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The Effects of Tourist Activities on Bird Species Diversity in the Tambing Lake Area, Lore Lindu National Park, Central Sulawesi, Indonesia

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Abstract: The increase in tourism activity in the Lake Tambing area has the potential to put pressure on the ecosystem, especially on wildlife that is sensitive to human disturbance. Lake Tambing located in Lore Lindu National Park, Central Sulawesi, is an area of high ecological value and home to a variety of endemic flora and fauna. This study aimed to analyze the potential of fauna, particularly bird populations, as indicators of ecological conditions and to observe the impact of tourism activities on bird diversity. The study was conducted from February to June 2025 at the camping ground and on the trackings trail using the line transect method. Data analysis included the Shannon-Wiener diversity index, evenness index, dominance index, and t-tests for comparisons between habitats. The study identified 56 bird species from 30 families, of which 26 are endemic to Sulawesi. Diversity index values ranged from 2.79 to 3.28, indicating moderate to high levels of diversity. Statistical tests showed that tourist activity had no significant impact on bird diversity in either habitat type. This indicates that anthropogenic disturbance at Lake Tambing remains at a low level. These findings provide an important scientific basis for sustainable tourism practices, standardization of birdwatching site design, and effective endemic species conservation efforts in the Lake Tambing area.

Keywords: Bird diversity; Carrying capacity; Ecotourism; Environmental; Lake Tambing, Lore Lindu National Park

Introduction

Conservation areas play a crucial role in maintaining ecosystem sustainability and biodiversity. In addition to serving as protected areas, conservation areas also have the potential to be developed as ecotourism-based nature destinations. One such area is Lake Tambing, located within the Lore Lindu National Park (TNLL) in Central Sulawesi. Lake Tambing is a highland lake located at an elevation of approximately 1.700 meters above sea level and covers an area of approximately 15 hectares. This area boasts relatively pristine environmental conditions and serves as a habitat for various endemic flora and fauna of Sulawesi. The diversity of fauna, particularly birds, makes this area a key location for birdwatching. Biodiversity is a key indicator in assessing the quality and stability of an ecosystem. High levels of species diversity indicate that the ecosystem has relatively stable environmental conditions and is able to provide sufficient resources for the various organisms living within it. In ecological studies, birds are often used as bioindicators due to their high sensitivity to changes in habitat conditions and vegetation structure (Parmar et al., 2016; Dietenberger et al., 2025). Bird communities also play a crucial role in maintaining ecosystem balance, particularly in pollination, seed dis`persal, and insect population

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control. According to Ramos-Mosquera et al. (2025) and Suarez-Castro et al. (2024), the presence of various bird guilds, such as insectivores, frugivores, and nectarivores, can reflect the complexity of an area's habitat structure. Therefore, studies of bird diversity are often used to evaluate the condition of forest ecosystems and conservation areas.

Birdwatching is a form of sustainable ecotourism that involves observing and identifying birds in their natural habitat. According to Samal et al. (2023) and Pollard et al. (2023), this ecotourism activity is the fastest-growing and most environmentally friendly. This is due to several reasons, such as its wide accessibility, minimal equipment requirements, and the birds' wide distribution (Sisriany & Furuya, 2025; Salman et al., 2020), which have made ecotourism one of the most popular nature-based recreational activities worldwide (Yang et al., 2025; Randler & Dutour, 2025). Birdwatching has rapidly grown as a popular recreational activity worldwide, including in China (Sánchez-Rivero et al., 2020; Stemmer et al., 2022). This growth aligns with the current rapid global economic development, rising education levels, and growing environmental awareness. Birdwatching tourism has significantly increased local income, improved environmental well-being, and contributed to local wildlife conservation efforts (Liu et al., 2021; Fardell et al., 2021). The continued popularity and growth of Lake Tambing tourism has also led to an increase in the number of participants and the scale of birdwatching in the area. Therefore, the impact of human activities during birdwatching on the survival and diversity of bird species gradually requires special and significant attention. To assess whether human activities affect wildlife, it is necessary to examine whether these activities affect the diversity of bird species in the area.

