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Avifaunal Diversity and Conservation Challenges in the Magat Wetland of the Philippines: Assessing the Impacts of Habitat Loss and Management Strategies

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Simple Summary: The study on the Magat Wetland areas in the Philippines highlights their importance as habitats for a diverse avifaunal population, including both endemic and migratory bird species. Key findings reveals that the Philippine duck (*Anas luzonica*), an endemic bird, is abundant, indicating favorable conditions. However, threats from habitat loss, climate change, and human activities such as aquaculture and tourism put pressure on these bird populations. Conservation efforts by local government and communities, including the development of a bird-watching site, have supported preservation, though unregulated activities still impact habitats. The study calls for sustained conservation, community engagement, and stricter policies to protect these areas.

Abstract: This study investigates avifaunal diversity in the Magat Wetland areas in the Philippines, which serve as habitats for both endemic and migratory bird species. Using transect surveys and data from Department of Environment and Natural Resources (DENR), the research recorded 24 bird species, with dominant populations of *E. garzetta* and *A. luzonica*. Moderate avifaunal diversity, reflected in a Shannon-Wiener Diversity Index of 1.62, suggests an ecologically stable environment with critical resources supporting both abundant and rare species. However, pressures from habitat loss due to aquaculture, agricultural expansion, and tourism activities pose ongoing challenges for conservation. Local government efforts, including the establishment of a bird-watching site and eco-tourism initiatives, have raised awareness and engaged communities in conservation. Statistical modeling revealed that for each 1% increase in forest cover, the avian population is expected to increase by about 84 individuals, holding other factors constant. This highlights forest cover loss as a key factor affecting avifaunal populations, underscoring the importance of habitat preservation. Future research should focus on understanding the impact of human activities, climate change, and habitat quality on bird populations. This research underlines the critical role of the Magat Wetland as a biodiversity hotspot, advocating for sustainable management practices to preserve its ecological integrity amid increasing human development pressures.

Keywords: diversity; conservation: wetland

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1. Introduction

The Philippines, a tropical country, is gifted with megadiverse flora and fauna with high endemism; sadly, it is also a region that undergoes an exceptionally great level of deforestation, habitat destruction, and biodiversity exploitation [1]. The Magat Wetland areas are prone to anthropogenic activities; this includes commercial-scale fish cage farming and agricultural corn-based farming around the land surrounding the areas. As a result of these human-induced actions, the conversion of forest into agricultural uses is very common. This is exacerbated by climate change; various studies have revealed the probable influence of climate change on water chemistry, quality, and volume in river tributaries and catchments, including dam reservoirs [2].

Thanh Nguyen et al. [3] suggest that torrential and extreme rainfall and severe river flooding events are expected to rise significantly in the future, reaching a surge in precipitation and streamflow from 29 to 35% and 37 to 56%, respectively. According to the DENR [4], no more than seven percent of rainforests have been left. Much of the country's biodiversity remains in the documentation phase

[5]. The Magat Dam is one of the largest dams in the Philippines. It is a multi-purpose dam with a storage capacity of 1.08 billion cubic meters, providing irrigation to 95,000 ha of land and hydroelectric power generation of 360 megawatts [6].

Comparative avifaunal diversity is an excellent indicator of ecosystem stability because birds respond quickly to changes in their environments [7]. The population changes are caused by numerous interacting effects [8]. According to local fish farmers, based on their observations, there is a slight decline in bird population in the area compared to the past 10 years. They further added that this may be the result of bird hunting for food and the growing population of floating farm farming, which disturbs their wetland habitat.

Conversion to aquaculture and unsustainable utilization of the forest is seen to be the major culprit in the decline of trees in the past years [9,10]. However, with the initiatives of the Local Government Unit, the establishment of a bird watching site cum ecopark, wherein visitors pay an entrance fee while appreciating the birds' habitat, has boosted conservation efforts. The people have become more aware of the importance of bird conservation. The involvement of locals in the rehabilitation, also known as the community-based approach, is vital for the success of the conservation efforts [11].

