion is a Crow-billed Drongo species found in the Jatipapak APNP mangrove ecosystem, the first record in this National Park and East Java. This species is thought to have expanded to the eastern part of Java Island during the migration periods. Furthermore, this record also updates the list of bird species in APNP, especially for migratory birds that use this area as a stopover site.

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Traditional ecological knowledge and utilization of rice in Sukoharjo District, Central Java, Indonesia

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Abstract. *Kusuma LA, Damayanti K, Damayanti JT, Nisa J, Nurwulandari M, Nazar IA, Yap CK, Md. Naim D, Setyawan AD. 2023. Traditional ecological knowledge and utilization of rice in Sukoharjo District, Central Java, Indonesia. Intl J Bonorowo Wetlands 13: 78-85.* Rice (*Oryza sativa* L.) is one of Indonesia's staple foods and a source of income for some communities. Sukoharjo District is one of Central Java's most promising rice producing areas. In managing rice farming, the community incorporates local knowledge and discovers collective understanding about rice plants. The research was conducted to determine the existence of Traditional Ecological Knowledge (TEK) by the Javanese people of Sukoharjo District, Central Java, Indonesia in managing rice varieties and influencing factors, as well as to learn about the community's perception of rice plants; the research employs a qualitative and quantitative ethnobiological approach. The results showed that although agriculture in Sukoharjo District is included in semi-modern agriculture, the community has TEK, which includes various rice varieties and paddy fields. Farmers in Sukoharjo District use Inpari 32 and in small quantities also the IR 64 rice varieties to manage their paddy fields instead of other varieties. Rice is widely used in various traditions, such as *rasulan*, *bersih desa*, *kacar kucur* (weddings), *syukuran*, and *kenduren*. Many parts of the rice plant are also used, such as rice stems (straw), grain, husks, bran, and rice. A small part of the Sukoharjo community uses rice as an important role in cultural behavior and in maintaining the rice varieties' biodiversity well. In managing agriculture, some communities still use traditional techniques and adjustments to modern technology, such as using modern tools and human labor to plant seeds. The application of rice in every activity of the people of Sukoharjo District shows a complex relationship between humans and nature.

Keywords: Agriculture, ethnobiology, local wisdom, rice, rice fields

INTRODUCTION

Humans and culture are inextricably linked, therefore we might refer to ourselves as cultural creatures. Culture can be ideas, symbols, and values used as guidelines for human actions (Akaka and Vargo 2014). Humans have the ability to think, feel, and behave according to what they want to express. Seven elements of culture are universal: language, technology system, livelihood system, social organization, knowledge system, religion, and art (Rahman et al. 2023). Various tribes in Indonesia employ their people's knowledge systems as a cultural pattern. Cultural patterns can be found in the fisheries, cattle, and agriculture industries, particularly the farming system. Farming in rice fields is one of the farmer's actions that can be carried out as a ritual procedure or tradition within a community.

Agriculture is one of the most important things in supporting human life. The agricultural sector can provide livelihoods for the surrounding community. The agricultural sector plays an important role in the economies of developing countries (Tangermann 2005). This sector provides food and employment directly and components of GRDP (Gross Regional Domestic Product). Rice (*Oryza sativa* L.) is one of primary food sources for some populations in Indonesia (Kim et al. 2020). Rice is also a source of income for some communities (Mew et al. 2003). Rice is a strategic commodity that receives the main treatment in agricultural development (Azzahra et al. 2023). According to the population census conducted by BPS (2019), the population growth rate of Indonesia from 2011 to 2017 was 8.22%, followed by an increase in rice consumption of 4.81% (BPS 2017). Suppose the rice increase consumption does not follow their production; it will cause increasing national rice demands (Hilalullaily et al. 2021). Therefore, it is necessary to increase rice production (supply side). The agricultural systems used in Indonesia are diverse, such as farming with modern, traditional techniques and a combination (Nurazaman et al. 2013). The community's thoughts and creativity inspired the traditional agricultural system, which contains positive values and local wisdom (Aras 2018).

