BIODIVERSITAS
Volume 25, Number 10, October 2024
Pages: 3884-3898

ISSN: 1412-033X
E-ISSN: 2085-4722
DOI: 10.13057/biodiv/d251049

Diversity of flora and fauna in various forest ecosystem types of South Sorong District, Southwest Papua Province, Indonesia

OBED N. LENSE[1,♥], JIMMY F. WANMA[1], FRANCINA F. KESAULIJA[1], FADHILAH I. MANSYUR[1], ARMANSYAH K. RACHIM[1], KELIOPAS KREY[2], BEATRIX WANMA[3], REYNOLD KESAULIJA[4], DINOSIUS SIMANJORANG[5], FIKTOR SIMBIAK[6]

[1]Faculty of Forestry, Universitas Papua. Jl. Gunung Salju, Manokwari 98314, West Papua, Indonesia. Tel.: +62-986-211050, ♥email: obedlense@yahoo.com
[2]Faculty of Mathematics and Natural Sciences, Universitas Papua. Jl. Gunung Salju, Manokwari 98314, West Papua, Indonesia
[3]Department of Forestry, Universitas Ottow Geysler. Jl. Kotaraja Dalam, Vim, Abepura, Jayapura 99224, Papua, Indonesia
[4]Environment, Forestry, and Land Agency. Jl. Malaingkedi, Sorong 98412, Southwest Papua, Indonesia
[5]Sustainable Forest Management Center (BPHL) Region XVI. Jl. Drs Esau Sesa, Manokwari 98315, West Papua, Indonesia
[6]Biodiversity Research Centre of Universitas Papua. Jl. Gunung Salju, Manokwari 98314, West Papua, Indonesia

Manuscript received: 23 July 2024. Revision accepted: 29 October 2024.

Abstract. *Lense ON, Wanma JF, Kesaulija FF, Mansyur FI, Rachim AK, Krey K, Wanma B, Kesaulija R, Simanjorang D, Simbiak F. 2024. Diversity of flora and fauna in various forest ecosystem types of South Sorong District, Southwest Papua Province, Indonesia. Biodiversitas 25: 3884-3898.* The distribution of unspoiled natural conditions, uniqueness, and high biodiversity are not limited to conservation areas but also to production and protected forest areas and other land use areas in Southwest Papua Province, Indonesia. These forest ecosystems have high flora, fauna, and areas that are priority animal pockets whose home ranges reach and enter essential ecosystem areas. However, the need for such diverse information has been an issue in this region. Hence, a diversity study of vegetation, mammals, birds, reptiles, amphibians, and butterflies in various ecosystem types is needed. The six types of ecosystems, namely the alluvial lowland forest of Nakna, the lowland karst forest of Boldon, the lowland limestone forest of Wara, the alluvial swamp forest of Konda, the peat swamp forest of Nakna, and the mangrove forest of Konda, were targeted. The line-plotted method was used for vegetation. Direct observation on a 1,500 m line transect, the point count method, and the Visual Encounter Survey were employed to collect data from mammals, birds, reptiles, amphibians, and butterflies. Results indicated that the lowland limestone forest of Nakna and the lowland karst forest of Boldon consisted of the highest number of trees (532 and 373 trees ha^{-1}, respectively), species (56 and 52 species ha^{-1}, respectively) per unit area. Unique and endemic orchid species, including *Dendrobium transversilobum* J.J.Sm. and *Bulbophyllum septemtrionale* (J.J.Sm.) J.J.Sm., also exist in this region, adding to the wonder of the region's biodiversity. The research also discovered a total of 9 species of mammals, 52 species from 25 families of birds, 39 species of reptiles and amphibians, of which species *Litoria sanguinolenta* (Van Kampen, 1909) is a new record to the region and 58 species of day butterflies from the Papilonoidea superfamily. Several key species of flora and fauna in this region require special attention as they are in alert status, which may require intervention to maintain their existence in nature so that they do not disappear or even become extinct.

Keywords: Endemic species, flora and fauna, forest ecosystem types, South Sorong District, species diversity

Abbreviations: ALLF-N: Alluvial Lowland Forest of Nakna; ASF-K: Alluvial Swamp Forest of Konda; LLKF-B: Lowland Karst Forest of Boldon; LLLF-W: Lowland Limestone Forest of Wara; MgF-K: Mangrove Forest of Konda; PSF-N: Peat Swamp Forest of Nakna

INTRODUCTION

Southwest Papua Province, Indonesia, consists of 28 conservation areas covering an area of 1,717,980.74 Ha, which is managed by the West Papua Natural Resources Conservation Center (Fatem et al. 2020a). High levels of biodiversity are present at the ecosystem, population, and species levels, as well as areas that are priority animal pockets whose home ranges reach and enter essential ecosystem areas (Fatem et al. 2020b). The distribution of high biodiversity areas is not limited to conservation areas but also to other forest areas (production forests and protected forests) and land use areas (APL). Activities are needed to identify areas with high biodiversity value, especially inventory and verification to monitor and safeguard high biodiversity areas outside the conservation area. The results of this identification can undoubtedly contribute to sustainable development in West Papua Province and Southwest Papua Province. In the Medium-term Development Plan for 2020-2024, as stated in Presidential Regulation of the Republic of Indonesia Number 18 of 2020, it is targeted that 70 million hectares will be verified as having high biodiversity value.

Furthermore, in the strategic plan matrix of the Ministry of Environment and Forestry for 2020-2024, as stated in the Regulation of the Minister of Environment and Forestry of the Republic of Indonesia Number: P.16/Menlhk/Setjen/Set.1/8/2020 concerning the Strategic Plan of the Ministry of Environment and Forestry for 2020 2024, Directorate General of Natural Resources and Ecosystem Regarding Environmental Quality, it is targeted to carry out inventory and verification of areas with high biodiversity value outside conservation areas covering an area of 43 million Ha. This target is expected to be achieved in 2024 and carried out in a participatory manner. Indicative mapping of regions with high biodiversity potential outside the West Papua conservation area carried out by the Ministry of National Development Planning (PPN/Bappenas) of Indonesia identified a potential area of 2,373,250.87 Ha. *Balai Besar Konservasi Sumber Daya Alam* (BBKSDA) West Papua, as a technical implementation unit for managing conservation areas in West Papua and Southwest Papua, is assigned and functions to carry out inventory and verify potential high biodiversity values outside conservation areas.

Southwest Papua Province is located in the western part of Papua Island, a division of the previous West Papua Province. Southwest Papua Province is known for its unspoiled natural conditions, uniqueness, and high biodiversity that spread across various natural ecosystems on land and in water (Maturbongs et al. 2014; Shaverdo et al. 2016; Sillanpää et al. 2017; Fatem et al. 2020b; Pattiselanno et al. 2022). This region has been targeted as having a high biodiversity value outside the nature reserve, nature conservation, and hunting park area. This refers to the Regulation of the Director General of Conservation of Natural Resources and Ecosystems (KSDAE) No: P.8/KSDAE/SET.3/KUM.1/11/2020 concerning Technical Instructions for Inventory and Verification of Areas with High Biodiversity Value Outside Nature Reserve Area, Nature Conservation Area, and Hunting Park. The analysis results referring to the Director General of KSDAE above show that Southwest Papua Province, including South Sorong District, consists of high biodiversity values. Even though identification has been carried out, this information is hoped to be integrated into regional spatial plans and other development plans in this province. This effort aligns with applicable national policy, namely Instruction of the President of the Republic of Indonesia Number 1 of 2023 concerning Mainstreaming Biodiversity Conservation in Sustainable Development, where regions are mandated to ensure the implementation of biodiversity management in regional planning and development. Hence, this study aimed to investigate the diversity of vegetation, mammals, birds, reptiles, amphibians, and butterflies in various ecosystem types in the South Sorong District region, Southwest Papua Province, Indonesia.

MATERIALS AND METHODS

Study area

The study area was located in South Sorong District, which is under the administrative control of Southwest Papua Province, Indonesia (Figure 1). The study was conducted in 6 different ecosystem types, as shown in Table 1.

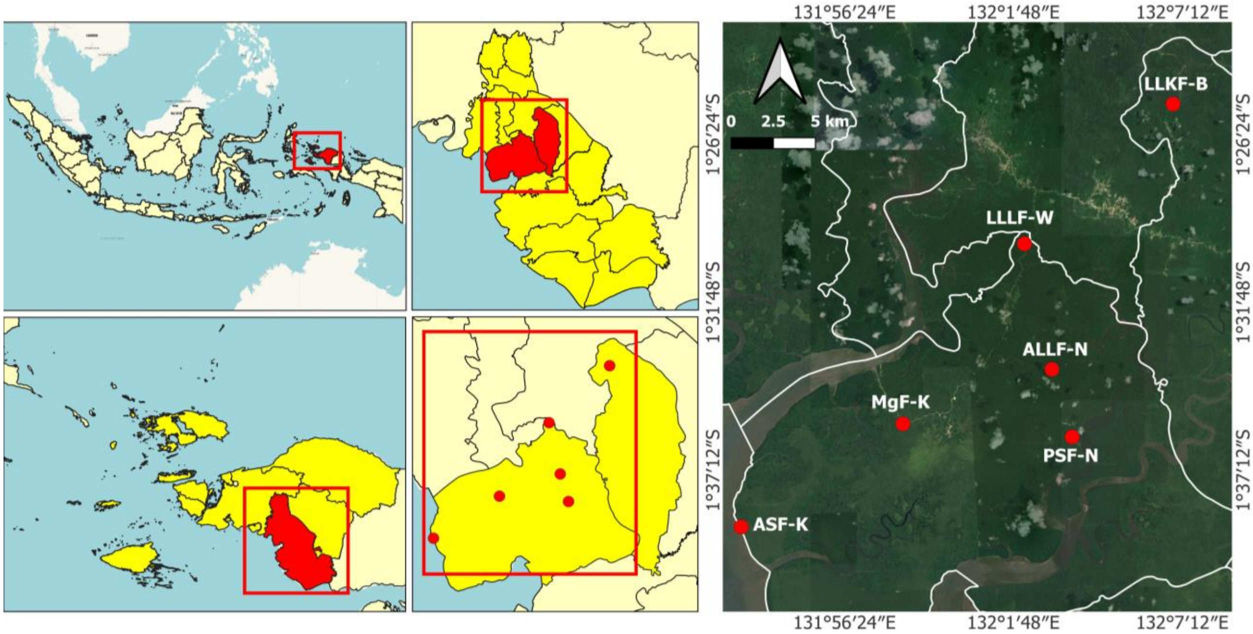

Figure 1. Study area in South Sorong District, Southwest Papua Province, Indonesia

Table 1. Six forest ecosystem types have been the target of the study in South Sorong District, Southwest Papua Province, Indonesia

Ecosystem	Coordinate	Abbreviation
Alluvial lowland forest of Nakna	132° 3' 1.988" E, 1° 33' 56.458" S	ALLF-N
Lowland karst forest of Boldon	132° 6' 54.395" E, 1° 25' 23.912" S	LLKF-B
Lowland limestone forest of Wara	132° 2' 9.278" E, ° 29' 53.888" S	LLLF-W
Alluvial swamp forest of Konda	131° 53' 5.983", E 1° 39' 0.733" S	ASF-K
Peat swamp forest of Nakna	132° 3' 40.898" E, 1° 36' 6.990" S	PSF-N
Mangrove forest of Konda	131° 58' 16.187" E, 1° 35' 41.604" S	MgF-K

The study was conducted from October 2023 to January 2024. The equipment used included a Global Positioning System (GPS), Bushnell 10 × 25 wide-angle binoculars, a long-range lens camera, trap cameras, a voice recorder, measuring tape, an observation tally sheet, stationery, a weight measuring instrument (scale) with an accuracy of 0.5%, cutting scissors, and a sample container (locked plastic bag/paper bag).