According to Taguiling et al. [12], many endemic and endangered species of birds are still sighted in the different ecological elevations of Ifugao. Some old reports even indicated that bird diversity is still high in the deeper parts of the Ifugao forest. Despite logging and conversion of forest into non-forest purposes, birds could still be protected. Several efforts to prioritize islands regarding their importance for biodiversity conservation have been compromised; only one study has taken on this challenge [13]. Wetland areas are usually the habitat for birds; these areas come in various forms, including lakes, parks [14,15], and gardens [16].

This is the first study of its kind in the site; while previous studies have highlighted the importance of the wetland for bird biodiversity, detailed data on how these pressures influence species richness, population trends, and habitat quality remain limited. The objectives of the study are to quantify avifaunal diversity in the Magat Wetland using diversity indices, assess variations in species richness across different habitat types, identify and model the key environmental factors (e.g., forest cover, human disturbance) that significantly influence avifaunal diversity and species distribution within the Magat Wetland, and analyze species-habitat relationships using generalized linear models (GLMs) to predict the presence and abundance of key bird species based on environmental and habitat variables.

2. Materials and Methods

2.1. Study Site

The study was conducted in the Magat Wetland areas and dam reservoir, which have supported hydropower facilities for decades, operated by SN Aboitiz Power-Magat, Inc. The reservoir is fed by the catchment basin from the Magat watershed and forest-reservation area, which was declared a protected area through Proclamation No. 573 on June 26, 1969 [6]. Figure 1 shows the study site, highlighting observation posts in three barangays (Sto. Domingo, Namnama, and Halag) within the municipalities of Alfonso Lista and Aguinaldo, where bird sightings were recorded.

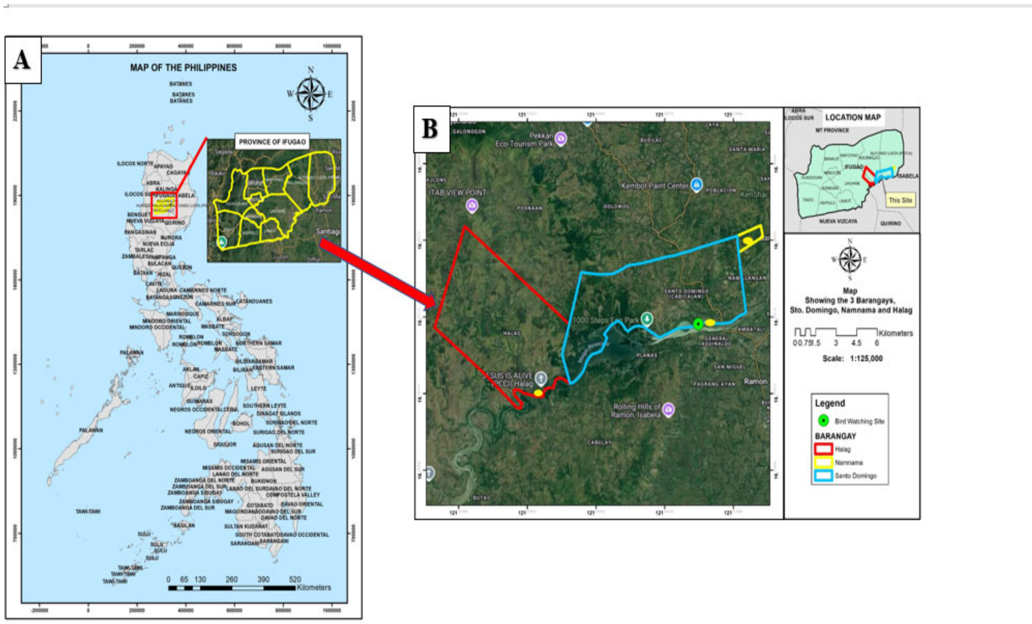

Figure 1. Map showing the location of the (A) Philippines, (B) Magat Wetland green circle showing the bird watching site.