Traditional Ecological Knowledge (TEK) is the knowledge possessed by indigenous or tribal communities about the relationship between humans and the surrounding natural environment (Efriani et al. 2020; Tynsong et al. 2020). TEK includes knowledge about plants, animals, and the environment, as well as traditional ways of utilizing and conserving natural resources. TEK also includes certain beliefs and rituals, such as before cutting down large trees for household purposes and building a house (Efriani et al. 2020). Factors that can influence TEK can be different from factors that influence the utilization of information technology. Several factors influencing TEK include interactions with the environment, cultural values, social factors such as policies, public opinion, cultural values, innovation and experimentation, and science and technology (Ludwig and Macnaghten 2020).

Sukoharjo District is one area with great potential as a rice producer in Central Java Province, Indonesia; it is one of the centers of rice production in this province (Prasetyo 2023). It is not surprising that Sukoharjo District is a granary in Central Java, Indonesia (Riyanto et al. 2023). This is supported by the irrigation system that meets the water needs in rice farming production supplied by the Bengawan Solo river flow (Rokhmah et al. 2022). This study aims to determine the existence of TEK (Traditional Ecological Knowledge) in Sukoharjo District in managing rice varieties, factors that influence rice management, and people's perceptions of rice plants.

MATERIALS AND METHODS

Study area

This research was conducted in three villages of the Javanese community in Sukoharjo District, Central Java, Indonesia (Figure 1), namely Serut and Nguter in Nguter Sub-district, and Joho in Mojolaban Subdistrictfor one month in October 2023. Geographically, Sukoharjo District is located at 110° 57' 33.70"E - 110° 42' 6.79"E, and between 7° 32' 17.00" - 7° 49' 32.00"S. Sukoharjo District has an area of 46,666 km² or 1.43% of the area of Central Java Province, Indonesia (Mukaroma et al. 2022). Topographically, Sukoharjo District consists of lowlands and hills. The lowland area is in the northern, while the hilly area is in the southern and eastern. Almost all residents of this district are Javanese and muslim, although other Indonesian ethnic groups can also be found, including Chinese and Arabs.

Data collection

This study used qualitative and quantitative techniques with an ethnobotanical approach. Data was collected through questionnaires to 65 respondents in the Sukoharjo District. In addition, the research also used observation techniques, and semi-structured and structured interviews (Adeoye-Olatunde and Olenik 2021). The observation was to obtain general information about the condition of paddy fields, types of rice plant varieties, management, and local wisdom in using rice plants. Informants are selected through very appropriate snowball techniques based on initial references from informal leaders (Wijayaningtyas et al. 2017). Informants comprised men and women and were categorized by age, latest education, and village origin (Table 1). Structured interviews were conducted with randomly selected households.

Data analysis

Qualitative data collected in the field and obtained from interviews were then re-checked. The data was then categorized and filtered based on its relevance to the research objectives. The data was presented based on two points of view, namely the informant's and the researcher's. Then, the data is narrated using descriptive and evaluative research (Lubis et al. 2019). The quantitative data was also analyzed to calculate the percentage of respondents who answered about the origin of agricultural Traditional Ecological Knowledge (TEK) obtained in the Sukoharjo District.