Procedures

The line-plotted method was used for the vegetation analysis (Valbuena et al. 2012; Threlfall et al. 2016; Veenendaal et al. 2018). Two line transects, with a minimum distance between plots of 300 m, were placed in each ecosystem-type (Robiansyah 2018). Five plots of 20 m × 20 m were laid at each transect. Vegetation analysis was performed using a quadratic sampling technique with a size of 20 m × 20 m for the tree category, 10 m × 10 m for the pole category, 5 m × 5 m for the sapling category, and 2 m × 2 m for the seedlings category (Villanueva and Buot 2018; Ardiyaningrum et al. 2021). Within each plot, seedlings and saplings were counted, whereas poles and trees with Diameter at Breast Height (DBH)≥10 cm were counted and measured for DBH and identified by an expert (Fiktor Simbiak; Biodiversity Research Centre of Universitas Papua (UNIPA), Manokwari, West Papua, Indonesia) in the field to genus level, or to species level where possible. Vouchers were collected for unidentified species and deposited in Herbarium Manokwariense of Research Center for Biodiversity, UNIPA, Manokwari, West Papua, Indonesia, for further identification. The names of species, abundance, diversity, richness, and dominance were observed. The structure of forest trees, species composition, functions, and benefits of vegetation were also covered (Threlfall et al. 2016; Robiansyah 2018; Murdjoko et al. 2021; Nero 2021).

Data collection on mammal species was done by direct observation on a 1,500 m line transect. The data collected was based on directly observing mammals within the observation path. The trail transect method was also employed to collect data on mammal species using trail cameras, spotlights, mist nets, and Elliot traps (Pattiselanno et al. 2019; McCullough et al. 2023).

Bird species were collected using the point count method (Klingbeil and Willig 2015; Martin-Garcia et al. 2023). Bird species identification and the terminology of family and species were based on Beehler and Pratt (2016). Bird voice was recorded and identified using the Xeno Canto website (Sarasa et al. 2017; Ortega and Sarria-Paja 2022). Observations were conducted twice: between 05.30 and 08.30 am and between 4.00 and 6.00 pm. Species, the number of each species, and time were recorded (Klingbeil and Willig 2015).

Data recorded for reptiles including species, number of each species found, sex (if known), age class (if known), which consist of adults and juveniles, distribution, time of encounter, habitat (terrestrial or aquatic), sample size of each species, activity at the time of discovery and position of the animal found in its habitat (horizontal and vertical position relative to the body of water) (Heyer et al. 2014; Kraus 2015; Sabath et al. 2016; Taylor et al. 2021). Field observation for reptiles was conducted at night (7.30-10.30 pm) on a 1,000m long transect. Visual Encounter Survey (VES), a modification of the free roam and belt transect methods, was employed in collecting reptile data (Heyer et al. 2014; Almeida-Gomes et al. 2016; Halstead et al. 2018; Gautam et al. 2020). This method is carried out by exploring various bodies of water and recording the types found and the conditions of the target area. The observed individuals were then captured and placed in labelled plastic. Several captured reptiles and amphibians were then preserved for initial identification. Samples of reptiles and amphibians were recorded for their morphological characteristics and body size and then preserved using 70% alcohol. A flashlight was used to observe amphibians and reptiles' activities in their original shelter, including holes in the ground, tree branches or leaves, forest litter, under or in gaps of rocks, and water puddles. Data on species richness and abundance was collected during mornings as reptiles were basking and feeding along a path, in a plot, along the side of a river, around the edge of a pond.

For butterfly species, the direct-seeing method was used (Dennis et al. 2017; Bro-Jørgensen et al. 2019). Species, species number, as well as characteristics of the habitat of each target area, were collected using a sweeping net (insect net), GPS (Global Positioning System), cork, tweezers, pilot paper, plastic box, writing equipment, insect pins (insect needles), digital camera, and butterfly identification guide book. Butterflies' samples were collected using a killing bottle (poison bottle), syringe, potassium cyanide, and 5% ammonia. Coordinates, altitude, habitat types, dominant plants, and habitat damage at the location were also recorded. Butterfly samples were captured on sunny days between 08.00 am and 3.00 pm. Unidentified butterfly species were taken for further identification in Henk's Insect Laboratory vans Mastrigt in Jayapura, Papua.

Data analysis

Vegetation data analysis was performed by calculating the Importance Value Index (IVI). The IVI calculation intends to identify common species and plays an important role in shaping ecosystem types. The following equations calculate the IVI (Komara et al. 2016; Addi et al. 2020; Elfrida et al. 2020):

$$Density\ (Ds) = \frac{Individual\ number\ of\ respective\ species}{Total\ area\ of\ the\ plot}$$

$$Relative\ Density\ (RDs) = \frac{Density\ of\ respective\ species}{All\ species\ density}\ x\ 100\%$$

$$Frequency\ (F) = \frac{Observation\ plot\ number\ where\ respective\ species\ existed}{Total\ number\ of\ observation\ plot}$$

$$Relative\ Frequency\ (RF) = \frac{Frequency\ of\ respective\ species}{All\ species\ frequency}\ x\ 100\%$$

$$Dominance = \frac{Basal\ area\ number\ of\ respective\ species}{Total\ area\ of\ the\ plot}$$

$$Relative\ Dominance\ (RD) = \frac{Dominance\ of\ respective\ species}{All\ species\ dominance}\ x\ 100\%$$

$$Importance\ Value\ Index\ (IVI) = RDs + RF + RD$$

The diversity and evenness of flora and fauna were calculated using the Shannon-Wiener Diversity Index and

Pielou Evenness Index model (Agbelade et al. 2017; Robiansyah 2018; Tu et al. 2020; Zhou et al. 2021), as illustrated below:

$$H = -\sum Pi \ln Pi$$

Where:

H : Shannon-Wiener Diversity Index

Pi : Relative proportion (n/N) of the individual of one particular species found. It entailed dividing (n) the number of an individual species by the total number of all species individual numbers (N) found in a particular environment.

Ln Pi: Natural logarithm (LN) of the value Pi

Σ : Summation of the outputs with the final value multiplied by negative one (- 1)

The Evenness Index of respective ecosystems was determined using the following formula:

$$E = \frac{H}{HMax}$$

Where:

E : The determined Evenness Index

H : The Shannon-Wiener Diversity Index

HMax : The natural logarithm of the number of specific categories/types of species in the sampled ecosystem LN(n).

The species abundance, diversity, richness, and evenness of flora and/or fauna were statistically analysed using SPSS version 29 software. After verifying the additivity (Tukey's test) and homogeneity of variance (Bartlett's test) of the data, Analysis of Variance (ANOVA) was carried out using a significance level of 0.05.

RESULTS AND DISCUSSION

Flora

Vegetation structure

Results indicated that the LLKF-B has the highest number of trees (532 trees ha^{-1}) per unit area, followed by the LLLF-W (373 trees ha^{-1}) (Figure 2). This figure also shows that the other four ecosystem types have no significant difference in species number per unit area which is ranging from 147 trees ha^{-1} to 256 trees ha^{-1}. These numbers have indicated that tree density in all ecosystem types remains well-maintained (Naidu and Kumar 2016; Wildi 2017). Except for ALLF-N, the dried lowland ecosystem (LLKF-B and LLLF-W) tends to have much higher tree abundance than that in the wet lowland ecosystem (PSF-N, MgF-K, and ASF-K). Furthermore, regarding species abundance, the LLLF-W and the LLKF-B presented the highest number of species, 56 species ha^{-1} and 52 species ha^{-1}, respectively (Figure 2).

Figure 2 shows that the rest of the ecosystem types have no significant difference in genera number per unit area, which ranges from 12 species ha^{-1} to 29 species ha^{-1} ($p \leq 0.05$). In terms of diameter classes, the results indicated that trees with diameter classes of 10-20 and 20-30cm with average species abundance of 192 species ha^{-1} and 177 species ha^{-1}, respectively, had been a dominant vegetation growth phase in all six ecosystem types (Figure 3). More than 65% of trees in this region had DBH ≤30 cm. The pattern of DBH classes of the tree species in this region's inverted J-shaped distribution indicates a forest dominated by young trees; only a few trees with DBH more than 60 cm, including *Metroxylon sagu* Rottb. and *Fagraea racemosa* Jack.

Species composition (tree phase)

The results of the study show that there are 23 species of tree phase found in LLLF-W in which *Anisoptera thurifera* (Blanco) Blume., *Vatica rasak* (Korth) Blume, *Itoa staphii* (Koord.) Sleumer, and *Hopea papuana* Diels, are the dominant species and share almost similar Important Value Index (IVI) of 35.9%, 28.7%, 27.6%, and 25.6%, respectively. It is slightly different from LLKF-B in which of the 17 species, *V. rassak* is the top dominant species, followed by *Calophyllum inophyllum* L., *I. staphii*, and *Artocarpus integer* (Thunb.) Merr. with IVI of 108,9%, 24,3%, 20.9%, and 20.8%, respectively. The same genera of *Artocarpus* are also still presented and are a dominant species in ALLF of Nakna where *Rhus lamprocarpa* Merr. & L.M.Perry has been the highest dominant species (IVI = 63.9%), followed by *Alphitonia macrocarpa* Mansfield, *Artocarpus odoratissimus* Blanco, and *Macaranga tessellata* Gage with IVI of 35.8%, 34.6%, and 33.8%, respectively.

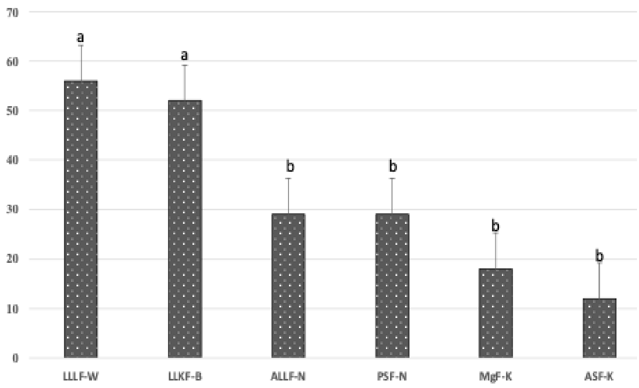

Figure 2. Species abundance in each ecosystem type of of South Sorong District, Indonesia. Ecosystems that share letters have means that do not differ significantly ($p \leq 0.05$)

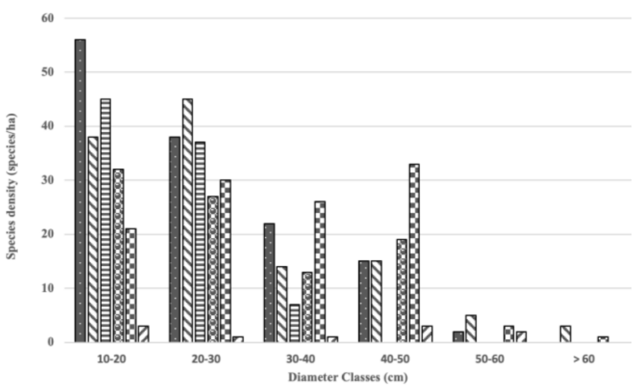

Figure 3. Distribution diameter classes of trees in each ecosystem type in the South Sorong District, Southwest Papua Province, Indonesia

Furthermore, in wetland ecosystems, including PSF of Nakna, *M. sagu* is the top dominant species (IVI = 74.4%), followed by *M. tessellata, A. odoratissimus*, and *Pimelodendron amboinicum* Hassk. with IVI of 57.7%, 26.04%, and 25.0%, respectively. Interestingly, two genera of *Artocarpus* and *Macaranga* are still present in the wetland ecosystem. Similar to PSF of Nakna and ASF of Konda, *M. sagu* is also the top dominant species (IVI = 268.9%%), followed by *Sonneratia alba* Sm. and *Hibiscus tiliaceus* L. with IVI of 21,7% and 9.4%, respectively. Finally, in the mangrove ecosystem of Konda, *Xylocarpus granatum* J.Koenig has been the top species (IVI = 130.9%), followed by *Bruguiera gymnorhiza* (L.) Lam., *Rhizophora apiculata* Blume, and *Rhizophora mucronata* Lam., with IVI of 113.3%, 19.5%, and 13.9%, respectively.