2.2. Avifaunal Survey

The composition and distribution of avian species were assessed using the transect survey method based on Mallari et al. [17]. Transect lines used were 100 m long along the slope used in the floral survey, extended up to 500 meters. All species of birds encountered along the transect line were recorded. For each species seen or heard, the following information was noted: species name and number of individuals. The avifaunal inventory was conducted early in the morning (from 6:00 to 9:00) and late in the afternoon (from 3:00 to 6:00) for 6 days.

2.3. Similarity Index

Sampling sites covered the three different identified project sites (Namnama, Sto Domingo Alfonso Lista, and Halag, Aguinaldo) shown in Figure 1. In each study site, wildlife inventories were conducted in the forested area and water bodies (river/creek, rice paddies). The Sorensen's Index of Similarity [18] was used to compare species composition between sampling sites. Similarity values (expressed in percentage) were calculated using the following equation:

$$SI = \frac{2K}{A + B} \times 100$$

where, K = number of species common to sites A & B

A = number of species for site A, and
B = number of species for site B.

2.4. Species Richness and Diversity

Species richness for each sampling site was measured using Menhinick's Richness Index [18] with the following equation:

R = S /ÖN,

where: S=total number of species per sampling site/elevation,
N= total number of individuals per sampling site/elevation.

The overall pattern of species richness in each site was determined by plotting the values of species richness indices against the sampling sites in a line graph. As for the species diversity, it was computed in each sampling site using Shannon's Diversity Index:

$$H¢ = -S [n1 / n] In [n1 / n]$$

where:n1 = number of individuals per species and
n = total number of individuals.

2.5. Data Gathering

The study was conducted on January 2023- August 2024, secondary data such as previous population count conducted by DENR was gathered with the permission from the Community Environment and Environment officer (CENRO). The population count was done by the DERN spanning from 2013 to date, this was done in order that the Magat wetland to be included in Ramsar site with the 20,000 minimum bird population. Validation count was conducted by the researcher's team, the survey focused on wetland avifaunal species, including endemic and migratory birds listed under the International Union for Conservation of Nature (IUCN) Red List. Secondary data were collected from the Department of Environment and Natural Resources – Community Environment and Natural Resources Office (DENR-CENRO) in Namillangan, Alfonso Lista, Ifugao. These data included images, documentation of previous bird assessments, and population counts. Available data was on 2013-2016 only, a validation count and latest data from DENR is on the current year. Latest forest cover in Ifugao Province was obtained from Global Forest Watch.

Unstructured interviews were also conducted with local residents, including fishermen and elderly individuals living near the Magat reservoir, to gather insights on changes in bird populations over time. A site reconnaissance was conducted to validate the secondary data. Furthermore, individual bird counts were performed to determine the current population of avifaunal species in the study area.

2.6. *Statistical Modeling*

The study used multiple regression models to investigate the relationships between various environmental variables and avifaunal diversity. Regression analysis is a statistical method used to identify and quantify the associations between dependent and independent variables, allowing researchers to determine how changes in environmental factors—such as habitat type, temperature, and vegetation cover—may influence the diversity of bird species in the area. Subsequent the establishment of these models, the researchers conducted a thorough assessment of model fit to ensure that the chosen models adequately represented the data.

Several criteria were utilized for this evaluation: R-squared (R^2): This statistic measures the proportion of variance in the dependent variable (in this case, avifaunal diversity) that can be explained by the independent variables (environmental factors) in the model. A higher R^2 value indicates a better fit, suggesting that the model explains a significant amount of the variability in avifaunal diversity. By integrating these model fit assessments, the study aims to ensure robust findings regarding the influence of environmental variables on avifaunal diversity, ultimately contributing to a better understanding of bird conservation in relation to ecological factors.