According to Zhang et al. (2026) and De Santis et al. (2023), it is crucial to evaluate whether human activities significantly impact the overall population parameters of species. Initially, human-induced disturbance was considered to have a negative impact, as it can increase the likelihood of predators finding nests. According to Rogers et al. (2023), tourism is an important form of urbanization, which is increasingly popular today and offers numerous benefits to communities. However, it is crucial to consider its diverse impacts on wildlife, especially local birds. They found that Eurasian tree sparrows in tourist areas exhibited shorter Flight Initiation Distances (FID) than those in non-tourist areas, indicating that Eurasian tree sparrows inhabiting areas with higher levels of human disturbance exhibit greater adaptability to anthropogenic disturbance. One of the most important aspects to consider when considering tourism within conservation areas is its impact on local bird populations. Birds play a crucial role as indicator species in assessing the health and biodiversity of an ecosystem. Bird populations demonstrate how human activities, including tourism, can affect their habitats and the surrounding environment. Several previous studies on the general impacts of tourism on natural habitats (Brandt & Buckley, 2018) including in Indonesia, have been limited to examining species diversity and the conservation status of bird populations in mountainous areas, including the impact of mountain climbing tourism on bird species (Abdullah et al., 2024; Wambugu et al., 2025).

Previous research on the impacts of tourism has largely focused on protected areas or tourist attractions, rarely examining other areas in the surrounding area that are not tourist attractions. Therefore, it is necessary to explore bird species diversity in response to varying levels of visitor disturbance in tourist areas, which will contribute to a more comprehensive understanding of the impacts of tourism activities on local birds. The increase in tourism activity in the Lake Tambing area has the potential to put pressure on the ecosystem, especially on wildlife that is sensitive to human disturbance. One of the tourist activities at Lake Tambing is bird watching. Therefore, a study of bird diversity is necessary as an indicator of ecosystem health and as a basis for sustainable Lake Tambing tourism management.

Method

The research was conducted from February to June 2025 in the Tambing Lake tourist area, Lore Lindu National Park. Administratively, this lake is located in Sedoa Village, North Lore District, Poso Regency, Central Sulawesi, Indonesia. This area is part of the Lore Lindu National Park management area with coordinates 1° 11′ 24″ S and 120° 10′ 48″ E at an altitude of approximately 1,700 meters above sea level. A map of the research location is presented in Figure 1 below.

Figure 1. Map of research location

Research Methods

This research is a descriptive study using field observation and a roaming method. Observations were conducted at two types of bird habitats in the Danu Tambing area: camping grounds (CG) and tracking trails (JT). At each research location, bird data were collected using the strip transect method. The observation trail was 1 km long and 50 meters wide (25 meters on the right and left sides of the trail). Observations were then conducted along the designated trail, directly recording the bird species encountered. Observations were repeated four times along each trail. A 30-minute time limit was set for each point before moving on to the next point. Bird observations were conducted using Nikon 8x40 binoculars, a Canon SX 430is camera with 45x magnification, and a Nikon D300s camera with a Nikon lens with 600x magnification. Bird identification was based on (Husby et al., 2025; H. Wang et al., 2022). Bird species identification was carried out using the guidebook by Dendup et al. (2021) and Gavali et al. (2025). Species diversity in bird communities is generally measured using ecological indices such as the Shannon-Wiener diversity index (H'), the evenness index (E), and the Simpson dominance index (D). The Shannon-Wiener index, developed by Claude Shannon, is widely used in ecological studies because it describes the combination of the number of species and the abundance of individuals within a community. Meanwhile, the dominance index, introduced by Fukaya et al. (2020) and Y. Wang et al. (2024), is used to determine the level of dominance of a particular species within a community.