Diversity and population dynamic

Diversity in each ecosystem type was calculated using the Shannon-Wiener Diversity Index to measure the diversity or variety of species in an ecological community (Agbelade et al. 2016, 2017; Naidu and Kumar 2016; Omayio and Mzungu 2019; Monarrez-Gonzalez et al. 2020). This method was named after two scientists, Claude Shannon and Warren Weaver, who developed information theory (Roswell et al. 2021). The study indicated that lowland primary forests in Wara and Boldon consistently presented the highest diversity values, ranging from 2.1 to 3.2 (Figure 4). Furthermore, as shown in Figure 5, all growth phase species are proportionally presented in each ecosystem type, with seedling and tree phases sharing a more significant proportion of abundance than other growth phases in all ecosystem types of the study area. This indicates that these ecosystem types have a good population dynamic that will support the regeneration processes.

Special flora

Based on the results of direct observation around the study area, the plant types that originate and are found in this area can be included in the categories of native plant types, endemic plant types, rare or threatened plant types, and plant types or multi-purpose trees (Figure 6).

Fauna

Mammals

Diurnal mammal observations were carried out simultaneously with bird observations in the morning and evening, while nocturnal mammal observations were carried out at night. Mammal species were also collected using trap cameras installed at 12 points in 5 ecosystems. Interviews with residents were also conducted to enrich information on mammal species.

Table 2 shows nine species of mammals found in this region. *Sus scrofa* (Linnaeus, 1758), or wild boar, is the most common type of mammal found in the study area of South Sorong. Wild boars were found in almost all ecosystem types through direct observation, voice recognition, footprints, and community interviews.

Birds

A total of 52 species of 25 families were invented. Forty-six species were found by direct observation and voice recognition, whereas six were described based on interviews with residents in the four ecosystem types.

Table 2. Mammal species found in the study area of South Sorong District, Southwest Papua Province, Indonesia

Species	Family	IUCN's status
Cercartetus caudatus (Milne-Edwards, 1877)	Burramyidae	LC
Pteropus sp.	Pteropodidae	LC
Sus scrofa (Linnaeus, 1758)	Suidae	LC
Dorcopsis muelleri (Lesson, 1827)	Macropodidae	LC
Phalanger orientalis (Pallas, 1766)	Phalangeridae	LC
Phalanger gymnotis (Peters & Doria, 1875)	Phalangeridae	LC
Spilocuscus maculatus (É.Geoffroy Saint-Hilaire, 1803)	Phalangeridae	LC
Zaglossus bruijnii (Peters & Doria, 1876)	Tachyglossidae	CR
Echymipera kalubu (Fischer, 1829)	Peramelidae	LC

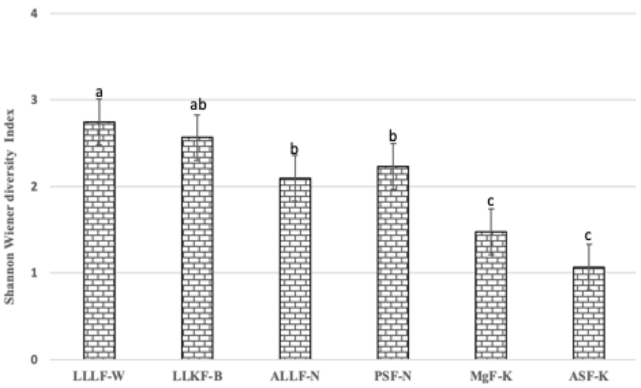

Figure 4. Shannon-Wiener Diversity Index is at various phases for all ecosystem types in the South Sorong District, Indonesia. Ecosystems that share letters have means that do not differ significantly (p≤0.05)

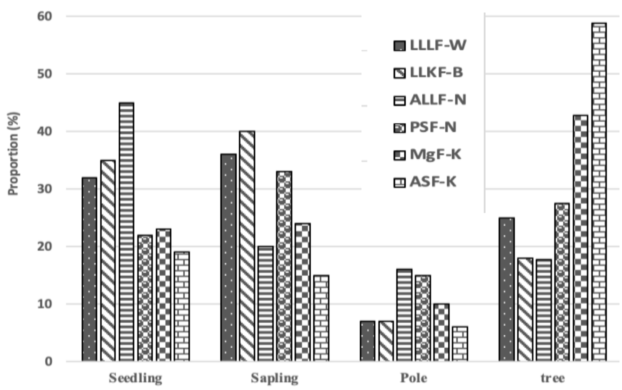

Figure 5. The proportion of seedlings, saplings, poles, and trees in various habitat types of South Sorong District, Indonesia

A B C

Figure 6. Several endemic species were found in the study area of South Sorong District, Indonesia. A. *Dendrobium transversilobum* J.J.Sm., B. *Bulbophyllum foetidum* Schltr., C. *Bulbophyllum septemtrionale* (J.J.Sm.) J.J.Sm. (Photographs: Jimmy Wanma)

Interestingly, as shown in Figure 8, ASF and Mgrv of Konda presented the highest average diversity index of 2.6 and 2.7, respectively. *Collocalia esculenta* (Linnaeus, 1758) and *Mayrimunia tristissima* (Wallace, 1865) are the most dominant species in all four ecosystem types. The weather can influence this number at the time of observation. The survey was conducted after rain, which caused more birds to be found.

Herpetofauna

The research indicates that a total of 43 species of herpetofauna. Eleven species of frogs, including Hylidae, Microhylidae, and Ranidae family, were found. Meanwhile, there are 32 species of reptiles recorded covering eight families, namely Agamidae, Scincidae, Geckonidae, Varanidae, Colubridae, Pythonidae, Boidae, and Elapidae. All species of frogs have been grouped according to their taxon to obtain a species richness profile per taxon as a biological indication of which taxa most commonly inhabit the forest ecosystem in the South Sorong District. The richness of the lizards reached 51.28%, surpassing the frogs and snakes taxon (Figure 9).

The diversity index calculation of frogs in the South Sorong Forest is in the medium category with a diversity index value of 2.20. Meanwhile, the reptile taxon reached the high category with a diversity index value of 3.01. It is essential to maintain the ecosystem functions at all sampling locations so that the level of diversity of frog and reptile species is maintained to that level of diversity index. The results also show different relative population numbers of each species, ranging from rare to abundant (Figure 10). The degree of scarcity of the frog population (55%) is lower than that of reptiles (68%). Frogs are more abundant (68%) than reptiles, which only reach 7%. In addition, giant tree frogs of *Litoria sanguinolenta* (Van Kampen, 1909), endemic to West Papua (IUCN 2019b) and the New Guinea bush frog of *Asterophrys turpicola* (Schlegel, 1837), endemic to New Guinea (IUCN 2019a), are rarely found in the study area. The South Sorong Forest area is a natural habitat for several protected and endemic herpetofauna species. The protected reptile species in this forest area have relatively rare population abundances.

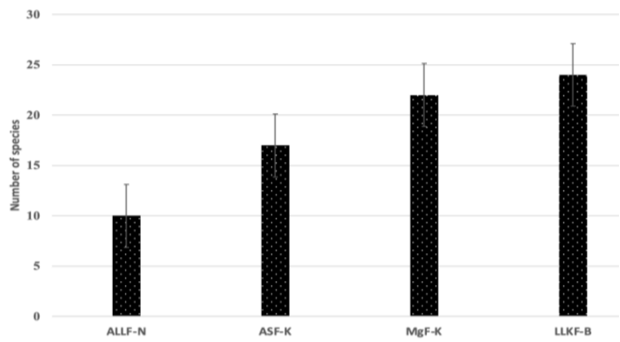

Figure 7. The bird species richness is present in each of the four ecosystem types in South Sorong District, Indonesia. Ecosystems that share letters have means that do not differ significantly (p≤0.05)

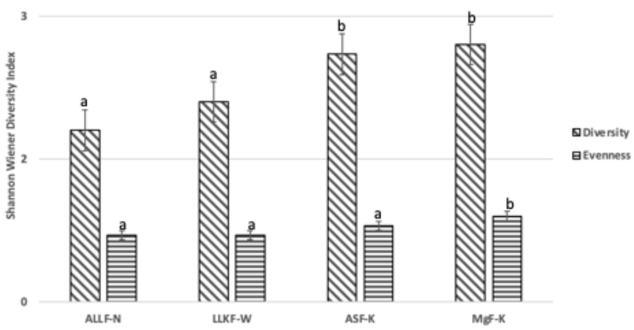

Figure 8. Diversity and evenness of bird species in four ecosystem types in the South Sorong District, Indonesia. Diversity values of each ecosystem that share letters have means that do not differ significantly (p≤0.05)

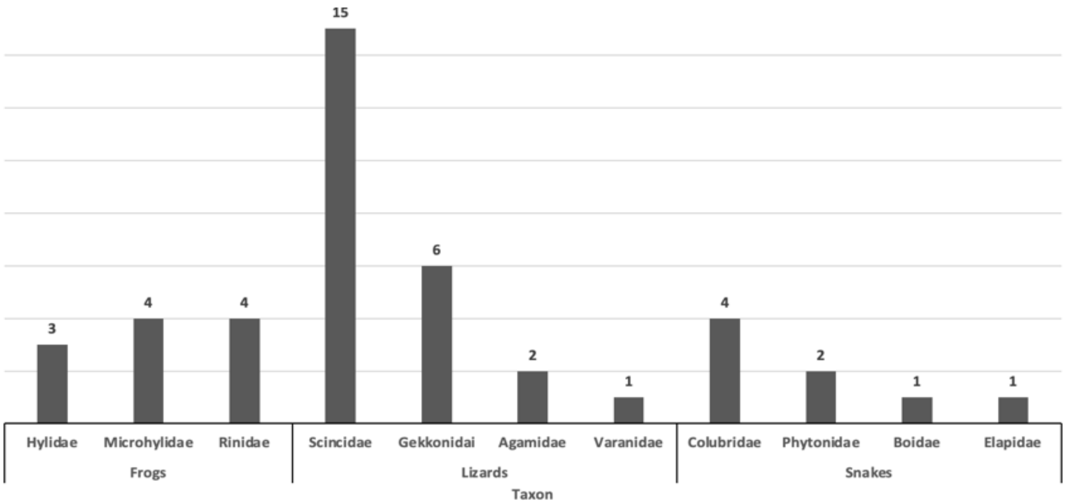

Figure 9. Species of frogs, lizards, and snakes of each family found in the study area of South Sorong District, Indonesia

