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**| RESEARCH ARTICLE**

# Inventory's Key Role in Conservation: Evaluating Biodiversity Indices and Identifying Priority Areas in Lebak Muncang

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**| ABSTRACT**
This study aims to inventory biodiversity in Lebak Muncang, Ciwidey, West Java, with a focus on identifying species of flora and fauna, analyzing diversity levels, and determining conservation priorities based on the protection status of species and ecosystem conditions. The study employed a field survey method, combining line transects and quadrat plots, for collecting data on fauna (dragonflies, butterflies, mammals, and herpetofauna). Species identification was carried out using determination keys and verified based on conservation status (IUCN Red List, CITES, and Permen LHK P.106/2018). Data were analyzed using the Shannon-Wiener diversity index (H'), Pielou evenness (E), and Margalef richness (R). Distribution mapping of protected species was conducted using a Geographic Information System (GIS) to determine conservation priority areas. This study identified 58 species of fauna, comprising 11 species of dragonflies, 31 species of butterflies, seven mammalian species, and nine herpetofauna species. Several protected species were identified, including the Javan leopard (Panthera pardus melas; Endangered/EN status), Javan surili (Presbytis comata), and Javan langur (Trachypithecus auratus) (both Vulnerable/VU status). The diversity index (H') was moderate for all groups, with high evenness (E>0.7). Butterflies had the highest species richness (R=6.43), while mammals had the lowest (R=1.75). Spatial analysis revealed critical areas that require protection, especially endemic primate habitats. Lebak Muncang has moderate biodiversity with the presence of key protected species. Anthropogenic pressures and habitat fragmentation pose a significant threat to the sustainability of ecosystems. Conservation recommendations include strengthening habitat protection, monitoring endemic species, and integrating policies based on biodiversity analysis.

**| KEYWORDS**: Biodiversity, ecological index, protected species, conservation, Lebak Muncang

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## Introduction

Biodiversity is a fundamental pillar for the sustainability of global ecosystems and a provider of essential ecosystem services, such as climate regulation, pollination, water purification, and vital food and medicinal resources for human life (Costanza et al., 2017). However, this crucial value faces increasingly intense threats, driven by climate change, habitat loss, and massive pollution, resulting in unprecedented rates of species extinction (IPBES, 2019). In a global context, Indonesia plays a crucial role as one of the world's megabiodiverse countries, harboring an unrivaled wealth of flora and fauna species. Unfortunately, this vital role is accompanied by significant conservation pressure, as deforestation, natural resource exploitation, and land conversion continue to pose serious challenges to biodiversity conservation efforts in the country (Hariadi & Lestari, 2021).

A biodiversity inventory is a systematic process of identifying and documenting the species present in an area, making it the first and fundamental step in any effective conservation effort (Primack & Richard, 2018). The primary objective is to gather baseline data on species richness, distribution, and abundance, which will then form the basis for management planning and protection policies. To quantitatively measure and compare biodiversity levels, researchers use biodiversity indices, such as the Shannon-Wiener Index or Simpson's Index (Magurran, 2004). These indices take into account not only the number of species (species richness) but also the relative abundance of each species (evenness), thus providing a more comprehensive picture of community structure. As such, the application of these indices helps assess ecosystem health and monitor changes in biodiversity over time, allowing early identification of potential degradation or the success of restoration efforts.

Identifying protected species is a crucial element in conservation efforts, as their presence reflects the urgency of legal and ecological protection. This identification should be conducted by national laws and regulations, such as Government Regulation No. 7/1999 on the Preservation of Plant and Animal Species, which was later amended and expanded through the Minister of Environment and Forestry Regulation No. P.106/MENLHK/SETJEN/KUM.1/12/2018 (Ministry of Environment and Forestry, 2018), which lists protected plant and animal species in Indonesia. Additionally, global conservation status is also important to consider through international lists, such as the IUCN Red List (IUCN, 2024), which categorizes species based on their risk of extinction. The presence of these species, especially those with endangered or critically endangered status, is a crucial indicator of the conservation status of an area, indicating that the ecosystem still supports vulnerable species and therefore has high conservation value (Walpole et al., 2001). Thus, the detection and monitoring of protected species not only fulfill a legal obligation but also directly demonstrate the need for coordinated and sustainable protection measures to prevent extinction and maintain ecosystem integrity.