2.7. Data Analysis

Avifaunal data on population counts and species frequency were encoded and analyzed using Microsoft Excel, where the data were transformed into appropriate tables and figures. The indices for species richness, similarity, diversity, and abundance were calculated using the aforementioned formulas. Additional statistical analyses, such as averages, percentages, and rankings, were applied to interpret the data.

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Species documentation and conservation status were referenced from existing literature, including works by researchrs [19–21]. The results were used to assess the current status of avifauna in the Magat wetland areas and to support local conservation efforts.

3. Results

3.1. Location of the Study Area

The Figure 1 presents the map depicting the location of the Magat Wetland area within two barangays. The site is sparsely populated, however growing number of population is seen in the surrounding areas since it was declared as popular local tourist site, as birdwatching site for wetland birds. This became the reason for rapid development for residential and commercial activities. In addition to this the commercial scale fish farming such as the floating net tilapia farming also visibly seen as expanding in the area. Figure 2 shows the Magat wetland across two province, the Ifugao and Isabela province including the Magat reservoir that feeds water to the Avoitiz hydropower plant..

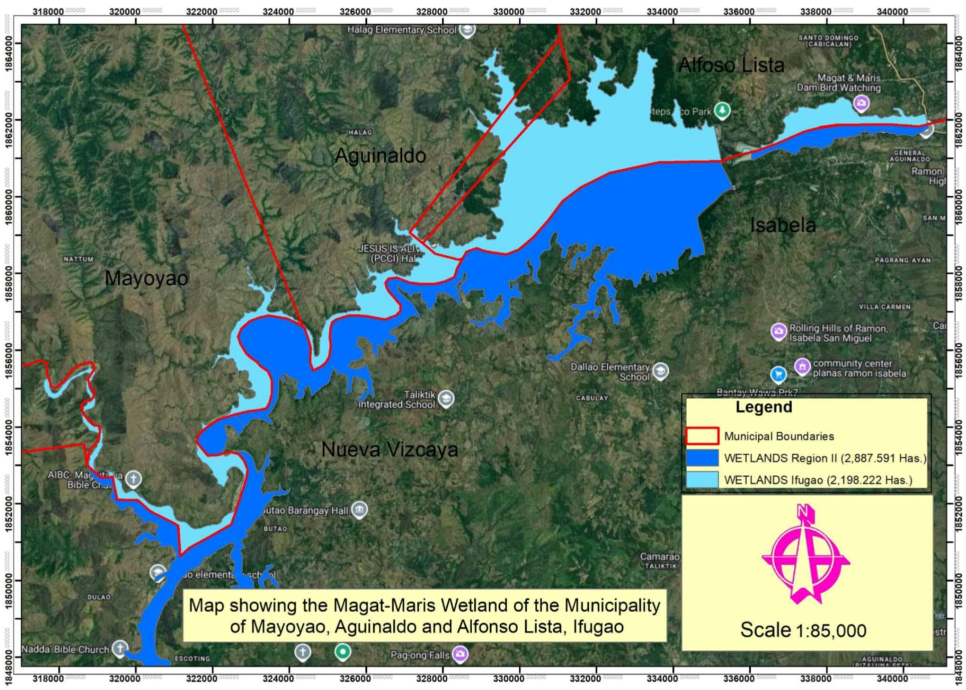

Figure 2. The Magat wetland in dark and ligth blue across the two study site (Barangay Sto Domingo and Ambatali.

3.2. Avian Population in the Two Sites

The Table 1 shows moderate avifaunal diversity across Sto Domingo and Ambatali, with a combined total of **21,575** individual birds observed, underscoring these sites' ecological importance. Dominant species like the **Little Egret** (*Egretta garzetta*), **Intermediate Egret** (*Ardea intermedia*), **Great Egret** (*Ardea alba*), and **Philippine Duck** (*Anas luzonica*) contribute significantly to the overall population. The **Little Egret** alone, with **9,489** individuals, comprises nearly half of the recorded birds, highlighting favorable habitat conditions that support a large population of these birds.