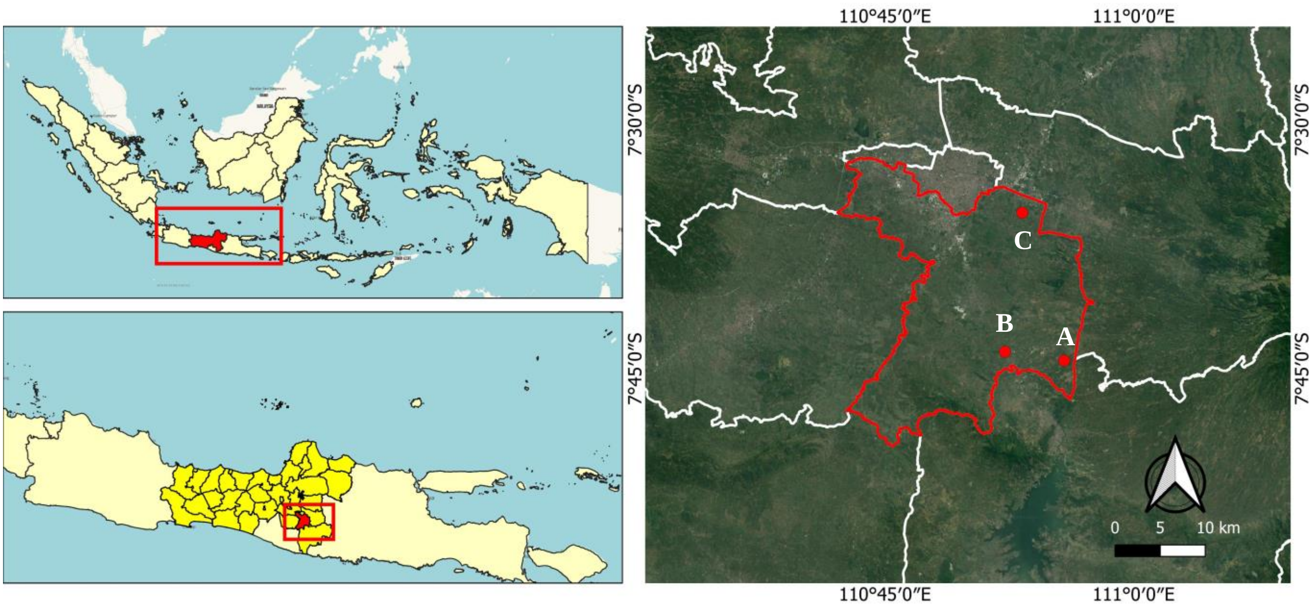

Figure 1. Map of research locations in Sukoharjo District, Central Java Province, Indonesia, namely A. Serut, B. Nguter, and C. Joho

Table 1. Characteristics of respondents

Respondent Characteristics	Number of Informants
Gender	
Male	49
Female	16
Age group (year)	
33 – 64	48
>65	17
Education	
No education	7
Elementary School	29
Junior High School	14
Senior High School	14
University	1
Village's origin	
Serut	29
Nguter	14
Joho	22
Total	**65**

RESULTS AND DISCUSSION

Source of the TEK on the rice

The Javanese people of Sukoharjo District obtained Traditional Ecological Knowledge (TEK) about varieties of rice types that were passed down from generation to generation from their ancestors. They resulted from a long process of cultural adaptation to local environmental conditions. Based on Table 2, of 65 respondents, the Javanese people of Sukoharjo District who participated in the study, as many as 44 respondents (67.7%) obtained TEK from ancestors, 4 respondents (6.2%) from relatives and friends, 2 respondents (3.1%) from farmer groups, and 15 respondents (23%) did not know the source of TEK obtained. There is no doubt that ancestors played an important role in spreading TEK. Learning capacity from ancestors is equivalent to 'vertical cultural transmission,' as socially derived knowledge is passed on from generation to generation or between generations (Hewlett 2021). Therefore, from the ancestors' learning about agriculture, there are many lessons about how to grow crops that create their own uniqueness in managing nature wisely and sustainably (Nawaz and Farooq 2021). This can be used as a reference for developing better agricultural technology in the future. Agricultural technology from ancestors, relatives or friends, and farmer groups can be developed through various knowledge, experiences, and direct practices in agriculture.

Of the 65 respondents of Sukoharjo District who participated in the study, as many as 35 (53.8%) used semi-modern techniques, 25 respondents (38.5%) used modern techniques, and 5 respondents (7.7 %) used traditional techniques. Traditional agricultural techniques generally still use human power in moving them, while modern agricultural techniques can use more sophisticated tools and technological developments in managing agricultural land and its results (Dhanaraju et al. 2022). The application of agricultural techniques from traditional to modern is used to increase the yield of agricultural production by using more sophisticated modern agricultural tools. However, it does not rule out the possibility that some have begun to use modern agricultural techniques in managing their agricultural sector. Sukoharjo farmers are adapting and adjusting to the current agricultural technology.