This study is located in Lebak Muncang, an area in Ciwidey, Bandung Regency, which is geographically dominated by hilly terrain with a mixed land cover of tea plantations, agricultural areas, and remnants of secondary forest. Ecologically, the area shows a transition between mountain ecosystems and cultivated land, creating a diverse habitat potential. Lebak Muncang was chosen as a research site for several important reasons. The area is believed to have high biodiversity potential due to its proximity to critical conservation areas and water resources; however, existing biodiversity data are still minimal. In addition, Lebak Muncang faces real threats from agricultural expansion and other anthropogenic activities that could potentially lead to habitat degradation and species loss (Nugroho et al., 2023). Therefore, this study is crucial for filling the existing research gap, specifically the lack of comprehensive data on species richness and the presence of protected species in Lebak Muncang, which is essential as a basis for formulating targeted conservation strategies (Suryadi & Wibowo, 2022).

This research aims to gain an in-depth understanding of the biodiversity of Lebak Muncang and identify strategic conservation measures. Specifically, this research will identify and comprehensively inventory the types of flora and fauna present in Lebak Muncang, providing crucial baseline data for conservation efforts (Magurran, 2004). Based on the results of the inventory and diversity index analysis, this study will also identify priority locations for conservation, focusing on areas with high diversity values or the presence of key species that require special attention (Margules & Pressey, 2000). Ultimately, this research will yield concrete and actionable policy recommendations and conservation strategies for biodiversity management in Lebak Muncang, thereby ensuring sustainable and effective protection efforts.

## Literature Review

### 2.1 Importance of Biodiversity Inventory

Biodiversity inventory serves as a foundational step in conservation planning, providing baseline data on species richness, distribution, and abundance. This information enables researchers and policymakers to assess ecosystem health, detect changes over time, and identify areas requiring urgent protection (Primack & Richard, 2018; Magurran, 2004). Quantitative tools, such as the Shannon-Wiener Index and Simpson's Index, allow for objective measurement of biodiversity by incorporating both species richness and evenness.

### 2.2 Role of Protected Species Identification

The detection and monitoring of protected species are essential in conservation strategies, as their presence reflects both ecological integrity and legal protection priorities. In Indonesia, the Minister of Environment and Forestry Regulation No. P.106/2018 specifies nationally protected species, while the IUCN Red List and CITES Appendices provide international references for conservation status. Protected species, especially those categorized as *Endangered* or *Vulnerable*, serve as indicators of ecosystem value and highlight areas that warrant targeted protection efforts (Walpole et al., 2001; IUCN, 2024).

### 2.3 Previous Studies on Biodiversity Index Evaluation

This literature review presents data from the last five years related to the importance of biodiversity inventory for evaluating biodiversity indices and identifying priority areas, particularly in regions such as Lebak Muncang.

**Table 1. Previous Research**

| No | Research Title | Writer | Source | Research Methods | Key Findings | Research Gap |
|---|---|---|---|---|---|---|
| 1 | Biodiversity Inventory as a Conservation Strategy in Community Forests (2020) | Widodo et al. | Indonesian Journal of Biodiversity | Field surveys, Shannon-Wiener index | An adequate inventory in determining priority conservation zones. | It has not been applied in agroforestry areas such as Lebak Muncang. |
| 2 | Assessment of Biodiversity Index for Conservation Priority in Agroforestry Landscapes (2021) | Sari & Handoko | Agroforestry Journal | Vegetation analysis, line transects, Simpson's index | Areas with high diversity indexes are less likely to receive formal protection. | There is no map of priority areas at the village scale. |
| 3 | Spatial Prioritization for Biodiversity Conservation in Fragmented Habitats (2019) | Nugroho et al. | Conservation Letters Indonesia | GIS, spatial analysis, protected area overlay | Habitat fragmentation accelerates biodiversity decline if it is not immediately inventoried and protected. | Lack of region-specific basic data, such as Lebak Muncang. |
| 4 | Evaluation of Local Biodiversity as a Basis for Conservation (2022) | Damayanti et al. | Journal of Tropical Ecology | Flora-fauna surveys, community interviews | Local inventory data supports community-based policies. | The community's participatory approach is still limited. |
| 5 | Integration of Diversity Inventory and Spatial Planning (2023) | Promise & Blessing | Journal of Regional Planning | Mixed-method (survey + spatial mapping) | The identification of priority areas has been successfully included in the village plan. | It has not been an optimal tool for measuring the biodiversity index. |