Data Analysis

Data analysis was performed using the Shannon-Wiener diversity index (H'), the evenness index (E), and the dominance index (D). A statistical t-test was also conducted to examine differences in diversity indexes between habitat types and visitor activity conditions. Data analysis was performed using several indices that measure the extent of the diversity of the species in question. The indices used include:

Species Diversity Index (H')

To measure bird species diversity, the Shannon-Weaver index (1949) in (Wei et al., 2025) was used, using the formula:

$$H' = - \Sigma (pi \ln pi) \quad (1)$$

Description:
H' = Shannon-Weaver diversity index
pi = Proportion of individuals of the i-th species to the total number of individuals
ln = Natural logarithm

Evenness Index (E)

The evenness index is used to determine the evenness of each species in each community encountered. The formula is:

$$E = \frac{H'}{\ln S} \quad (2)$$

Description:
E = Evenness Index
H' = Shannon-Wiener Index
S = Number of Species
Ln = Natural Logarithm

Simpson's Dominance Index (D)

To determine the dominance value that determines or establishes dominant, subdominant, or non-dominant bird species in an observation route, the Simpson (1949) dominance index formula is used:

$$D = \Sigma \left(\frac{ni}{N}\right) \quad (3)$$

Description:
D = Dominance index
ni = Number of individuals of the i-th species
N = Total individuals of all species

Result and Discussion

The results in Table 1 show that 56 bird species belonging to 30 families were recorded in the Tambing Lake tourist area. Of these, 26 are endemic to Sulawesi. The families with the largest number of species include Columbidae, Cuculidae, and Muscicapidae.

Table 1. Species Composition and Bird Diversity Index Values in Two Habitat Types and Three Tourist Visit Conditions in the Tambing Lake Area

Types of Birds	Latin Name	Family	National holiday		Weekend		Non-Visitors	
			CG	JT				
Remetuk laut	*Gerygone sulphurea*	*Acanthizidae*	2	1	1	2	3	2
Elang-alap kepala-kelabu	*Accipiter griseiceps**	*Accipitridae*	0	0	0	1	0	0
Elang-ikan kecil	*Icthyophaga humilis* (NT)	*Accipitridae*	0	0	0	0	1	1
Elang sulawesi	*Nisaetus lanceolatus**	*Accipitridae*	1	2	0	1	1	1