Traditional Ecological Knowledge (TEK) on rice fields

Moreover, TEK on 19 types of local rice (*O. sativa*) commonly cultivated by the Javanese people of Sukoharjo District in rice fields has been recorded (Table 3). The types of rice commonly found in Sukoharjo District consist of Inpari 5, Inpari 16, Inpari 23, Inpari 32, Inpari 33, Inpari 46, Inpari 50, IR 64, Membramo, Sunggal, Tri Sultan, C4, Ciherang, Mekongga, Cakrabuana, Situ Bagendit, Mentik Wangi, Rajalele Srinuk, and Si Denok. The 19 recorded rice species are categorized locally (folk taxonomy) and differentiated based on four criteria: seed shape, plant shape, rice size, and seed properties, those ecological characteristics needed to grow well on the land.

Table 2. Sources of Traditional Ecological Knowledge (TEK) of rice management cultivation in Sukoharjo District, Central Java, Indonesia

Sources of the TEK	Respondent	Percentage	Rice management system	Respondent	Percentage
Ancestors/parents	44	67.7%	Traditional	5	7,7%
Relatives and friends	4	6.2%	Modern	25	38,5%
Far's group	2	3.1%	Semi-modern	35	53,8%
Do not know/not answering	15	23%			
Total	65	100%		65	100%

Table 3. Application of Traditional Ecological Knowledge (TEK) on diversity, rice fields and management by local people of Sukoharjo District, Central Java, Indonesia

Kind of TEK	Description
19 varieties of rice are used	Inpari 5, Inpari 16, Inpari 23, Inpari 32, Inpari 33, Inpari 46, Inpari 50, IR 64, Membramo, Sunggal, Tri Sultan, C4, Ciherang, Mekongga, Cakrabuana, Situ Bagendit, Mentik Wangi, Rajalele Srinuk, Si Denok
2 types of rice fields are applied	Rainfed (*sawah tadah hujan*) and irrigated land (*sawah irigasi*)
The traditional Javanese calendar system used in agricultural	*Pranata mangsa*, to determine the best time to plant crops

Most Sukoharjo District people prefer to plant Inpari 32, and in small quantities also the IR 64 rice variety. Inpari 32 is one type of Indonesian local rice commonly cultivated. The characteristics of the Inpari 32 rice variety are: inbred rice varieties, grown on irrigated land, medium grain shape, upright shape, the weight of 1000 is around 27 grams, and the rice produced is superior but less water (Rosalina and Nirwanto 2021). While, IR 64 comes from IRRI, Los Banos, Philippines, has several advantages compared to other types of rice, such as a shorter rice age, about 120 days HSS (Days After Sowing); have better resistance to pests and diseases (Gunawan et al. 2023); the yield is higher than some other varieties, such as Ciherang, with an average grain yield of 6.3 tons/ha and a fluffy rice texture when cooked (Joshi et al. 2020). Other types of rice are relatively rarely planted, related to harvest time, productivity, resistance to pests and diseases, organoleptic properties (taste, color, aroma, texture), etc.

The distinguishing factor between the 19 types of rice varieties in Sukoharjo is that each type of rice has a unique genetic combination, which can affect physical characteristics, productivity, and resistance to pests and diseases. Rice types can differ in grain shape and size, color, texture, and stalk length. Rice types can differ in yield or productivity (Sultana et al. 2022). Some rice types may produce more grain per hectare than others, for example, hybrid rice varieties. The harvest from these hybrid varieties can reach twice the amount of local rice. Rice types can also have differences in the quality of the rice, such as softness, chewiness, and aroma (Bergman 2019).

Based on research, Javanese people in Sukoharjo District use two types of rice fields, namely rainfed land and irrigated, one of the two types of rice fields can affect the planting period to harvest rice plants (Table 3). Rainfed rice fields are rice fields whose irrigation depends on rainfall (*sawah tadah hujan*) (Rini et al. 2021); this type can be found in areas higher than irrigation systems, irrigated rice fields or paddy fields (*sawah irigasi* or *sawah*). In comparison, irrigated rice fields have irrigation systems from many sources, such as springs or river dams (Massey et al. 2022). Irrigation on rice fields is intended to be able to meet the water needs of plants. Furthermore, both types of paddy fields can affect the planting period to harvest rice plants.