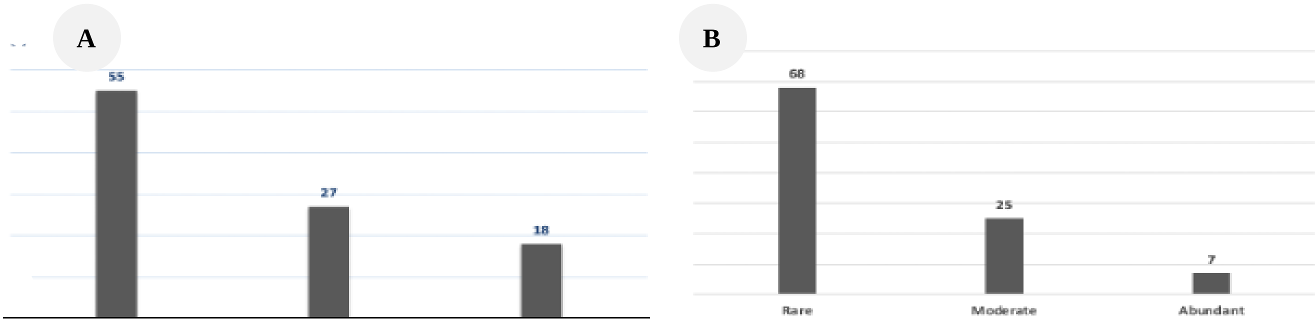

Figure 10. The proportion (%) of the degree of species' scarcity of: A. Frogs; and B. Reptiles in the study area of South Sorong District, Indonesia

Figure 11 demonstrates that the species accumulation lines from the four families are still in flux, with new species added until the last day of observation. Our previous studies in Arfak Mountains District, South Manokwari District, and Tambrauw District revealed the discovery of 105 butterflies in the Papilionidae superfamily invented within ten days of observation. This suggests that with an extended sampling period, the number of diurnal butterfly species in South Sorong District could potentially exceed 80, underscoring our research's significant impact and potential in entomology.

Day butterflies

The research shows that this area has 58 species of day butterflies from the Papilionoid superfamily. The ALLF-N presented the highest number of species (26 species), followed by PSF-N, LLLF-W, MgF-K, LLKF-B, and ASF-K with number of species 19,17,17,13, and four species, respectively. Furthermore, butterflies of the Nymphalidae family have the highest number of species (27 species), followed by butterflies from the Lycaenidae, Pieridae, and Papilionidae families, with number of species of 17 species, nine species, and five species, respectively. Furthermore, Figure 12 shows that PSF-N has the highest diversity index (3.76). ALLF-N, LLLF-W, MgF-K, and LLKF-B shared similar diversity indexes, ranging from 2.3 to 3.0.

Discussion

Flora

Vegetation structure. Sago and mangrove ecosystems presented fewer plant species than other lowland forest types. This is because the substrates where sago grows and where mangroves grow are very different and require the adaptability of certain plants, an extraordinary feat of nature (Tomlinson 2016; Karim 2021). Interestingly, the pattern of DBH classes of the tree species in this region's inverted J-shaped distribution indicates a forest dominated by young trees. Only a few trees with DBH more than 60 cm, including *M. sagu* and *F. racemosa*. This pattern suggests a good potential for the reproduction and recruitment of forests as well as the development of secondary forests (Robiansyah 2018; Geng et al. 2019; Ardiyaningrum et al. 2021). Likewise, almost all ecosystem types do not have trees with a diameter class of >60 cm. This may be caused by small-scale logging activities in the lowland primary forests, especially in the LLLF-W, ALLF-Na, and PSF-K. Figure 3 also shows that ASF-K has the least species diversity in all diameter classes, as *M. sagu* and several mangrove species dominate this ecosystem.

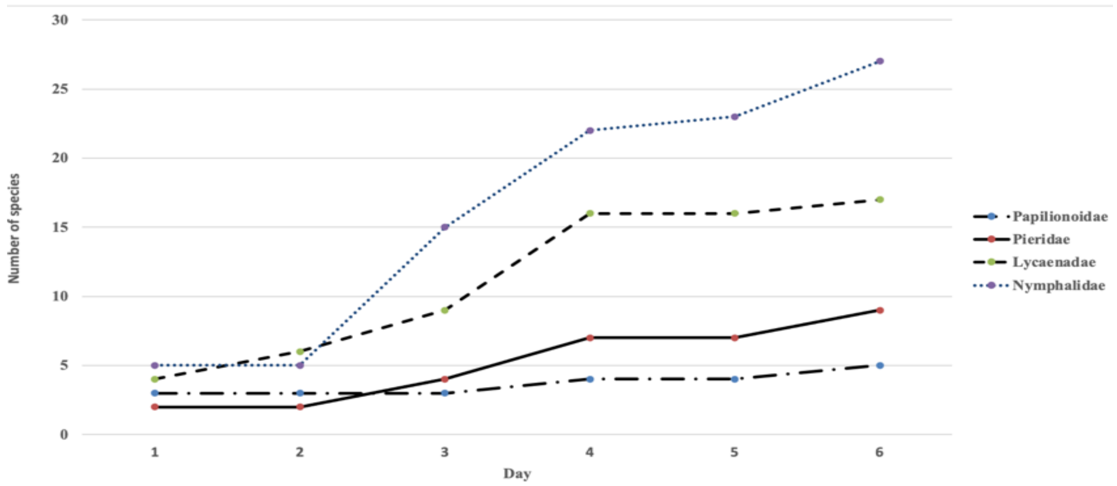

Figure 11. Number of butterflies per family per day found in the study area of South Sorong District, Indonesia

Table 3. Endemic and conservation status of frogs and reptiles found in the study area of South Sorong District, Indonesia

Spesies	Endemic Papua	Permen KLHK No. 106 (2018)	IUCN (2023)	CITES
Reptile				
Cryptoblepharus novaeguineae (Mertens, 1928)	+	-	LC	-
Chondropython viridis (Schlegel, 1872) (Figure 14)	-	+	LC	II
Varanus indicus (Daudin, 1802)	-	+	LC	II
Candoia aspera (Günther, 1877)	+	-	LC	II
Leiopython albertisii (Peters & Doria, 1878)	+	-	LC	II
Total	3	2	5	4
Frogs				
Asterophrys turpicola (Schlegel, 1837)	+	-	LC	-
Litoria infrafrenatus (Günther, 1867)	-	-	LC	-
Papurana daemeli (Steindachner, 1868)	+	-	LC	-
Papurana papua (Lesson, 1829)	+	-	LC	-
Cornufer papuensis (Meyer, 1875)	+	-	LC	-
Cornufer punctatus (Peters & Doria, 1878)	+	-	LC	-
Total	5	0	6	0

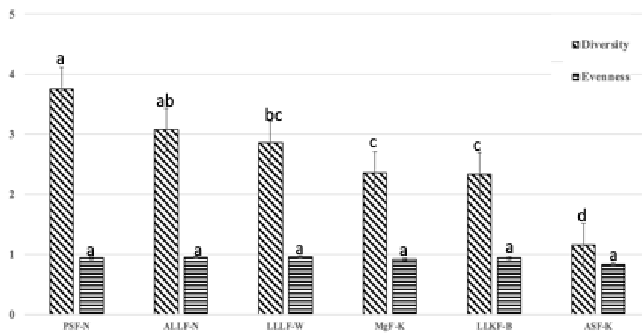

Figure 12. Diversity and Evenness of day butterfly superfamily Papilionidae found in each South Sorong District, Indonesia ecosystem type. The diversity and evenness values of each ecosystem that shares letters mean they do not differ significantly (p≤0.05)

Species composition (tree phase). *Vatica* genus is a plant genus belonging to the Dipterocarpaceae family. This genus includes several tree species, mainly found in the tropical forests of Southeast Asia. Trees in the *Vatica* genus produce high-quality wood. This wood is often used in the wood industry for various purposes, including construction, furniture, and wooden craft items (Ali et al. 2021; Teong et al. 2021). Several plant components of the genus *Vatica* have potential value in traditional medicine. Some local communities may use extracts or parts of certain plants for medicinal purposes (Robiansyah 2018). Despite these advantages, it is essential to note that excessive deforestation and other environmental changes may threaten the sustainability of the *Vatica* genus. Conservation and sustainable forest management are vital to ensuring that the benefits of this genus can be maintained in the long term while protecting biodiversity and forest ecosystems.

Furthermore, due to its "sasi" forest status, *M. sago* species dominate the tree growth phase at PSF-N, followed by *M. tessellata* and *A. odoratissimus*. The average number of sago trees is 38 individuals/ha. Sago is sometimes considered environmentally friendly because it can be grown without pesticides or synthetic fertilisers. Using sago can also reduce pressure on natural forests if managed well. Technological development and innovation can bring new potential in the use of sago. For example, developing functional food or beverage products from sago can be a new business opportunity. Despite these advantages, it is essential to note that sago cultivation can pose challenges, especially in environmental management and biodiversity protection. Therefore, sustainable and science-based management of sago cultivation is critical to ensure that the positive benefits of this plant can continue without harming the environment.

Sago trees can grow in less fertile soil and tolerate harsh environmental conditions, as seen at the survey location in Konda. This makes it suitable for growing in areas that do not support other food crops. Local communities in South Sorong often cultivate sago, which can positively contribute to social and economic justice. Sago is a source of income for many farmers where this plant grows. Furthermore, the *Rhus* genus belongs to the Anacardiaceae family. *Rhus* is a genus of plants that includes several plant species, and some of these may have economic value or use in traditional medicine. However, it is rare to find local people using this type of plant for this purpose. Some *Artocarpus* species can be used in agroforestry practices, helping to increase soil productivity and providing beneficial shade for other plants. The mangrove of Konda offers a critical habitat for various biological species, including fish, birds, shellfish, and other marine animals. This supports biodiversity in coastal ecosystems. Mangrove trees also can capture and store carbon. Therefore, mangrove forests play a role in mitigating climate change by helping reduce the amount of carbon in the atmosphere (Arifanti et al. 2022; Rahim et al. 2024). Mangrove forests that are well maintained can be an attraction for ecotourism. This provides opportunities for environmental education and empowering local communities. It is important to remember that mangrove forests can face threats from human activities, such as illegal logging, land use change, and pollution. Therefore, the preservation and sustainable management of mangrove forests is essential to ensure that these benefits can continue to be enjoyed by the community and the environment as a whole.