Types of Birds	Latin Name	Family	National holiday		Weekend		Non-Visitors	
Elang-ular sulawesi	*Spilornis rufipectus**	*Accipitridae*	0	0	0	0	1	0
Cekakak sungai	*Todiramphus chloris*	*Alcedinidae*	1	1	1	0	1	2
Walet polos	*Aerodramus vanikorensis*	*Apodidae*	0	0	0	1	4	4
Walet sapi	*Collocalia esculenta*	*Apodidae*	5	1	0	0	0	0
Cangak merah	*Ardea purpurea*	*Ardeidae*	0	0	0	0	2	0
Kapasan sulawesi	*Lalage leucopygialis**	*Campephagidae*	0	0	0	0	1	1
Kepudang-sungu biru	*Coracina temminckii**	*Campephagidae*	3	0	3	1	3	3
Kepudang	*Coracina sp.**	*Campephagidae*	0	0	0	2	0	0
Kepudang-sungu kerdil	*Coracina abbotti**	*Campephagidae*	0	0	1	1	0	0
Pergam tutu	*Ducula forsteni*	*Columbidae*	0	0	0	1	0	0
Uncal ambon	*Macropygia amboinensis*	*Columbidae*	3	0	0	0	2	0
Walik kembang	*Ptilinopus melanospila*	*Columbidae*	0	1	0	0	0	2
Walik-kuping merah	*Ptilinopus fischeri*	*Columbidae*	1	0	1	0	0	1
Walik raja	*Ptilinopus superbus*	*Columbidae*	0	0	4	1	0	2
Gagak sulawesi	*Corvus typicus**	*Corvidae*	0	0	0	2	0	0
Kadalan sulawesi	*Rhamphococcyx calyorhynchus**	*Cuculidae*	0	0	1	0	1	2
Kedasih hitam	*Surniculus lugubris*	*Cuculidae*	0	2	0	2	2	2
Kedasih laut	*Chalcites minutillus*	*Cuculidae*	0	0	0	0	1	0
Tuwur asia	*Eudynamis melanorhynchus*	*Cuculidae*	0	3	0	0	0	0
Wiwik uncuing	*Cacomantis sepulcralis*	*Cuculidae*	1	0	0	1	1	1
Cabai panggul-kuning	*Dicaeum aureolimbatum**	*Dicaeidae*	2	0	0	0	0	8
Cabai sulawesi	*Dicaeum nehrkorni**	*Dicaeidae*	0	0	2	2	1	2
Srigunting	*Dicrurus montanus**	*Dicruridae*	1	2	3	1	1	1
Tepekong jambul	*Hemiprocne longipennis*	*Hemiprocnidae*	0	0	0	0	2	2
Layang-layang batu	*Hirundo javanica*	*Hirundinidae*	0	2	0	0	0	0
Cikarak sulawesi	*Myza celebensis**	*Meliphagidae*	0	0	1	1	0	0
Cikarak telinga putih	*Myza sarasinorum**	*Meliphagidae*	1	0	0	1	1	0
Myzomela merah-tua	*Myzomela boiei*	*Meliphagidae*	10	0	0	8	2	2
Cirik-cirik sulawesi	*Meropogon forsteni**	*Meropidae*	2	2	2	2	0	2
Kehicap sulawesi	*Hypothymis puella**	*Monarchidae*	1	0	0	0	0	0
Sikatan belang	*Ficedula westermanni*	*Muscicapidae*	0	2	0	0	0	0
Sikatan bodoh	*Ficedula hyperythra*	*Muscicapidae*	2	2	0	1	0	0
Sikatan dahi-biru	*Cyornis hoevelli**	*Muscicapidae*	0	2	4	0	0	0
Sikatan matari	*Culicicapa helianthea*	*Muscicapidae*	7	9	4	2	0	8
Sikatan pulau	*Eumyias panayensis*	*Muscicapidae*	4	0	2	1	2	2
Burung-madu sepah-raja	*Aethopyga sepahraja*	*Nectariniidae*	0	0	0	1	0	0
Kepodang kuduk-hitam	*Oriolus chinensis*	*Oriolidae*	3	1	2	2	2	2
Kancilan perut-kuning	*Pachycephala sulfuriventer**	*Pachycephalidae*	3	5	1	2	2	2
Caladi sulawesi	*Dendrocopos temminckii**	*Picidae*	0	0	2	0	2	0
Kring-kring bukit	*Prioniturus platurus**	*Psittaculidae*	0	6	0	2	9	9
Perkici kuning-hijau	*Trichoglossus flavoviridis**	*Psittaculidae*	8	21	8	6	3	6
Serindit sulawesi	*Loriculus stigmatus**	*Psittaculidae*	0	2	5	0	1	0
Kareo padi	*Amaurornis phoenicurus*	*Rallidae*	0	0	0	1	0	0
Kipasan sulawesi	*Rhipidura teysmanni*	*Rhipiduridae*	5	3	3	2	2	0
Trinil pantai	*Actitis hypoleucos*	*Scolopacidae*	0	0	0	0	9	9
Jalak alis-api	*Enodes erythrophris**	*Sturnidae*	4	0	2	1	9	7
Cinenen gunung	*Orthotomus cucullatus*	*Sylviidae*	1	7	0	2	4	0
Malia sulawesi	*Malia grata**	*Timaliidae*	1	2	1	0	0	1
Pelanduk sulawesi	*Trichastoma celebense**	*Timaliidae*	3	2	3	1	2	2
Anis geomalia	*Geomalia heinrichi**	*Turdidae*	1	0	0	0	0	0
Kacamata dahi hitam	*Zosterops atrifrons*	*Zosteropidae*	0	2	0	2	0	0
Kacamata gunung	*Zosterops montanus*	*Zosteropidae*	0	0	0	1	1	1

Description: CG = Camping Ground; JT = Tracking Route; * = Sulawesi endemic species; Bold numbers = dominant species; NT = Near Threatened

The diversity index values ranged from 2.79 to 3.28, indicating a moderate to high diversity category. Evenness values ranged from 0.87 to 0.94, indicating a relatively even distribution of individuals across species. Several examples of bird species found in the Lake Tambing tourist area are presented in Figure 2.