Table 1. Avian population count in the two sites of Ifugao and Isabela Province.

Avifauna	Scientific Name	Population Count		Total
		Sto Domingo Site	Ambatali Site	

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Philippine duck	*Anas luzonica*	572	1382	1954
Tufted duck	*Aythya fuligula*	419	85	504
Little Egret	*Egretta garzetta*	5651	3838	9489
Intermediate Egret	*Ardea intermedia*	1521	1703	3224
Barn swallows	*Hirundo rustica*	1030		1030
Common Kingfisher	*Alcedo atthis*	49		49
Grey Heron	*Ardea cinerea*	655	179	834
Great Egret	*Ardea alba*	1213	3,036	4249
Great blue heron	*Ardea herodias*	24	179	203
Osprey	*Pandion haliaetus*		3	3
Pied Bushchat	*Saxicola caprata*		7	7
Blue Rock Thrush	*Monticola solitarius*		2	2
Emerald Dove	*Chalcophaps indica*	2		2
Pied Triller	*Lalage nigra*		1	1
Yellow-vented bulbul	*Pycnonotus goiavier*	1	3	4
Black Winged Stilt	*Himantopus himantopus*		2	2
Purple Heron	*Ardea purpurea*	1	3	4
Great Billed Heron	*Ardea sumatrana*	1	5	6
Brahminy Kite	*Haliastur indus*		1	1
Chestnut Munia	*Lonchura atricapilla*		1	1
Philippine scops owl	*Otus megalotis*		1	1
Olive Backed Sunbird	*Cinnyris jugularis*		1	1
Grey-Streaked Flycatcher	*Muscicapa griseisticta*	1	1	2
White-throated Kingfisher	*Halcyon smyrnensis*		2	2
Grand Total		**11140**	**10435**	**21575**

Distribution patterns indicate habitat preferences across the two sites. Sto Domingo hosts higher densities of Little Egrets and Intermediate Egrets, while Ambatali appears to favor species like the **Philippine Duck** and supports unique sightings such as the **Osprey** (*Pandion haliaetus*). Certain species are scarce, such as the **Yellow-vented Bulbul** (*Pycnonotus goiavier*) and the **Philippine Scops Owl** (*Otus megalotis*), with only one individual observed in each case. These low counts may reflect these birds' specialized habitat needs or a transient presence for migratory species like the **Grey-Streaked Flycatcher** (*Muscicapa griseisticta*), which passes through the area briefly each year (Table 1). The observed diversity points to Sto Domingo and Ambatali as vital habitats, especially for endemic species like the Philippine Duck, whose populations are limited to specific regions and are vulnerable to threats such as habitat loss and hunting.

The existence of migratory species, including the **Barn Swallow** (*Hirundo rustica*) and **Osprey**, suggests that these sites serve as crucial stopover points, providing essential resources along migratory paths. To preserve this biodiversity, strategic conservation measures could focus on habitat preservation, which is fundamental for sustaining species with specific environmental needs. Regular monitoring programs would be valuable to track population changes and address threats like pollution or climate change proactively. Additionally, involving local communities in conservation

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can raise awareness and potentially attract eco-tourism, generating resources for ongoing preservation efforts.

Generally, Sto Domingo and Ambatali's role in supporting a wide range of bird species, including both resident and migratory populations, emphasizes the ecological importance of maintaining these habitats, benefiting both biodiversity and broader ecosystem health.

3.3. Avian Relative Frequencies

3.3.1. Dominance of Certain Species

Table 2 provides valuable understandings into the structure and abundance of bird species across the Sto Domingo and Ambatali sites. Here's a detailed discussion based on the relative frequencies calculated. **Little Egret (***E. garzetta***)** with a relative frequency of approximately **43.95%,** the Little Egret is the most abundant species in the dataset. Its high population may indicate favorable habitat conditions, such as ample food supply and nesting sites.