Diversity and population dynamic. The diversity and richness of forest vegetation have an essential role in maintaining ecosystem balance and providing lifelong benefits. Forests with high levels of diversity are often more resistant to disturbance and environmental change. They can provide various ecosystem services such as water supply, carbon sequestration, and habitat for multiple species (Forrester and Bauhus 2016; Geng et al. 2019; Ardiyaningrum et al. 2021). This demonstrates that succession has occurred in which new vegetation replaces old vegetation due to various disturbances in these forest areas (Arroyo-Rodríguez et al. 2017; Powers and Marín-Spiotta 2017; Matsuo et al. 2021). Meanwhile, the diversity value is low in forests that tend to be homogeneous, such as the MgF-K and ASF-K ecosystems, ranging from 0.4 to 2.0. These ecosystems are suspected to be dominated by certain mangrove and sago palm species that can grow in less fertile soil and tolerate harsh environmental conditions (Yamamoto et al. 2020; Ehara et al. 2021; Karim 2021). This makes it suitable for growing in areas that may not support other food crops. Figure 4 also shows that LLKF-B, ALLF-N, and PSF-N shared similar diversity indexes. Diversity helps maintain ecological balance by regulating animal and plant populations (Forrester and Bauhus 2016; Geng et al. 2019; Ardiyaningrum et al. 2021). Changes in species composition can affect food chains and interactions between species. In addition, species diversity often reflects cultural heritage and local wisdom, and various cultures usually have traditional knowledge about using and conserving natural resources (Fatem et al. 2020b). Therefore, maintaining and understanding biodiversity is a challenge and priority for the conservation and sustainable management of natural resources. Reasonable conservation efforts can ensure that current and future generations can continue enjoying biodiversity's benefits.

Furthermore, abundant seedlings and saplings indicate a healthy regeneration process. In contrast, the high number of tree stages suggests the availability of parent trees as seed sources for regenerating disturbed forests in this area (Potter et al. 2017; De Medeiros-Sarmento et al. 2021). Each type of ecosystem found in the study area has a specific capacity, influencing how many plants can succeed in each ecosystem. Changes in environmental carrying capacity can trigger changes in population dynamics. The study of population dynamics of forest vegetation has direct implications for forest conservation and management practices. Understanding how plant populations move can help select effective conservation and management strategies. Forest vegetation population dynamics include changes in the composition and structure of plants in a forest over time. This involves factors such as plant growth, reproduction, death, and regeneration. The study of population dynamics of forest vegetation is essential for understanding how plant communities change and adapt to environmental changes and other factors (Soliveres et al. 2015; Franklin et al. 2016; Thom et al. 2017). The plant life cycle, including phases such as vegetative growth, reproduction, and senescence, contributes to population structure. Population structure can include the age and size distribution of plants and the process of changing the composition and structure of forest vegetation over time. Succession can occur through various stages, from primary succession after significant disturbances to secondary succession after minor disturbances (Arroyo-Rodríguez et al. 2017; Powers and Marín-Spiotta 2017; Matsuo et al. 2021). All of these processes occur in the South Sorong forest ecosystem types, which are the dynamic processes of the forest itself.

Special flora. The unique species of *D. transversilobum* is a miniature epiphytic plant that grows abundantly on mossy tree trunks in warm places around 50-500 meters above sea level (masl). This orchid has an erect stem that gradually widens until it reaches a peak. It ends in one leaf, apical, inner conduplicate slightly rotted at the top, oval leaves, and some bloom in autumn; occasionally, the flowers open in sequence. The flowers of this orchid were approximately 8 mm. This type of orchid, called lithophytic or terrestrial orchid, is found mainly in Papua and New Guinea and grows well in forested hillsides (Ormerod and

Juswara 2022). It is often seen on tree trunks, rocks, and the ground at 400 to 1,000 masl. It has cylindrical and oval pseudobulbs 15-20 cm long and ends in an apical, erect, elliptical, acuminate, and narrow leaf. The flowering inflorescence is ovate and acuminate but does not grow back or open well, and foul-smelling flowers are limited to the top of the spike. Flowers measure approximately 2.5 cm. Furthermore, *B. septemtrionale* is found in Maluku, Papua, and Papua New Guinea in lowland forests at a height of about 40 meters as an epiphytic orchid that grows hot and blooms in late spring with a length of 44 cm, which is equipped with about six sheaths crowded along the flower stalk (Ma et al. 2024).

Fauna

Mammals. *S. scrofa*, or wild boar, has been a primary meat source for sale and sustenance; this species has been heavily hunted by trapping and shooting. This finding is similar to that of Pattiselanno et al. (2019), who found that wild pigs and deer are the most common wildlife hunted by locals in West Papua Province as food sources. Forest common wallaby (*D. muelleri*) or ground kangaroos occupy the western part of mainland Papua's lowlands and the Misool, Salawati, and Yapen Islands (Al Hatmi et al. 2020). The distribution of this particular species is extensive and can be found near human settlements. Wide eyes are typical of this nocturnal species. However, these animals can be active during part of the day when there is sunlight. This species has a vast population in this area, but only footprints were found during field observations. This species has a large natural population, but in several areas, including South Sorong, it is seriously threatened by hunting for local consumption. The study also found several types of cuscus, including spotted cuscus (*S. maculatus*) and eastern cuscus (*P. orientalis*). These two species are common and often found throughout Papua New Guinea and West Papua, including the South Sorong District (Sinery et al. 2020; Widayanti et al. 2020; Hamilton and Parnaby 2022). Spotted cuscus has been a hunting target due to its unique shape and beautiful feather colour. Besides consuming the meat, the skin can be used as an attractive decoration/display in the house. This species is widespread and can be found at 0 to 1200 meters above sea level in primary and secondary forests throughout Papua, except savanna areas (Sinery et al. 2020).

Meanwhile, eastern cuscus (*P. orientalis*) does not have spots. Like spotted cuscus (*S. maculatus*), this species also hunts for consumption. However, unlike wild pigs and deer, all species of cuscus in West Papua Province are only used for family subsistence and not for trade (Pattiselanno et al. 2019). Eastern cuscus is distributed in Papua but has not been reported in the southern region. Its distribution is from 0 to 1,500 meters above sea level and can be found in primary forests, secondary forests, and former gardens. This species is of interest to the public for consumption. Eastern cuscus is distributed in Papua New Guinea and West Papua but has not been reported in the southern region. Its distribution is from 0 to 1500 meters above sea level and can be found in primary, secondary, and former gardens (Kerby et al. 2022). The study also invented the long-beaked echidna (*Z. bruijnii*), one of three types of echidna found in Papua (Pattiselanno et al. 2022). According to the IUCN, this animal is classified as critically endangered, with conditions continuing to decline (Wheelhouse et al. 2022). Although the Indonesian government has prohibited hunting this species, based on interviews with locals, it is still often caught and traded. This species is also being hunted in other parts of West Papua Province, such as Tambrauw Regency and Bintuni Regency (Pattiselanno et al. 2019).

Birds. Bird species found in this study are relatively higher than those in the mangrove forest of Bintuni Bay (24 species) (Cita and Budiman 2019) and small islands in Maluku (22 species) (Latumahina et al. 2020). However, it is still much lower than the number of bird species (74) found in Nimbokrang forests, Papua, Indonesia (Pangau-Adam et al. 2021). As shown in Figure 7, LLKF-B and MgF-K presented the highest number of species. The *C. esculenta* and *M. tristissima* were the most dominant species discovered during the study. The "mambruk" *Goura cristata* (Pallas, 1764), one of three mambruk endemic to Papua Island (Diamond et al. 2019; Keiluhu et al. 2019), was also found in this ecosystem type. *G. cristata* was identified based on their voice and feathers. Figure 7 also indicates that the ASF of Konda presented a lesser number of species. As it is located near the coastline, the bird species in this ecosystem type are dominated by species from the Ardeidae and Laridae families, including *Hydroprogne caspia* (Pallas, 1770), Pacific reef heron *Egretta sacra* (Gmelin, 1789), as well as several other migratory birds such as *Fregata minor* (Gmelin, 1789), *Ardea sumatrana* (Raffles, 1822) and *Butorides striata* (Linnaeus, 1758). The old secondary forest (ALLF-N) has presented the lowest number of species, *C. esculenta* being the dominant species. According to research by Burbidge and Fuller (2007), there has been a significant change in species richness, community composition, and bird abundance since rainfall in central Australia. It is also supported by Gibbons et al. (2023) states that some rain-responsive birds will use rain showers to bathe and come out to dry their feathers in the sun when the rain stops. Shorebirds such as *Hirundo rustica* (Linnaeus, 1758), *Gygis alba* (Sparrman, 1786), and *H. caspia* were also invented, especially in the Konda ASF. Whereas the survey was conducted from October to November during the migrational season, several species of migratory birds from Eurasia were also found, such as *H. rustica* and *H. caspia*. These species flew to the Australo-Papuan region to spend the summer. In addition, regarding the evenness index, each ecosystem type has no significant differences (Figure 8). It is suspected that several dominant bird species are in the case (Beehler and Pratt 2016).

Herpetofauna. The number of herpetofauna found in this study (43 species) is relatively higher than that found in Kei Island, Maluku, in which only 39 species (26 lizards, ten snakes, and three frogs) (Karin et al. 2018), in Peleng Island, Banggai Kepulauan, Central Sulawesi, Indonesia (34 species) (Riyanto and Rahmadi 2021), Blitar, Tulungagung, Malang, Mojokerto, Kediri, and Batu City, East Java Indonesia (Rohman et al. 2022), and at the Tunjung Nyaho Campus of the University of Palangkaraya, Indonesia (Maulidi et al. 2020) (12 species, respectively). However, the number of species found in this study (43 species) is still much lower than that in Ujung Kulon National Park, East Java, which consists of 86 species (65 amphibians and 21 reptiles) (Milto and Lukin 2020), a specific region in West Java Province, Indonesia (74 species) (Erawan et al. 2021), and Lake Skadar's watershed, Serbia (51 species) (Crnobrnja-Isailović et al. 2018). The results also show that the species richness of frogs is much lower than that of reptiles. Furthermore, as shown in Figure 9, the Scincidae family has the highest number of species (15) in this region. This finding is higher than in Ujung Kulon National Park, West Java's specific area, and Lake Skadar's watershed, Serbia (Crnobrnja-Isailović et al. 2018; Milto and Lukin 2020; Erawan et al. 2021).

Lizards, especially from the Scincidae family, are abundant in all ecosystem types of South Sorong. Most occupy a forest floor starting from the zero point of the observation track to the 500-meter point of the transects. Meanwhile, frogs, especially Microhylidae and Ranidae, are less abundant in their habitat. The abundance of their population was indicated by the high intensity of meetings and through their voices. Only eight snake species were found in the study area. However, this number is still suspected to increase if the observation time is extended. The South Sorong Forest ecosystem contains reptiles and amphibian species with great potential for maintaining ecosystem balance. The number of reptiles and amphibians found in the forests of South Sorong is relatively lower compared to findings from Tambrauw but higher when compared to Maybrat (Krey et al. 2019). Differences in sampling effort, survey length, levels of ecosystem diversity, habitat, and altitude cause this difference (Karin et al. 2018).

Habitat support still ensures life, such as temperature, humidity, and food availability. Frogs live in natural habitats along the Ubadari River, forests, and roadsides. There are four native families of frogs in New Guinea, namely Hylidae, Microhylidae, Ranidae, and Myobatrachidae (Esterina 2023). Frog species from the Myobatrachidae family were not found in this study. Most frog species from the three families found in this study inhabit densely vegetated habitats. Almost all families of snake taxa were found in this survey. The abundance of frog and reptile populations will one day change. Degradation of habitat function services due to excessive clearing of the forest canopy and erosion, which causes downstream impacts on the turbidity of river water, small streams, ponds, and swamps, will be a long-term disturbance and threat to these species.