2.4 Research Gap and Relevance to the Current Study

Although prior research has demonstrated the value of biodiversity inventory in conservation planning, its application in agroforestry and mixed-use landscapes such as Lebak Muncang remains limited. There is also a lack of high-resolution spatial mapping of priority areas at the village scale, which is crucial for local-level conservation policy integration. This study addresses these gaps by combining biodiversity index analysis with GIS-based spatial prioritization, producing actionable data for conservation planning in Lebak Muncang.

**Methodology**

3.1 Study Area

This research was conducted in Lebak Muncang, situated in the Ciwidey District of Bandung Regency, West Java. The study area is geographically located at approximately 7°10'00" S and 107°25'00" E, encompassing a region illustrated on map (picture 1).

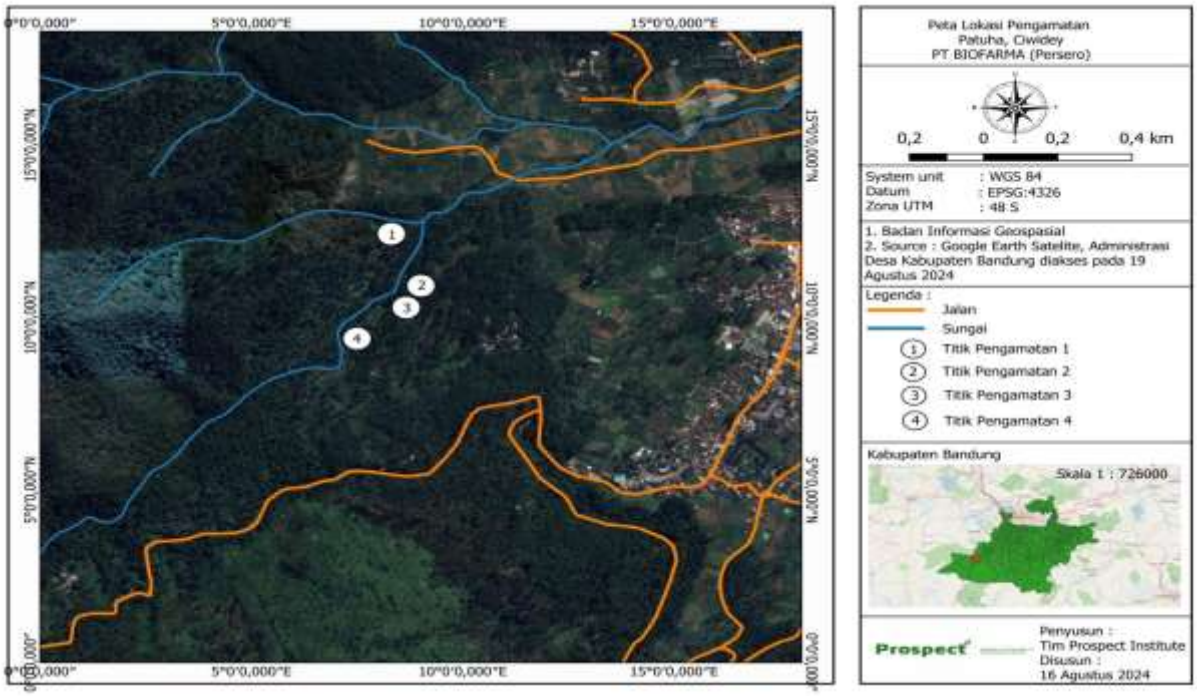


Figure 1. Image Siteplan Research of PT BioFarma (Persero) 2024

The site is characterized by a mixed agricultural ecosystem that includes coffee and vegetable plantations, alongside fragments of secondary forest and shrubland on the hills. The implementation of this research took place in July 2024 and utilized monitoring and evaluation documents from the 2019-2023 period.