Most farmers in Sukoharjo District do not use special calculations from planting to harvesting. However, some farmers use *pranata mangsa* calculations to manage their rice plants. *Pranata mangsa* is a traditional Javanese agricultural calendar system used by farmers, fishermen, and hunters. System used by farmers to determine the best time to plant crops, especially rice. *Pranata mangsa* is based on the apparent circulation of the sun, which moves north and south every year at the equator (Sobirin 2018). If the sun is in the northern equator, it means the dry season (*musim kemarau* or *ketiga*); if it is in the southern equator, it is the rainy season (*musim hujan* or *rendeng*). In addition, if the sun is around the equator, there will be a transitional season (*musim pancaroba*). The transition season consists of two types: the transition to the rainy and dry seasons. The *pranata mangsa* calculation system is not only used by farmers; fishermen and hunters also use *pranata mangsa* to reduce risk and prevent high production costs (Witasari 2015).

Subak in Bali and *pranata mangsa* in Java are two traditional systems used in agriculture in Indonesia. Although they have differences in origins, philosophy, and practices, both have significant relevance in managing agriculture and irrigation in their respective regions. The *subak* system in Bali regulates the management of rice field irrigation using the Pura Subak network and applies values of justice, openness, harmony, and togetherness. *Pranata mangsa* provides guidance in determining the timing of planting and harvesting based on observations of natural phenomena and seasons (Lestari et al. 2023). *Pranata mangsa* is still used by some farmers in Java today, although it has undergone some adaptations due to climate change and technological advances. *Pranata mangsa* are still relevant in today's climate change era. *Pranata mangsa* are based on real experience and rational observations of farmers in the past. Despite climate change, there is still a clear correlation between the natural phenomena that occur in *pranata mangsa* and current conditions. *Pranata mangsa* can provide valuable guidance in understanding weather patterns and growing seasons (Prahmana et al. 2021).

TEK is important as it can provide valuable insights into sustainable resource management and conservation practices. This knowledge can make farmers more careful in managing environmental changes, such as disruption of balance in rice fields (Iskandar and Iskandar 2018). Rice cultivation in Sukoharjo District is traditionally managed based on TEK, which includes knowledge of the local ecology, beliefs, and farmers' customs. TEK in rice varieties is a dynamic system to adapt to various ecological, socio-economic, and cultural changes. For example, Javanese farmers in Sukoharjo District use TEK to manage rice biodiversity and modernize rice cultivation practices. They know various varieties of rice plant types, how to manage them both irrigated and rainfed, and their habit of dry and rainy seasons. Therefore, Sukoharjo people harvested rice on average two to three times a year, with a planting-to-harvesting period of approximately 90-100 days.

Tradition ceremony and utilization of rice

The Javanese people of Sukoharjo District utilize rice for several traditions and beliefs that are passed down from generation to generation; for example, they conduct *rasulan, syukuran, kacar kucur, kenduren* (incl. *slametan*), and *bersih desa* traditional ceremonies (Table 4). A small part of the community of Sukoharjo District has a belief related to rice plants, such as the existence of a fertility goddess in agriculture, namely *Dewi Sri*. This has its roots in old beliefs which have now been abandoned by the majority of Javanese people or Sundanese people (as *Nyi Pohaci*) because they converted to Islam, but are still believed by the majority of Balinese people who continue to adhere to the old beliefs, namely Hinduism. *Dewi Sri* is believed by the Balinese people to be the embodiment of God who creates prosperity and soil fertility, especially in the livelihoods of farmers and traders (Anggraini 2020). A small part of the Sukoharjo District community still maintains this myth that *Dewi Sri* is a goddess who nurtures rice plants. Another form of local wisdom found among the people of Sukoharjo District is the *rasulan* tradition. The *rasulan* tradition, sometimes also called *bersih desa*, an activity to clean the village from bad luck, is usually held annually by a group of people. The *rasulan* tradition was originally held by rice farmers as an expression of gratitude to *Dewi Sri* for the well-produced harvest (Latifah 2023). The ritual of worshiping *Dewi Sri*, who is believed to be the nurturer of rice plants, is also often practiced by farmers in Jatiluwih Village, Bali (Wiasti 2015). This ceremony is carried out in unison by events such as organizing shadow puppets or other art shows.