On the other hand, the complex ecological structure of hydrology, climate (micro-climate), and amphibian biology greatly influence the species composition and health of amphibian populations in the future. Even though in the IUCN red list data, most of the herpetofauna species found have the status of Least Concern (LC) (Pratama 2023), we still need to be careful. *L. sanguinolenta* (Figure 13), with LC status, is reportedly distributed in the Lorentz National Park Area based on the geographic distribution map published by IUCN in 2020 (IUCN 2019b). This finding is a new record for the Southwest Papua region, so its habitat needs to be preserved.

Day butterflies. Several factors may be involved in this situation; firstly, ALLF Nakna is a newly cleared primary forest, so butterfly food is available. Other factors include a diversity of vegetation species (variety of food), a river, less human activity, correct collection time (10.00 am to 01.00 pm), and the weather condition (sunny) during sampling activities. Although the ASF Konda is far from human activities, the ecosystem is dominated by sago palms and mangroves. Hence, few plants are suitable for butterflies. The sampling time (1.00-3.00 pm) is different from the correct time, as 08.00-12.00 am is the peak of butterfly activity in looking for food and drying their wing (Soule et al. 2020; Dell'Aglio et al. 2024). It is also supported by Bahar and Wahid (2020) that where the volume of nectar in several butterfly food plants, such as *Lantana camara* L., *Hibiscus rosasinensis* L., and *Coffea canephora* Pierre ex A.Froehner, was found to be higher in the morning and started to decrease in the afternoon. The sugar content of nectar in the three plant species ranges from 17.25-24.5% in the morning and 5.62-6.5% in the afternoon (Bahar and Wahid 2020). The total number of species (58 species) of day butterflies found in this study is more than those found in other regions, such as those conducted by Frahtia et al. (2022), who invented 15 species from three families of day butterflies in Chettaba Forest, Constantine (Northeastern Algeria). However, the number of species found in this region is still far less compared to those found in the lowland rainforest, Jambi Province, Sumatra, Indonesia (204 species) (Panjaitan et al. 2020), in Shenzhen, a young megacity in southern China (74 species from six families) (Sing et al. 2016), and that found in the mountainous region of northern Vietnam (231 species) (Franzén et al. 2017). Habitat conditions, precision factors, and observation time significantly influence the results of our research. It is suspected that butterflies of the Nymhalidae family generally have more than one host plant, meaning that Nymphalidae are polyphagous (have more than one type of food) so that Nymphalidae can still meet their food needs even if their leading food is not available (Nylin et al. 2014; Muto-Fujita et al. 2017). However, the number of Day Butterflies may increase if sampling days increase, highlighting the importance of these factors in our research (Figure 11).

Furthermore, PSF-N has the highest diversity index (3.76) (Figure 12). This ecosystem type is a former village forest used as a community garden. The location is slightly open so that enough sunlight reaches the forest floor, and many flowering plants support it. Even though the ALLF-N, LLLF-W, and MgF-K are forest ecosystems with human activities (tree felling), they are still slightly close to the river. As mentioned by Ansari et al. (2019) that butterflies like areas where water flows, sand, damp rocks, and rotten fruit, animal and human waste for sucking minerals that will be used as butterfly metabolic catalysts.

Figure 13. Giant tree frog *L. sanguinolenta*, a new record in South Sorong District, Indonesia (Photographs: Kelly Krey)

Figure 14. *Chondropython viridis*, the protected snake of Papua, Indonesia, was found in the study area of South Sorong District, Indonesia (Photographs: Kelly Krey)

Delias dice Vollenhoven *Delias ennia* Wallace

Figure 15. Butterfly species really like forest boundaries found in the study area of South Sorong District, Indonesia (Photographs: Beatrix Wanma)

Meanwhile, open areas will be used by butterflies in matting area activities because they allow butterflies to interact with each other without being obstructed by the canopy and tree trunks. On the other hand, ASF-K presented the lowest diversity value. It is suspected that incorrect sampling time (1.00-3.00 pm) was the main factor involved. Another factor probably was the unavailability of food, as this site does not have a variety of plant species for food. Even though ALLF-N and LLLF-W have a high diversity index, if we look at the several types of butterflies that differ based on their tolerance to the habitat, such as *D. dice* (Snellen van Vollenhoven, 1865) and *D. ennia* (Wallace, 1867) (Figure 15), species really like forest boundaries. Figure 12 also shows that all sampling sites are categorised as low dominance, meaning they have a stable species evenness, where the D value ranges from 0.05 to 0.36. In addition, an evenness value ranges from 0.84 to 0.96, meaning the distribution of species of the species found in this region is even (Koneri et al. 2019; Rushayati et al. 2024).

In conclusion, overall, the study indicates that the target forest ecosystem types, namely the alluvial lowland forest of Nakna, the lowland karst forest of Boldon, the lowland limestone forest of Wara, the alluvial swamp forest of Konda, the peat swamp forest of Nakna, and the mangrove of Konda are mostly still natural and well maintained. Results indicated that the lowland limestone forest of Wara and the lowland karst forest of Boldon consisted of the highest number of trees (532 and 373 trees ha^{-1}, respectively), number of species (56 and 52 species ha^{-1}, respectively), and number of genera (50 and 47 genera ha^{-1}), respectively per unit area. Unique and endemic orchid species, including *D. transversilobum* and *B. septemtrionale*, also exist in this region. The research also invented a total of 9 species of mammals, 52 species from 25 families of birds, 39 species of reptiles and amphibians, of which species *L. sanguinolenta* is a new record in the region, and 58 species of day butterflies from the Papilonoidea superfamily. Several key species of flora and fauna in this region require special attention as they are in alert status, which may require intervention to maintain their existence in nature so that they do not disappear or even become extinct.

ACKNOWLEDGEMENTS

We want to thank the Indonesian Conservation Foundation (YKI) for the support, opportunity, and cooperation in carrying out this study. Also, we thank the Head of the South Sorong XIV Production Forest Management Unit (KPHP), Southwest Papua, Indonesia, for his support and collaboration. Lastly, I highly appreciate the University of Papua Research Team, Indonesia, for their support, time, and expertise so that the writing of this report could be completed on time and according to mutual expectations.

REFERENCES

Addi A, Soromessa T, Bareke T. 2020. Floristic composition and vegetation community analysis of Gesha and Sayilem Forest in Kaffa Zone South Western Ethiopia. Biodiversitas 21 (7): 2878-2888. DOI: 10.13057/biodiv/d210702.

Agbelade AD, Onyekwelu JC, Apogbona O. 2016. Assessment of urban forest tree species population and diversity in Ibadan, Nigeria. Environ Ecol Res 4 (4): 185-192. DOI: 10.13189/eer.2016.040401.

Agbelade AD, Onyekwelu JC, Oyun MB. 2017. Tree species richness, diversity, and vegetation index for Federal Capital Territory, Abuja, Nigeria. Intl J For Res 2017 (1): 4549756. DOI: 10.1155/2017/4549756.

Al Hatmi S, Al Hinai A, AL Qassabi Z, Amorim AM, Anderson C, Anderson WR. 2020. General Idex to Volume 77.2020. Edinburgh J Bot 77 (3): 557-577. DOI: 10.1017/S0960428620000190.

Ali S, Hussain SA, Tohir MZM, Nuruddin AA. 2021. Investigation of kinetic decomposition characteristics of Malaysian wood species using Coats and Redfern (CR) method. Mater Today Proc 42 (Part 1): 178-185. DOI: 10.1016/j.matpr.2020.11.341.

Almeida-Gomes M, Vieira MV, Rocha CFD, Metzger JP, De Coster G. 2016. Patch size matters for amphibians in tropical fragmented landscapes. Biol Conserv 195: 89-96. DOI: 10.1016/j.biocon.2015.12.025.

Ansari MS, Basri R, Shekhawat SS. 2019. Insect pests infestation during field and storage of fruits and vegetables. In: Malik A, Erginkaya Z, Erten H (eds). Health and Safety Aspects of Food Processing Technologies. Springer, Cham. DOI: 10.1007/978-3-030-24903-8_7.

Ardiyaningrum I, Budiastuti MTS, Komariah K. 2021. Short Communication: Species composition and diversity of vegetation in dryland agricultural landscape. Biodiversitas 22 (1): 65-71. DOI: 10.13057/biodiv/d220109.

Arifanti VB, Kauffman JB, Subarno, Ilman M, Tosiani A, Novita N. 2022. Contributions of mangrove conservation and restoration to climate change mitigation in Indonesia. Glob Change Biol 28 (15): 4523-4538. DOI: 10.1111/gcb.16216.

Arroyo-Rodríguez V, Melo FPL, Martínez-Ramos M, Bongers F, Chazdon RL, Meave JA, Norden N, Santos BA, Leal IR, Tabarelli M. 2017. Multiple successional pathways in human-modified tropical landscapes: New insights from forest succession, forest fragmentation and landscape ecology research. Biol Rev Camb Philos Soc 92 (1): 326-340. DOI: 10.1111/brv.12231.

Bahar AN, Wahid KA. 2020. Design of an efficient N× N butterfly switching network in Quantum-dot Cellular Automata (QCA). IEEE Trans Nanotechnol 19: 147-155. DOI: 10.1109/tnano.2020.2969166.

Beehler BM, Pratt TK. 2016. Birds of New Guinea: Distribution, Taxonomy, and Systematics. Princeton University Press, Princeton, New Jersey, USA. DOI: 10.1515/9781400880713.

Bro-Jørgensen J, Franks DW, Meise K. 2019. Linking behaviour to dynamics of populations and communities: Application of novel approaches in behavioural ecology to conservation. Philos Trans R Soc Lond B Biol Sci 374 (1781): 20190008. DOI: 10.1098/rstb.2019.0008.

Burbidge AA, Fuller PJ. 2007. Gibson Desert birds: Responses to drought and plenty. Emu-Austral Ornithol 107 (2): 126-134. DOI: 10.1071/MU06044.

Cita KD, Budiman MAK. 2019. Bird diversity and its association in mangrove habitats of Teluk Bintuni Regency, West Papua. IOP Conf Ser: Earth Environ Sci 394: 012006. DOI: 10.1088/1755-1315/394/1/012006.

Crnobrnja-Isailović J, Polović L, Ljubisavljević K, Čađenović N, Čubrić T, Haxhiu I. 2018. Diversity and conservation status of Batrachofauna and Herpetofauna in the Lake Skadar Region. In: Pešić V, Karaman G, Kostianoy AG (eds). The Skadar/Shkodra Lake Environment. The Handbook of Environmental Chemistry, vol 80. Springer, Cham. DOI: 10.1007/698_2018_252.

De Medeiros-Sarmento PS, Ferreira LV, Gastauer M. 2021. Natural regeneration triggers compositional and functional shifts in soil seed banks. Sci Total Environ 753: 141938. DOI: 10.1016/j.scitotenv.2020.141934.

Dell'Aglio DD, McMillan OW, Montgomery S. 2024. Using motion-detection cameras to monitor foraging behaviour of individual butterflies. Ecol Evol 14 (7): e70032. DOI: 10.1002/ece3.70032.

Dennis EB, Morgan BJT, Brereton TM, Roy DB, Fox R. 2017. Using citizen science butterfly counts to predict species population trends. Conserv Biol 31 (6): 1350-1361. DOI: 10.1111/cobi.12956.