3.2 Sampling Design

A systematic sampling method was employed to obtain representative biodiversity data for this study. This method involved analyzing both primary and secondary data concerning fauna, with a particular focus on species identified as having a high threat status. The fauna examined included dragonflies, butterflies, mammals, and herpetofauna. Data collection was executed using a combination of line transects and quadrat plots, as outlined by Kent and Coker (1992).

3.3 Species Identification

The species identification process was conducted meticulously through several stages. Specimens collected or observed in the field were identified using standard identification keys and field guides relevant to each respective taxa (e.g., Mackinnon et al., 2010 for birds; van Steenis, 2006 for plants). When necessary, additional verification was sought in consultation with taxonomists who specialize in particular groups of organisms to ensure the accuracy of identification. Following the completion of taxonomic identification, the conservation status of each species was thoroughly verified. This verification process referenced the IUCN Red List (IUCN, 2024) for global conservation status and the CITES Convention Appendices (CITES, 2023) for international trade status. Furthermore, national protected status was confirmed by the Minister of Environment and Forestry Regulation (Permen LHK) No. P.106/MENLHK/SETJEN/KUM.1/12/2018 concerning Protected Plant and Animal Species (Ministry of Environment and Forestry, 2018), which serves as the primary legal reference in Indonesia.

3.4 Biodiversity Index Analysis

The biodiversity data collected were subsequently analyzed quantitatively to calculate various biodiversity indices, including the Shannon-Wiener biodiversity index (H'), Margalef species richness index (R), and Pielou evenness index (E). Additionally, findings related to protected species will be presented in tabular form, detailing species names, taxonomic classification, national conservation status (as per Permen LHK P.106/2018), and global conservation status (as per the IUCN Red List).

3.5 Spatial Analysis

Spatial distribution maps will be created using Geographic Information Systems (GIS) to visually represent the locations of protected species, highlighting critical areas that require conservation efforts (ESRI, 2020). This spatial analysis also includes overlay analysis, which is essential for determining priority locations. Spatial overlay analysis entails combining two or more geographically distinct spatial data layers (thematic maps) to produce a new integrated output data layer. In the field of biodiversity, this analysis

allows researchers and policymakers to identify and analyze complex spatial relationships among various biotic and abiotic factors.

For example, a distribution map layer for endangered species can be overlaid with land cover maps, road network maps, and maps of protected areas. The results of this overlay can visually and quantitatively illustrate areas where a species' critical habitat intersects with high-risk human activities (e.g., forest encroachment or infrastructure development) or identify potential ecological corridors that connect fragmented conservation areas. Thus, it serves as a valuable tool for defining conservation priority areas (hotspots), assessing habitat suitability, and planning effective, data-driven natural resource management strategies (Longley et al., 2015). The application of this approach is crucial for informed decision-making that aims to mitigate threats to biodiversity and ensure sustainable spatial planning (ESRI, 2022).

**Result and Discussion**

1. Overview of Inventory Results

This research successfully identified a total of 58 distinct species of fauna in the diverse ecosystem of Lebak Muncang. These species were systematically categorized into four main groups: 11 species of dragonflies, comprising 141 individual specimens; 31 species of butterflies, represented by 106 individuals; seven species of mammals, with a total of 31 individuals; and nine species of herpetofauna, which included 33 individual specimens. Particularly noteworthy was the discovery of three protected species: the Javan leopard (**Panthera pardus melas**), classified as Endangered (EN) on the IUCN Red List; the Javan Surili (**Presbytis comata**), and the Javan Lutung (**Trachypithecus auratus**), both of which are classified as Vulnerable (VU). The presence of these rare and protected animals underscores that Lebak Muncang retains significant conservation value, despite its location being subjected to considerable human-induced pressures such as deforestation and urban development.