But along with the times, the *rasulan* tradition began to be abandoned by the community; the more modern society has advanced its thinking and practices, and they think it not practical to organize *rasulan* anymore. The people's lifestyle changes have resulted in their response to the *rasulan* tradition, such as the assumption that the tradition is old-fashioned or outdated. Some respondents even said that the *rasulan* tradition is a tradition that violates their religions. So, it is rare to find the *rasulan* tradition in Sukoharjo District anymore. However, according to some respondents, some community groups still strongly believe in this custom, so they still preserve this tradition. The development of the increasingly modern era has made *rasulan* experience a shift in meaning and belief. Previously, this tradition was a form of gratitude to *Dewi Sri*; now, *rasulan* is a form of community request to *Allah* God Almighty that they've given smoothness, safety, and ease in finding sustenance. It also expresses gratitude to *Allah* God Almighty for the bestowed harvest.

People's lives are very dependent on the existence of rice plants. Knowledge related to rice plant biology is important for the community to know how to carry out traditional ceremonies and fulfill their life needs, such as managing rice plants. Traditional ceremonies in the community will be passed down from generation to generation (Kistanto 2016). Traditional ceremonies found among the Javanese people of Sukoharjo District include utilizing several parts of rice to carry out traditions, such as rice in the *kacar kucur* tradition in the Javanese traditional wedding procession. In addition, rice is also used, which is processed into rice for traditional events such as *syukuran* (thanksgiving) events, as well as *kenduren* (incl. *slametan*) (salvation) rituals containing joint prayers, which are usually served *tumpeng* (the rice serving shaped into a cone and arranged together with the side dishes) from processed rice.

The locals of Sukoharjo District also use rice for their everyday requirements, both the rice stalk and the rice grain, as shown in Table 5. The rice produced by Sukoharjo District farmers is mainly consumed on a daily basis, with some sold. The same is true with grain, which they use for animal feed and sell to others. Farmers sell their agricultural products not just in grain but also in rice. Other components of the rice are typically used for natural fertilizer or compost, which farmers commonly obtain through straw processing. Furthermore, utilizing straw for compost is a chemical fertilizer substitute, which lowers farmers' production expenses when purchasing fertilizers. Most farmers have the habit of burning straws to eradicate the remains of the rice harvest. Burning straw directly in the field accelerates land preparation for the next planting period. Some farmers also sometimes handed over their straws to people with livestock for animal feed. In addition to the rice processing products, the community can also produce bran as animal feed.

Table 5. The utilization of rice plants by the local people of Sukoharjo District, Central Java, Indonesia

Part of the rice plant	Utility	Processed
Rice stalk (straw)	Livestock food	Directly consumed
	Source of nutrients for plants	Composted, burned
Grain-rice		
Husk	Growing media	Planting media mix
Rice bran	Animal feed	Mixed fodder for livestock
Rice grain	Food source	Cooked

Table 4. Utilization of rice as a means of traditional ceremonies in Sukoharjo District, Central Java, Indonesia

Traditions	Description
Rasulan	An activity held by farmers from ancient times that is still preserved today, usually held after the harvest period as a gratitude to *Allah* God Almighty
Bersih desa	A ceremony conducted by the community to ward off bad luck that contains salvation and offerings in addition to traditional performances or games. *Rasulan* and *bersih desa* have different philosophies, but the forms of activity are relatively the same, so they are considered the same event.
Kacar kucur	Wedding tradition in Javanese traditional marriage is carried out by the husband as a symbol of the husband's ability to fulfill household needs.
Syukuran	A celebration that contains a prayer event by serving tumpeng rice (the rice serving shaped into a cone and arranged together with the side dishes)
Kenduren	The activity of praying and eating together for an event
Slametan	The activity of praying for people who have died, accompanied by eating together, it is a form of *kenduren*.