Diamond J, Bishop KD, Sneider R. 2019. An avifaunal double suture zone at the Bird's Neck Isthmus of New Guinea. Wilson J Ornithol 131 (3): 435-458. DOI: 10.1676/18-167.

Ehara H, Kakuda K, Miyazaki A, Naito H, Nakamura S, Nitta Y, Okazaki M, Sasaki Y, Toyota K, Watanabe A, Watanabe M, Yamamoto Y, Goto Y, Kimura SD. 2021. Sago Palm in Peatland. In: Osaki M, Tsuji N, Foead N, Rieley J (eds). Tropical Peatland Eco-management. Springer, Singapore. DOI: 10.1007/978-981-33-4654-3_17.

Elfrida E, Mubarak A, Suwardi AB. 2020. Short Communication: The fruit plant species diversity in the home gardens and their contribution to the livelihood of communities in rural area. Biodiversitas 21 (8): 3670-3675. DOI: 10.13057/biodiv/d210833.

Erawan TS, Jauhan J, Husodo T, Wulandari I, Fauzi DA, Megantara EN, Shanida SS. 2021. Herpetofauna diversity and distribution based on the elevational range in West Java, Indonesia. Biodiversitas 22 (10): 4308-4319. DOI: 10.13057/biodiv/d221023.

Esterina R. 2023. Morphology and karyotype of two frog species from Irian Jaya. Formosa J Appl Sci 2 (10): 2369-2382. DOI: 10.55927/fjas.v2i10.6351.

Fatem SM, Djitmau DA, Ungirwalu A, Wanma AO, Simbiak VI, Benu NMH, Tambing J, Murdjoko A. 2020a. Species diversity, composition, and heterospecific associations of trees in three altitudinal gradients in Bird's Head Peninsula, Papua, Indonesia. Biodiversitas 21 (8): 3596-3605. DOI: 10.13057/biodiv/d210824.

Fatem SM, Syufi Y, Baru J, Marwa J, Runtuboi YY, Tawer V, Situmorang S, Runtuboi FR. 2020b. The Sausapor Declaration: Challenges in promoting good governance to protect customary communities and natural resources in Tambrauw District, West Papua. For Soc 4 (2): 330-337. DOI: 10.24259/fs.v4i2.9346.

Forrester DI, Bauhus J. 2016. A review of processes behind diversity-Productivity relationships in forests. Curr For Rep 2: 45-61. DOI: 10.1007/s40725-016-0031-2.

Frahtia K, Attar MR, Diabi C. 2022. Diversity and richness of day Butterflies species (Lepidoptera: Rhopalocera) in the Chettaba Forest, Constantine, Northeastern Algeria. Biodiversitas 23 (7): 3429-3436. DOI: 10.13057/biodiv/d230715.

Franklin J, Serra-Diaz JM, Syphard AD, Regan HM. 2016. Global change and terrestrial plant community dynamics. Proc Natl Acad Sci 113 (14): 3725-3734. DOI: 10.1073/pnas.1519911113.

Franzén M, Schrader J, Sjöberg G. 2017. Butterfly diversity and seasonality of Ta Phin Mountain area (N. Vietnam, Lao Cai Province). J Insect Conserv 21: 465-475. DOI: 10.1007/s10841-017-9985-z.

Gautam B, Chalise MK, Thapa KB, Bhattarai S. 2020. Distributional patterns of amphibians and reptiles in Ghandruk, Annapurna Conservation Area, Nepal. Reptiles Amphibians 27 (1): 18-28. DOI: 10.17161/randa.v27i1.14440.

Geng S, Shi P, Song M, Zong N, Zu J, Zhu W. 2019. Diversity of vegetation composition enhances ecosystem stability along elevational gradients in the Taihang Mountains, China. Ecol Indic 104: 594-603. DOI: 10.1016/j.ecolind.2019.05.038.

Gibbons EK, Close PG, Van Helden BE, Rooney NJ. 2023. Water in the city: Visitation of animal wildlife to garden water sources and urban lakes. Urban Ecosyst 26: 1413-1425. DOI: 10.1007/s11252-023-01391-3.

Halstead BJ, Kleeman PM, Rose JP. 2018. Time-to-detection occupancy modeling: An efficient method for analyzing the occurrence of amphibians and reptiles. J Herpetol 52: 416-425. DOI: 10.1670/18-049.

Hamilton SG, Parnaby H. 2022. Occurrence of the ground cuscus *Phalanger gymnotis* (Phalangeridae: Marsupialia) in the Trans-Fly Region, Papua New Guinea. Aust Mammal 44 (3): 397-403. DOI: 10.1071/AM21009.

Heyer R, Donnelly MA, Foster M, Mcdiarmid R. 2014. Measuring and Monitoring Biological Diversity: Standard Methods for Amphibians. Smithsonian Institution, Washington DC.

IUCN. 2019a. IUCN Red List of Threatened Species: *Asterophrys turpicola*. IUCN Red List of Threatened Species. https://www.iucnredlist.org/en.

IUCN. 2019b. IUCN Red List of Threatened Species: *Litoria sanguinolenta*. IUCN Red List of Threatened Species. DOI: 10.2305/IUCN.UK.2004.RLTS.T55752A11361391.en.

IUCN. 2023. IUCN Red List of Threatened Species.

Karim HA. 2021. Ecological study of Sago Palm (*Metroxylon sagu Rott ver molat* (Becc.)) in the natural habitat at Malili District East Luwu South Sulawesi. IOP Conf Ser: Earth Environ Sci 807: 022031. DOI: 10.1088/1755-1315/807/2/022031.

Karin BR, Stubbs AL, Arifin U, Bloch LM, Ramadhan G, Iskandar DT, Arida E, Reilly SB, Kusnadi A, McGuire JA. 2018. The herpetofauna of the kei islands (Maluku, Indonesia): Comprehensive report on new and historical collections, biogeographic patterns, conservation concerns, and an annotated checklist of species from Kei Kecil, Kei Besar, Tam, and Kur. Raffles Bull Zool 66: 704-738. https://escholarship.org/uc/item/14d553xm.

Keiluhu HJ, Pangau-Adam MZ, Maury HK, Waltert M. 2019. Effects of anthropogenic disturbance on a Victoria crowned pigeon *Goura victoria* population in Northern Papua, Indonesia. J Asia-Pac Biodivers 12 (4): 493-497. DOI: 10.1016/j.japb.2019.07.007.

Kerby G, Ford A, Summerhayes GR, Leavesley MG, Palin JM. 2022. Fit for purpose: Investigating adaptations in late Pleistocene lithic technology to an island environment at Buang Merabak, New Ireland, Papua New Guinea. World Archaeol 54 (2): 317-337. DOI: 10.1080/00438243.2023.2172070.

Klingbeil BT, Willig MR. 2015. Bird biodiversity assessments in temperate forest: The value of point count versus acoustic monitoring protocols. PeerJ 3: 973. DOI: 10.7717/peerj.973.

Komara LL, Choesin DN, Syamsudin TS. 2016. Plant diversity after sixteen years post coal mining in East Kalimantan, Indonesia. Biodiversitas 17 (2): 531-538. DOI: 10.13057/biodiv/d170223.

Koneri R, Nangoy MJ, Siahaan P. 2019. The abundance and diversity of butterflies (Lepidoptera: Rhopalocera) in Talaud Islands, North Sulawesi, Indonesia. Biodiversitas 20 (11): 3275-3283 DOI: 10.13057/biodiv/d201121.

Kraus F. 2015. Impacts from invasive reptiles and amphibians. Ann Rev Ecol Evol Syst 46 (1): 75-97. DOI: 10.1146/annurev-ecolsys-112414-054450.

Krey K, Taran D, Burwos H, Sidik I. 2019. The snakes collection from Papua, Indonesia with notes on analysis of stomach content. Vogelkop: Jurnal Biologi 2 (1): 36-45. DOI: 10.30862/vogelkopjbio.v2i1.57.

Latumahina FS, Mardiatmoko G, Sahusilawane J. 2020. Bird diversity on small islands in Maluku. IOP Conf Ser: Earth Environ Sci 486: 012024. DOI: 10.1088/1755-1315/486/1/012024.

Ma P, Li M, Xing Z, Deng J, Deng M, Luo Y. 2024. Taxonomic studies of the genus *Bulbophyllum* (Orchidaceae) from Indo-Myanmar and Himalaya Biodiversity Hotspots: Three newly recorded species in the flora of China, four new synonyms of *Bulbophyllum*. Taiwania 69 (1): 122-128. DOI: 10.6165/tai.2024.69.122.

Martin-Garcia S, Cortazar-Chinarro M, Rodríguez-Recio M, Jiménez J, Höglund J, Virgós E. 2023. Comparing minimum number of individuals and abundance from non-invasive DNA sampling and camera trapping in the red fox (*Vulpes vulpes)*. Biodivers Conserv 32: 1977-1998. DOI: 10.1007/s10531-023-02586-y.

Matsuo T, Martínez-Ramos M, Bongers F, van der Sande MT, Poorter L. 2021. Forest structure drives changes in light heterogeneity during tropical secondary forest succession. J Ecol 109 (8): 2871-2884. DOI: 10.1111/1365-2745.13680.

Maturbongs RA, Dransfield J, Baker W. 2014. *Calamus kebariensis* (Arecaceae)-A new montane rattan from New Guinea. Phytotaxa 163 (4): 235-238. DOI: 10.11646/phytotaxa.163.4.4.

Maulidi A, Purnaningsih T, Maulina A, Gunawan YE, Rizki M. 2020. Short Communication: Herpetofauna diversity at the University of Palangka Raya, Indonesia. Biodiversitas 21 (10): 4509-4514. DOI: 10.13057/biodiv/d211006.

McCullough JM, DeCicco LH, Herr MW, Holland P, Pikacha D, Lavery TH, Olson KV, DeRaad DA, Tigulu IG, Mapel XM, Klicka LB, Famoo R, Hobete J, Runi L, Rusa G, Tippet A, Boseto D, Brown RM, Moyle RG, Andersen MJ. 2023. A survey of terrestrial vertebrates of Tetepare Island, Solomon Islands, including six new island records. Pac Sci 76 (4): 411-435. DOI: 10.2984/76.4.6.

Milto KD, Lukin YA. 2020. A revised herpetofauna of Ujung Kulon National Park, West Java, Indonesia. Russ J Herpetol 27 (6): 353-368. DOI: 10.30906/1026-2296-2020-27-6-353-368.

Monarrez-Gonzalez JC, Gonzalez-Elizondo MS, Marquez-Linares MA, Gutierrez-Yurrita PJ, Perez-Verdin G. 2020. Effect of forest management on tree diversity in temperate ecosystem forests in northern Mexico. PLoS One 15 (5): e0233292. DOI: 10.1371/journal.pone.0233292.

Murdjoko A, Djitmau DA, Sirami EV et al. 2021. Tree species diversity of Pegunungan Bintang, Papua, Indonesia as potency of wood supply. Biodiversitas 22 (12): 5666-5676. DOI: 10.13057/biodiv/d221263.

Muto-Fujita A, Takemoto K, Kanaya R, Nakazato T, Tokimatsu T, Matsumoto N, Kono M, Chubachi Y, Ozaki K, Kotera M. 2017. Data integration aids understanding of butterfly-host plant networks. Sci Rep 7: 43368. DOI: 10.1038/srep43368.