Figure 2. Some examples of bird species found in the Tambing Lake tourist area

Table 2. Bird Ecology Index in Two Habitat Types and Three Tourist Visit Conditions in the Tambing Lake Area

Parameters	CG National Holidays	National Holidays JT	Weekend CG	JT Weekend	Non-CG Visitors	Non-Visitors JT
Total Individuals	76	85	57	58	71	98
Total Species	26	25	23	33	28	34
Diversity Index (H')	2.98	2.79	2.94	3.28	3.07	3.19
Evenness Index (E)	0.92	0.87	0.94	0.94	0.92	0.91
Species Dominance	7	5	8	2	4	6

Furthermore, the bird ecological index for two habitat types and three tourist visit conditions in the Tambing Lake area is presented in Table 2. The research results in Table 2 indicate that the tracking trail habitat has a higher bird species diversity index than the camping ground area. This is likely due to the relatively lower human activity on the tracking trail, resulting in less disturbance to the animals. Furthermore, a comparison between national holidays, weekends, and days without visitors indicates that tourist activity does not significantly impact the bird diversity index. Statistical tests indicate that the differences are insignificant.

Table 3. Bird Diversity Index Values under Various Observation Conditions

Observation Conditions	Habitat	Total Individuals	Total Species	Diversity Index (H')	Equity Index (E)	Dominance (D)
National Holidays	Camping Ground	76	26	2.98	0.92	7
National Holidays	Jalur Tracking	85	25	2.79	0.87	5
Weekends	Camping Ground	57	23	2.94	0.94	8
Weekends	Jalur Tracking	58	33	3.28	0.94	2
Non-Visitors	Camping Ground	71	28	3.07	0.92	4
Non-Visitors	Jalur Tracking	98	34	3.19	0.91	6

Description: H' = Shannon-Wiener Diversity Index; E = Evenness Index; D = Dominance Index; CG = Camping Ground; JT = Tracking Route

Nevertheless, some changes in bird behavior were observed. As visitor numbers increased, some species tended to arrive earlier and their activity durations became shorter. This indicates a behavioral response to human presence. The results of the t-test for bird diversity indices between habitats in the Tambing Lake area are presented in Table 4 below.

Table 4. Results of the t-Test of the Bird Diversity Index Between Habitats

Habitat Comparison	H' Habitat 1	H' Habitat 2	t count	t table (α = 0.05)	Description
CG vs. JT National Holidays	2.98	2.79	0.41	2.02	Not significantly different
CG vs. JT Weekends	2.94	3.28	0.73	2.02	Not significantly different
CG vs. JT Non-Visitors	3.07	3.19	0.25	2.02	Not significantly different

The t-test results (α = 0.05) in Table 4 above indicate no significant difference in the bird diversity index between the camping ground (CG) and tracking trail (JT) habitats under various tourist conditions, including national holidays, weekends, and when there are no visitors. However, conditions when there are no visitors show higher diversity index values than when there are many visitors, such as national holidays and weekends. The relatively natural habitat conditions and dense vegetation allow birds to avoid disturbance without having to permanently abandon their habitat. The difference in the number of bird species found in the two habitat types is highly dependent on the number of visitors, which of course affects the presence of birds in the Lake Tambing tourist area. This is confirmed by Tu et al. (2020) and Xu et al. (2022) who stated that diverse habitat types also influence the number of bird species found, as well as human activity within the habitat. Another factor that can influence the difference in the number of bird species found is the constant playing of music during tourist visits. This has disturbed several bird species that are sensitive to sound, causing them to migrate to more suitable locations (Machar et al., 2025; Gumede et al., 2022). The ecological index classification of birds in the Lake Tambing area is presented in Table 5.