Rice farming activities carried out by the community also produce several parts of the rice plant that can be utilized directly or indirectly for the community, such as rice. Other parts, such as waste produced by rice, certainly require processing to be utilized. The processing of rice waste aims to minimize environmental losses. It can also increase the farmers' income by reprocessing rice waste into something that has a selling value, such as husks, which are processed into husk charcoal (Rahmiati et al. 2019). A study conducted by Handayani et al. (2014) states that rice waste, such as husks, can also be processed into silica gel. This product can absorb excess moisture in the air by adding CH_3COOH to the silica gel produced by rice husks; rice contains silica as much as 87%-97% dry weight after experiencing complete combustion. Rice waste has many potential benefits for the community, but some people have not processed rice waste efficiently. Most of them only process some parts of the waste from rice for animal feed, compost, or burn directly.

Management of the rice farming

Communities in Sukoharjo District generally manage rice farming using semi-modern methods, but few also use modern methods (Table 2). They use modern tools such as tractors and rice threshers to manage rice farming (Figure 2.A). Meanwhile, planting seedlings still use human labor to get more satisfactory results (Figure 2.B). According to some respondents, planting rice seeds using modern tools produces less than optimal results because the seeds are not neatly organized. Traditional rice management is considered more optimal, because farmers want to maintain traditional agriculture with guaranteed security and stability of the rice production (Maitra et al. 2021). In addition, almost all rice varieties get the same treatment in each rice planted. However, the Inpari 32 rice variety gets special treatment (Figure 2.C); only using a little water to survive in its initial growth phase. The initial phase of planting rice seeds does not require constant stagnant water, just wet and dry. This is useful when the oxidation process occurs in the root zone, so that the soil becomes fertile and plant roots can grow thickly (Li et al. 2019).

Rice cultivation management involves a number of challenges. These obstacles include fertilizer scarcity, difficult water flow, and pests and diseases that attack their plants. Pests that disturb rice plants will negatively impact the development of rice and the rice crop yield. In Sukoharjo District, in managing rice farming, most of them use deep-well water, irrigation channels, and reservoir water; the more difficulties they face in managing rice farming are pests. In some locations in Sukoharjo District where rice management farming still relies on rainwater, farmers find it difficult to manage rice plants because the season is difficult to predict due to climate change. In this case, the Inpari 32 rice variety has its advantages in rainfed locations; even this variety has difficulty in the rainy season because it will be hard to live if there is too much water flow.