Table 2: Species of Dragonflies, Butterflies, Mammals, and Herpetofauna found in Lebak Muncang

| No. | Species Name | | Number | Conservation Status | | |
|---|---|---|---|---|---|---|
| | Latin Name | Local Name | | IUCN | CITES | P.106 |
| **Dragonflies** | | | | | | |
| 1 | *Pantala flavescens* | Capung-kembara buana | 16 | LC | NA | - |
| 2 | *Agriocnemis pygmaea* | Capung jarum kecil | 1 | LC | NA | - |
| 3 | *Coeliccia membranipes* | Capung jarum hutan | 2 | LC | NA | - |
| 4 | *Euphaea variegata* | Capung intan sunda | 21 | LC | NA | - |
| 5 | *Ischnura aurora* | Capung golden dartlet | 1 | LC | NA | - |
| 6 | *Orthetrum pruinosum* | Capung-sambar merah | 47 | LC | NA | - |
| 7 | *Orthetrum sabina* | Capung-sambar hijau | 10 | LC | NA | - |
| 8 | *Orthetrum testaceum* | Capung-sambar jingga | 15 | LC | NA | - |
| 9 | *Pseudagrion pruinosum* | Capung jarum metalik | 8 | LC | NA | - |
| 10 | *Rhodothemis rufa* | Capung merah punggung metalik | 8 | LC | NA | - |
| 11 | *Vestalis luctuosa* | Capung-hutan cahaya-biru | 12 | LC | NA | - |
| | | Number of individuals | 141 | | | |
| | | Number of species | 11 | | | |
| **Butterflies** | | | | | | |
| 12 | *Mycalesis mineus* | Dark brand bush brown | 24 | NE | NA | - |
| 13 | *Ariadne ariadne* | Angled castor | 1 | NE | NA | - |
| 14 | *Catopsilia pomona* | Lemon emigrant | 2 | NE | NA | - |

| No. | Species Name | | Number | Conservation Status | | |
|---|---|---|---|---|---|---|
| | Latin Name | Local Name | | IUCN | CITES | P.106 |
| 15 | *Catopsilia scylla* | Orange emigrant | 1 | NE | NA | - |
| 16 | *Cepora judith* | Orange gull | 1 | NE | NA | - |
| 17 | *Chersonesia rahria* | Maplet | 1 | NE | NA | - |
| 18 | *Delias belisama* | Jezebel butterfly | 4 | NE | NA | - |
| 19 | *Delias hiparate* | Painted jezebel | 2 | NE | NA | - |
| 20 | *Delias sp* | Jezebel | 4 | NE | NA | - |
| 21 | *Euploea mulciber* | Climena crow | 2 | VU | NA | - |
| 22 | *Eurema blanda* | Three-spot grass yellow | 6 | NE | NA | - |
| 23 | *Graphium agamemnon* | Tailed jay | 2 | NE | NA | - |
| 24 | *Graphium doson* | Common jay | 1 | NE | NA | - |
| 25 | *Graphium sarpedon* | Common bluebottle | 1 | LC | NA | - |
| 26 | *Hebomoia glaucippe* | Great orange-tip | 1 | NE | NA | - |
| 27 | *Hypolimnas bolina* | Great eggfly | 1 | NE | NA | - |
| 28 | *Ideopsis juventa* | Grey glassy tiger | 2 | NE | NA | - |
| 29 | *Jamides alecto* | Metallic cerulean | 1 | NE | NA | - |
| 30 | *Junonia atlites* | Grey pansy | 5 | NE | NA | - |
| 31 | *Junonia hedonia* | Brown pansy | 1 | NE | NA | - |
| 32 | *Leptosia nina* | Psyche | 1 | NE | NA | - |
| 33 | *Logania marmorata* | Pale mottle | 1 | NE | NA | - |
| 34 | *Melanitis phedima* | Dark evening brown | 3 | NE | NA | - |
| 35 | *Mycalesis sudra* | Sudra Bush-brown | 6 | NE | NA | - |
| 36 | *Papilio arjuna* | Arjuna peacock | 1 | NE | NA | - |
| 37 | *Papilio helenus* | Red helen | 5 | LC | NA | - |
| 38 | *Papilio memnon* | Great mormon | 2 | NE | NA | - |
| 39 | *Symbrenthia anna* | Jezter | 1 | NE | NA | - |
| 40 | *Symbrenthia hypselis* | Himalayan Jester | 1 | NE | NA | - |
| 41 | *Telchinia issoria* | Yellow coster | 1 | NE | NA | - |
| 42 | *Ypthima pandocus* | Common three-ring | 21 | NE | NA | - |
| | | Number of individuals | 106 | | | |
| | | Number of species | 31 | | | |