Naidu MT, Kumar OA. 2016. Tree diversity, stand structure, and community composition of tropical forests in Eastern Ghats of Andhra Pradesh, India. J Asia-Pac Biodivers 9 (3): 328-334. DOI: 10.1016/j.japb.2016.03.019.

Nero BF. 2021. Structure, composition and diversity of restored forest ecosystems on mine-spoils in South-Western Ghana. PLoS One 16 (6): e0252371. DOI: 10.1371/journal.pone.0252371.

Nylin S, Slove J, Janz N. 2014. Host plant utilization, host range oscillations and diversification in Nymphalid butterflies: A phylogenetic investigation. Evolution 68 (1): 105-124. DOI: 10.1111/evo.12227.

Omayio D, Mzungu E. 2019. Modification of Shannon-Wiener Diversity Index towards quantitative estimation of environmental wellness and biodiversity levels under a non-comparative Scenario. J Environ Earth Sci 9 (9): 46-57. DOI: 10.7176/jees/9-9-06.

Ormerod P, Juswara L. 2022. Notes on some Malesian Orchidaceae IV. Harvard Pap Bot 27 (2): 169-176. DOI: 10.3100/hpib.v27iss2.2022.n6.

Ortega SVM, Sarria-Paja M. 2022. Bird identification from the Thamnophilidae family at the Andean Region of Colombia. In: Saeed K, Dvorský J (eds). Computer Information Systems and Industrial Management. CISIM 2022. Lecture Notes in Computer Science, vol 13293. Springer, Cham. DOI: 10.1007/978-3-031-10539-5_18.

Pangau-Adam M, Slowik J, Trei J-N, Waltert M. 2021. Negative effects of logging on bird dispersed plants in Northern Papuan Lowland Forest, Indonesia. Trop Conserv Sci 14: 194008292110311. DOI: 10.1177/19400829211031171.

Panjaitan R, Drescher J, Buchori D, Peggie D, Harahap IS, Scheu S, Hidayat P. 2020. Diversity of butterflies (Lepidoptera) across rainforest transformation systems in Jambi, Sumatra, Indonesia. Biodiversitas 21 (11): 5119-5127. DOI: 10.13057/biodiv/d211117.

Pattiselanno F, Apituley JRM, Arobaya AYS, Koibur JF. 2019. Short Communication: Using wildlife for local livelihood-Experiences from the Bird’s Head Peninsula, West Papua, Indonesia. Biodiversitas 20 (7): 1839-1845. DOI: 10.13057/biodiv/d200708.

Pattiselanno F, Iriansul, Barnes PA, Arobaya AYS. 2022. Using local ecological knowledge to locate the western long-beaked Echidna *Zaglossus bruijnii* on the Vogelkop Peninsula, West Papua, Indonesia. Oryx 56 (4): 636-638. DOI: 10.1017/S0030605321000351.

PERMEN KLHK (2018). Peraturan Menteri Lingkungan Hidup dan Kehutanan Nomor P.20/MENLHK/SETJEN/KUM.1/6/2018 tentang Jenis Tumbuhan dan Satwa yang Dilindungi. [Indonesian]

Potter KM, Jetton RM, Bower A, Jacobs DF, Man G, Hipkins VD, Westwood M. 2017. Banking on the future: Progress, challenges and opportunities for the genetic conservation of forest trees. New Forests 48: 153-180. DOI: 10.1007/s11056-017-9582-8.

Powers JS, Marín-Spiotta E. 2017. Ecosystem processes and biogeochemical cycles in secondary tropical forest succession. Ann Rev Ecol Evol Syst 48: 497-519. DOI: 10.1146/annurev-ecolsys-110316-022944.

Pratama FW. 2023. Herpetofauna Diversity in Palayo Waterfall, Cipta Karya Village, Bengkayang Regency, West Kalimantan, Indonesia. Nat Sci: J Sci Technol 12 (1): 45-50. DOI: 10.22487/25411969.2023.v12.i1.16317.

Rahim A, Soeprobowati TR, Putranto TT, Al Falah MH, Gell P. 2024. Contribution of mangrove forest carbon stocks on climate change mitigation: A case study at Tuntang Estuary, Central Java. J Coast Conserv 28: 65. DOI: 10.1007/s11852-024-01059-w.

Riyanto A, Rahmadi C. 2021. Amphibian and reptile diversity of Peleng Island, Banggai Kepulauan, Central Sulawesi, Indonesia. Biodiversitas 22 (5): 2930-2939. DOI: 10.13057/biodiv/d220558.

Robiansyah I. 2018. Diversity and biomass of tree species in Tambrauw, West Papua, Indonesia. Biodiversitas 19 (2): 377-386. DOI: 10.13057/biodiv/d190204.

Rohman F, Priambodo B, Akhsani F, Rahayu SE, Wangkulangkul S, Kundariati M. 2022. Revealing herpetofauna diversity at Brantas River, East Java, Indonesia: Evidence of decreasing populations. Biodiversitas 23 (3): 1475-1481. DOI: 10.13057/biodiv/d230335.

Roswell M, Dushoff J, Winfree R. 2021. A conceptual guide to measuring species diversity. Oikos 130 (3): 321-338. DOI: 10.1111/oik.07202.

Rushayati SB, Ginoga LN, Wijayanto AK, Zulhidayat H, Suryani R. 2024. Environmental services potency of butterfly biodiversity as an ecotourism object in DKI Jakarta Province. IOP Conf Ser: Earth Environ Sci 1366: 012028. DOI: 10.1088/1755-1315/1366/1/012028.

Sabath N, Itescu Y, Feldman A, Meiri S, Mayrose I, Valenzuela N. 2016. Sex determination, longevity, and the birth and death of reptilian species. Ecol Evol 6 (15): 5207-5220. DOI: 10.1002/ece3.2277.

Sarasa G, Granados A, Rodríguez FB. 2017. An approach of algorithmic clustering based on string compression to identify bird songs species in xeno-canto database. 3rd International Conference on Frontiers of Signal Processing (ICFSP). DOI: 10.1109/ICFSP.2017.8097150.

Shaverdo HV, Panjaitan R, Balke M. 2016. A new, widely distributed species of the *Exocelina ekari*-group from West Papua (Coleoptera, Dytiscidae, Copelatinae). ZooKeys 554: 69-85. DOI: 10.3897/zookeys.554.6065.

Sillanpää M, Vantellingen J, Friess DA. 2017. Vegetation regeneration in a sustainably harvested mangrove forest in West Papua, Indonesia. For Ecol Manag 390: 137-146. DOI: 10.1016/j.foreco.2017.01.022.
Sinery AS, Burwo H, Worabay M, Jowey NR, Setiawan B. 2020. Mammals diversity in the Nutmeg Plantation area at Teluk Wondama and Teluk Bintuni Regency in West Papua Province, Indonesia. World J Adv Res Rev 5: 79-85. DOI: 10.30574/wjarr.2020.5.1.0004.
Sing K-W, Dong H, Wang W-Z, Wilson J-J. 2016. Can butterflies cope with city life? Butterfly diversity in a young megacity in southern China. Genome 59 (9): 751-761. DOI: 10.1139/gen-2015-0192.
Soliveres S, Smit C, Maestre FT. 2015. Moving forward on facilitation research: Response to changing environments and effects on the diversity, functioning and evolution of plant communities. Biol Rev Camb Philos Soc 90 (1): 297-313. DOI: 10.1111/brv.12110.
Soule AJ, Decker L, Hunter MD. 2020. Effects of diet and temperature on monarch butterfly wing morphology and flight ability. J Insect Conserv 24: 961-975. DOI: 10.1007/s10841-020-00267-7.
Taylor EN, Diele-Viegas LM, Gangloff EJ, Hall JM, Halpern B, Massey MD, Rödder D, Rollinson N, Spears S, Sun B, Telemeco RS. 2021. The thermal ecology and physiology of reptiles and amphibians: A user's guide. J Exp Zool A: Ecol Integr Physiol 335 (1): 13-44. DOI: 10.1002/jez.2396.
Teong CQ, Setiabudi HD, El-Arish NAS, Bahari MB, Teh LP. 2021. *Vatica rassak* wood waste-derived activated carbon for effective Pb(II) adsorption: Kinetic, isotherm and reusability studies. Mater Today Proc 42 (Part 1): 165-171. DOI: 10.1016/j.matpr.2020.11.270.
Thom D, Rammer W, Seidl R. 2017. The impact of future forest dynamics on climate: Interactive effects of changing vegetation and disturbance regimes. Ecol Monogr 87 (4): 665-684. DOI: 10.1002/ecm.1272.
Threlfall CG, Ossola A, Hahs AK, Williams NSG, Wilson L, Livesley SJ. 2016. Variation in vegetation structure and composition across urban green space types. Front Ecol Evol 4: 66. DOI: 10.3389/fevo.2016.00066.
Tomlinson PB. 2016. The Botany of Mangroves. Cambridge University Press, England. DOI: 10.1017/CBO9781139946575.
Tu H-M, Fan M-W, Ko JC-J. 2020. Different habitat types affect bird richness and evenness. Sci Rep 10 (1): 1221. DOI: 10.1038/s41598-020-58202-4.
Valbuena R, Packalén P, Martı´n-Fernández S, Maltamo M. 2012. Diversity and equitability ordering profiles applied to study forest structure. For Ecol Manag 276: 185-195. DOI: 10.1016/j.foreco.2012.03.036.
Veenendaal EM, Torello-Raventos M, Miranda HS, Sato NM, Oliveras I, van Langevelde L, Asner GP, Lloyd J. 2018. On the relationship between fire regime and vegetation structure in the tropics. New Phytol 218 (1): 153-166. DOI: 10.1111/nph.14940.
Villanueva ELC, Buot Jr IE. 2018. Vegetation analysis along the altitudinal gradient of Mt. Ilong, Halcon Range, Mindoro Island, Philippines. Biodiversitas 19 (6): 2163-2174. DOI: 10.13057/biodiv/d190624.
Wheelhouse J, Vogelnest L, Nicoll RG. 2022. Skeletal radiographic anatomy of echidnas: Insights into unusual mammals. J Mammal 103 (4): 920-931. DOI: 10.1093/jmammal/gyab138.
Widayanti R, Pradana RAB, Kunda RM, Pakpahan S. 2020. Genetic characterization and phylogenetic study of Indonesian cuscuses from Maluku and Papua Island based on 16S rRNA gene. Vet World 13 (11): 2319-2325. DOI: 10.14202/vetworld.2020.2319-2325.
Wildi O. 2017. Data Analysis in Vegetation Ecology. Cabi, England. DOI: 10.1079/9781786394224.0000.
Yamamoto Y, Yanagidate I, Miyazaki A, Yoshida T, Irawan AF, Pasolon YB, Jong FS, Matanubun H, Arsy AA, Limbongan J. 2020. Growth characteristics and starch productivity of folk varieties of Sago Palm around Lake Sentani near Jayapura, Papua State, Indonesia. Trop Agric Dev 64 (1): 23-33. DOI: 10.11248/jsta.64.23.
Zhou J, Gao Y, Wang Y, Zhao YJ. 2021. The effect of different afforestation tree species on plant diversity after 50 years on Mount Tai, China. Appl Ecol Environ Res 19 (6): 4515-4526. DOI: 10.15666/aeer/1906_45154526.