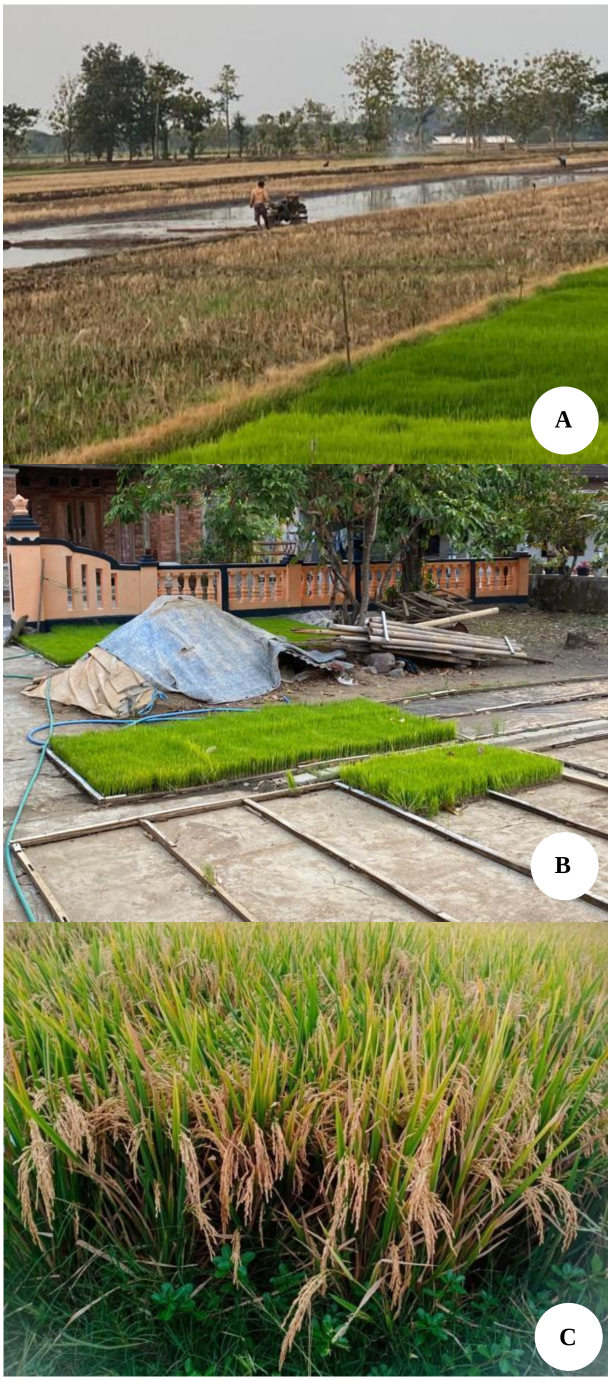

Figure 2. A. Rice field plowing with tractors in Sukoharjo District, Central Java, Indonesia, B. Farmers growing rice seedlings, C. Inpari 32 rice variety, is about to be harvested in rice fields

The Sukoharjo community manages the rice crops mostly using chemical fertilizers. However, some farmers managing rice farming use a mixture of chemical and organic fertilizers in the form of straw from the rice harvested-waste that has been burned and made into compost in a ratio of 50:50. According to some respondents, managing rice plants using chemical fertilizers will yield more satisfactory results than using organic fertilizers because the rice produced is higher than when using organic fertilizers. Therefore, most farmers in Sukoharjo District prefer to use chemical fertilizers in managing rice farming. However, the continuous use of chemical fertilizers and not balanced with organic fertilizers can reduce the quality of rice field soil (Pahalvi et al. 2021). In addition, chemical fertilizers are easier to obtain than organic fertilizers. The people of Sukoharjo District usually use chemical fertilizers, such as urea, ZA, and NPK. These chemical fertilizers are obtained from government subsidies distributed through farmer groups in each village.

There is no difference in the planting media used for each rice variety in Sukoharjo District; all rice varieties in this district can grow on the same planting media. Land management before planting rice is done by plowing the land using a tractor (Figure 2.A), but some still use the traditional way using a hoe. After plowing, the land is left for a few days to be irrigated, and then rice seedlings are planted using traditional methods. After the seedlings are planted, they are left for 10 days with flooded watering and then given fertilizer to increase the pH and herbicide to eradicate weeds. Previously, rice seedlings had been prepared separately by planting rice sprouts in seedling beds measuring around 1-2 x 3-5 m^2, covering 5% of the planting area. The rice sprouts are made from rice grains in buckets or sacks soaked/sprinkled with water and left moist for 2-3 days, then spread in seedling beds. Seedlings aged 2-3 weeks are ready to be planted in rice fields (Figure 2.B).

Based on this research, it can be concluded that although agriculture in Sukoharjo District is included in semi-modern agriculture, the community has TEK (Traditional Ecological Knowledge) which includes various varieties of rice and paddy fields. Javanese farmers in Sukoharjo District know 19 rice varieties, but prefer using Inpari 32 or in small quantities also the IR 64 rice varieties to manage their rice fields. Rice is widely used in various traditions, namely in *rasulan*, *bersih desa*, *kacar kucur*, *syukuran*, and *kenduren*. Many parts of the rice plant are also used, such as rice stems (straw), grain, husks, bran, and rice. A small part of the Sukoharjo community uses rice as an important part of cultural behavior, which is good for maintaining the biodiversity of rice varieties. The application of rice in every activity of the people of Sukoharjo District shows that there is a complex relationship between humans and nature.

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