| No. | Species Name | | Number | Conservation Status | | |
|---|---|---|---|---|---|---|
| | Latin Name | Local Name | | IUCN | CITES | P.106 |
| **Mammals** | | | | | | |
| 43 | *Callosciurus notatus* | Bajing kelapa | 9 | LC | NA | - |
| 44 | *Panthera pardus ssp.melas* | Macan tutul jawa | 1 | EN | II | Protected |
| 45 | *Presbytis comata* | Surili jawa | 2 | VU | NA | Protected |
| 46 | *Sus scrofa* | Babi hutan | 5 | LC | NA | |
| 47 | *Trachypithecus auratus* | Lutung jawa | 6 | VU | II | Protected |
| 48 | *Tupaia javanica* | Tupai kekes | 7 | LC | NA | - |
| 49 | *Urva javanica* | Garangan jawa | 1 | LC | NA | - |
| | | Number of individuals | 31 | | | |
| | | Number of species | 7 | | | |
| **Herpetofauna** | | | | | | |
| 50 | *Eutropis multifasciata* | Kadal kebun | 1 | LC | NA | - |
| 51 | *Bronchocela cristatella* | Bunglon jambul hijau | 1 | LC | NA | - |
| 52 | *Chalcorana chalconota* | Katak pohon bergaris | 10 | LC | NA | - |
| 53 | *Cyrtodactylus marmoratus* | Cecak jari lengkung jawa | 1 | LC | NA | - |
| 54 | *Hemiphyllodactylus typus* | Tokek cebol | 2 | NE | NA | - |
| 55 | *Limnonectes kuhlii* | Bangkong tuli | 12 | LC | NA | - |
| 56 | *Odorrana hosii* | Kongkang racun | 3 | LC | NA | - |
| 57 | *Polypedates leucomystax* | Katak pohon bergaris | 1 | LC | NA | - |
| 58 | *Wijayarana masonii* | Kongkang jeram | 2 | LC | NA | - |
| | | Number of individuals | 33 | | | |
| | | Number of species | 9 | | | |

Source: Index Biodiversity Report 2024

2. Biodiversity Level

Comprehensive analysis of the identified fauna groups reveals that they possess a moderate level of biodiversity, as indicated by Shannon-Wiener index values that range from 1.71 to 2.77. Among these groups, butterflies exhibited the highest species richness, with a value of 6.43, indicating a thriving diversity in this category. Conversely, mammals and herpetofauna displayed relatively lower species richness levels, indicating potential ecological concerns. These findings suggest that, although the ecosystem in Lebak Muncang is not currently in a state of crisis, it has not yet achieved optimal environmental health. The abundance of butterfly species is likely linked to a rich availability of nectar-producing plants. In contrast, the limited diversity of mammals can be attributed mainly to ongoing human activities, such as agricultural expansion and habitat fragmentation, which disrupt their natural environments.