The results of the ecological index analysis in Table 5 indicate that the level of bird diversity in the Tambing Lake area is classified as moderate to high, with Shannon index values ranging from 2.79 to 3.28. A high evenness value (0.87–0.94) indicates a relatively even distribution of individuals across species and not dominated by any one species. Statistical tests show that the calculated t-value is smaller than the tabulated t-value, indicating no significant difference between the bird diversity indices in the camping ground and tracking trail habitats. This indicates that tourism activities in the Tambing Lake area still pose a low level of disturbance to the bird community. These results align with those of Yang et al. (2025) and Davison et al. (2022), who found that anthropogenic disturbance from birdwatching tourism had no significant impact on hornbills or their breeding success rates, nor did they affect their locomotor behavior, preening, or social behavior in Yunnan Province, China.

Table 5. Ecological Index Classification of Birds in the Lake Tambing Area

Ecological Parameters	Value	Category
Diversity Index (H')	2.79 – 3.28	Medium – High
Evenness Index (E)	0.87 – 0.94	High Evenness
Dominance Index (D)	2 – 8%	Low Dominance

However, they found that disturbance significantly affected breeding behavior, particularly during the pre-nesting period, with weaker effects observed during the nesting period. Overall, the impacts of birdwatching activities at birdwatching stations are complex and multifaceted, with disturbance and protective effects occurring simultaneously without overriding each other

during the breeding period. Furthermore, Huang et al. (2023) and Engel et al. (2024) examined the impact of anthropogenic disturbance caused by photographers on blue-crowned laughingbirds (Pterorhinus courtoisi) in Wuyuan, Jiangxi Province, China. They reported that disturbance from photographers made these birds more cautious in selecting nest sites and increased nest heights, potentially exacerbating the species' endangered status.

This contrasts with the results of Slater et al. (2019), who reported their ordination analysis of bird communities, which showed a clear stratification of species composition between highly visited and less visited routes. Rarely visited trails on Mount Prau, Central Java, Indonesia, provide habitat for a variety of endemic species and birds with high conservation status, while highly visited trails show reduced bird diversity. These findings underscore the negative impact of mountain tourism on bird biodiversity in this mountainous region. They also indicate the need for conservation strategies to balance mountain tourism with biodiversity preservation on Mount Prau. Such strategies should limit visitor numbers, control access in sensitive areas, and implement ecotourism methods that support wildlife. According to Mmbaga et al. (2024), in ecotourism, tourist activities, including bird watching, generally take place in natural habitats with abundant predator populations. The presence of tourists, especially bird watchers, does not always have a negative impact; in fact, it can act as a deterrent to predatory birds, indirectly reducing the threat of predation on the bird populations they prey upon.

The results of this research will have significant implications for ecotourism management in the Lake Tambing area and other areas with similar status. According to Siregar et al. (2025), mitigating the negative effects of tourism activities on bird species can be done by limiting the number of visitors and their access to sensitive areas and practicing impact reduction plans. Qosyim et al. (2021) and Nurmawan et al. (2025) emphasized that developing ecotourism activities that promote wildlife-friendly practices, such as bird watching tours involving trained guides, can help foster a more beneficial relationship between tourism and biodiversity conservation efforts.

Conclusion

Soil characteristics in the habitat of *Gymnostoma rumphianum* (Miq.) L.A.S. Johnson in Tojo Una-Una Regency demonstrate a close relationship between physical and chemical properties in determining soil fertility. Soil texture is the primary controlling factor, with sandy soil in Betaua Village exhibiting lower bulk density, higher permeability, and lower water content, while finer-textured soil in Podi Village exhibits the opposite. Chemically, the soil at all locations has an alkaline pH (8.05–8.28), which reduces phosphorus availability, making this element the primary limiting factor. Nitrogen and organic carbon contents are low to moderate, with variations influenced by organic matter conditions and decomposition processes, as reflected in the C/N ratio. Meanwhile, potassium is relatively available and not a limiting factor, and the low DHL value indicates the absence of salinity stress in the soil. Future research is recommended to examine different locations and soil depths to obtain a more comprehensive picture of the soil characteristics in this habitat.

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Author Contributions

Conceptualization.; methodology.; Y.; validation; S. S.; formal analysis.; investigation; resources.; A. A.; data curation.; writing—original draft preparation.; writing—review and editing.; R. W.; visualization: S. N. Alls authors have read and agreed to the published version of the manuscript.

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