Table 3: Analysis Results of Diversity Index (H'), Evenness Index (E), and Species Richness Index (R)

| No | Taksa | H’ | E | R |
|---|---|---|---|---|
| 1 | Dragonflies | 1,99 | 0,83 | 2,02 |
| 2 | Butterflies | 2,77 | 0,81 | 6,43 |
| 3 | Mammals | 1,71 | 0,88 | 1,75 |
| 4 | Herpetofauna | 1,71 | 0,78 | 2,29 |

Source: Analysis Prospect Institute 2024

3. Important Species Discovered

The Javan leopard serves as an apex predator within its ecosystem, playing a crucial role in regulating prey populations and thereby maintaining ecological balance. The Javan Surili and Javan Lutung play a significant role as seed dispersers, facilitating forest regeneration and serving as bioindicators for assessing forest health and biodiversity. These species are predominantly found in secondary forest areas that have remained relatively intact amidst surrounding human activity. Their presence serves not only as an ecological indicator of habitat integrity but also demonstrates that Lebak Muncang continues to provide suitable environments for rare and sensitive wildlife species.

4. Priority Areas for Conservation

Based on thorough spatial analysis, three conservation priority zones have been delineated: (1) a core zone located in the forested hills that serves as a critical habitat for rare and endangered animals; (2) a buffer zone characterized by high diversity of butterfly species, which presents substantial potential for ecotourism initiatives; and (3) connecting corridors that link fragmented habitats, promoting genetic exchange and population viability among wildlife. The generated conservation map highlights the need to preserve these ecological corridors to maintain connectivity and support biodiversity within the remaining habitat fragments.

5. Challenges and Recommendations

The primary threats to biodiversity in Lebak Muncang stem from agricultural expansion, illegal hunting, and habitat fragmentation resulting from infrastructure development. To mitigate these threats, several strategic measures must be implemented: first, enhancing legal protections and enforcement in the core conservation zone to safeguard rare species; second, initiating restoration projects that involve planting native food sources to re-establish ecological corridors; and third, fostering community engagement through sustainable ecotourism activities that support local livelihoods while promoting conservation efforts. The most significant challenge remains the management of human-wildlife conflicts, which can arise from competition for resources. However, the most incredible opportunity exists in forging strong partnerships with established conservation organizations that are already active in the region, enabling more robust and collaborative conservation strategies.

## 4. CONCLUSION

Biodiversity research conducted in the diverse ecosystem of Lebak Muncang, located in Ciwidey, Bandung Regency, identified a remarkable 58 species of fauna categorized into four primary groups: dragonflies (11 species), butterflies (31 species), mammals (7 species), and herpetofauna (9 species). The analyses revealed that the ecosystems in this region exhibit moderate biodiversity, as evidenced by a Shannon-Wiener index (H') ranging from 1.71 to 2.77. This range suggests a relatively balanced variety of species, complemented by a high evenness of species distribution, indicated by a Pielou index (E) greater than 0.78.

Among these groups, butterflies were particularly notable, showcasing the highest species richness, as reflected in a Margalef R index of 6.43. This finding implies that the habitat in Lebak Muncang continues to sustain a vibrant and diverse butterfly population, which is crucial for pollination and maintaining ecological balance. Conversely, the mammal and herpetofauna groups demonstrated lower species richness, which suggests potential environmental pressures, such as habitat fragmentation, deforestation, and other human-induced disturbances.

A critical aspect of this study was the identification of three protected species within the area: the Javan leopard (Panthera pardus melas), categorized as Endangered (EN) by the International Union for Conservation of Nature (IUCN); the Javan surili (Presbytis comata), designated as Vulnerable (VU); and the Javan langur (Trachypithecus auratus), also classified as Vulnerable (VU). The presence of these endemic Javanese primates significantly enhances the conservation value of Lebak Muncang, as they play vital ecological roles, including seed dispersal and serving as indicators of forest health, which are essential for the ecosystem's sustainability.

The rehabilitation initiatives undertaken by Bio Farma, in collaboration with local communities and various environmental organizations, exemplify proactive conservation efforts in Lebak Muncang. These initiatives highlight the necessity for long-term monitoring and rigorous habitat protection to ensure the survival of both flora and fauna in the region.

Based on previous research, several solutions can be implemented to preserve endangered species such as Panthera pardus as key species in Lebak Muncang. These include:

- Re-structuring the access zone of utilization (Natural Resources).
- Limiting anthropogenic activities.

Specifically, in the conservation area of Lebak Muncang, the zoning of utilization should involve re-structuring access. The local government and stakeholders (e.g., PT BioFarma), as indicated by prior research, can redefine the boundaries for some key species, where their habitats (including mammals, butterflies, dragonflies, and herpetofauna) have been fragmented by agricultural land use or residential development.

This fragmentation results in limited home ranges and increases the risk of inbreeding, which can reduce the survivability of offspring. Additionally, human activities such as hunting pose a significant threat, putting key animals in Lebak Muncang at risk of extinction. Immediate protective measures are essential to prevent this (Hernawan, 2025).

Therefore, the mitigation of restricted areas in Lebak Muncang should be achieved through physical segregation measures. The implementation of a strict and adaptive zoning system is an important strategy to preserve ecosystems and provide space for nature to recover. Zoning can be divided into three areas: a core conservation zone (for sensitive habitats and key resources), a limited-use zone (for research and education), and a sustainable tourism zone (with low-impact facilities and educational approaches). Each zone must be supported by clear spatial boundaries, land-use regulations, and integrated monitoring involving both local communities and authorities.

A study by Zeng et al. (2012), on the Wolong Nature Reserve and Wuliangsuhai wetlands in China demonstrated that zoning can effectively protect biodiversity when accompanied by proper design and active management, including access restrictions and protection during critical biological periods. With this structured and participatory approach, the Patuha area holds the potential to be wisely managed in a way that supports ecotourism and the local economy without compromising its ecological functions.

- **Ecological and Social Mapping:**
  The first step is to map the biophysical and social conditions of the Patuha area, including sensitive habitats, watercourses, and community activities, in order to determine zones that are ecologically and culturally appropriate.
- **Establishment of Zoning Areas:**
  Based on the mapping results, define the boundaries of the core conservation zone, limited-use zone, and sustainable tourism zone in a legal and participatory manner, using digital maps and involving local community participation.
- **Development of Regulations and Guidelines:**
  Formulate rules for the use of each zone, including activity limits, prohibitions, and penalties for violations, to ensure compliance with the ecological functions of each area.
- **Development of Environmentally Friendly Infrastructure:**
  Public facilities should only be built in the tourism zone, with low-carbon designs such as interpretive trails, educational signboards, and observation points, without disrupting the core and limited-use zones.
- **Training for Staff and Local Communities:**
  Train field staff and community members to serve as guides, monitors, and educational facilitators in order to strengthen participatory and sustainable management capacity.
- **Regular Monitoring and Evaluation:**
  Conduct regular monitoring of ecosystem conditions, visitor impacts, and biodiversity changes to evaluate the effectiveness of zoning and inform data-driven improvements.
- **Implementation of Visitor Quotas and Ecological Calendars:**
  Apply a system of visitor limits and scheduled access based on key biological seasons—such as mating, nesting, or flowering periods—to avoid disrupting natural cycles.
- **Conservation Awareness and Education:**
  Provide on-site information materials and organize educational activities and public campaigns to help visitors and local residents understand the importance of zoning and conservation functions.
- **Multi-Stakeholder Partnerships:**
  Establish collaboration with government bodies, Indigenous communities, academics, and NGOs to support collaborative management and ensure the long-term sustainability of the zoning program.

Overall, the findings of this study underline the importance of implementing data-driven management strategies to preserve and enhance biodiversity in Lebak Muncang. Key recommendations include utilizing spatial analysis (GIS) to map conservation priorities and pinpoint critical areas in need of protection, restoring ecological corridors to mitigate the impacts of habitat fragmentation, and fostering increased community involvement in ecosystem-based conservation programs. Through the adoption of these proactive measures, it is possible to maintain and enhance biodiversity in Lebak Muncang, thereby safeguarding the ecological balance and ensuring the sustainability of natural resources for future generations.

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