Table 2. Relative frequencies of avian species in the two sites.

Avifauna	Scientific Name	Population Count	Relative Frequency (%)
Philippine duck	*Anas luzonica*	1954	9.06
Tufted duck	*Aythya fuligula*	504	2.33
Little Egret	*Egretta garzetta*	9489	43.95
Intermediate Egret	*Ardea intermedia*	3224	14.93
Barn swallows	*Hirundo rustica*	1030	4.77
Common Kingfisher	*Alcedo atthis*	49	0.23
Grey Heron	*Ardea cinerea*	834	3.86
Great Egret	*Ardea alba*	4249	19.67
Great blue heron	*Ardea herodias*	203	0.94
Osprey	*Pandion haliaetus*	3	0.01
Pied Bushchat	*Saxicola caprata*	7	0.03
Blue Rock Thrush	*Monticola solitarius*	2	0.01
Emerald Dove	*Chalcophaps indica*	2	0.01
Pied Triller	*Lalage nigra*	1	0.005
Yellow-vented bulbul	*Pycnonotus goiavier*	4	0.018
Black Winged Stilt	*Himantopus himantopus*	2	0.01
Purple Heron	*Ardea purpurea*	4	0.018
Great Billed Heron	*Ardea sumatrana*	6	0.028
Brahminy Kite	*Haliastur indus*	1	0.005
Chestnut Munia	*Lonchura atricapilla*	1	0.005
Philippine scops owl	*Otus megalotis*	1	0.005
Olive Backed Sunbird	*Cinnyris jugularis*	1	0.005
Grey-Streaked Flycatcher	*Muscicapa griseisticta*	2	0.01
White-throated Kingfisher	*Halcyon smyrnensis*	2	0.01
Grand Total		**21575**	**100%**

Egrets are often found in wetlands, which may be abundant in these areas, suggesting that habitat management could be focused on preserving such environments. The **Intermediate Egret (***A. intermedia***)** and **Great Egret (***A. alba***)**: These species follow as the second and third most frequent, with relative frequencies of **14.93%** and **19.67%,** respectively. Their high populations, like that of the Little Egret, also point to a suitable ecological niche in the surveyed sites, emphasizing the importance of wetlands in supporting these birds.

3.3.2. Low Abundance of Other Species

Numerous species have very low relative frequencies, such as **Osprey (***P. haliaetus***)**, **Pied Bushchat (***S. caprata***)**, and **Common Kingfisher (***A. atthis***)**, each contributing less than **1%** to the general population count. This could suggest that these species have more specialized habitat requirements or face more significant pressures from habitat loss, competition, or predation. The

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Grey Heron (*Ardea cinerea***)** and **Great Blue Heron (***Ardea herodias***)** also show moderate counts, indicating a presence in the area but not in significant numbers compared to more abundant species (Table 2). The predominance of specific species, especially the Egrets, indicates the ecological health of the area. However, the presence of species with low relative frequencies raises concerns regarding biodiversity. Conservation efforts should aim to protect habitats not just for abundant species but also for those that are less common. Identifying and preserving critical habitats, such as wetlands and riparian zones, can support not only the more frequent species but also those at risk. The relative frequencies can help prioritize which species and habitats may require immediate conservation action.

3.4. Shannon-Wiener Diversity Index og Magat Wetland Areas

Table 3 shows the Shannon-Wiener Diversity Index (H') in the site, it is a widely used measure of biodiversity that incorporates both species richness (the number of different species) and species evenness (the distribution of individuals among those species). An index value of **1.62** suggests a moderate level of biodiversity within the avifaunal community studied. The **Little Egret** having the highest population count (9,489), while many other species have very low counts (e.g., **Osprey** with only 3 individuals). Richness contributes to ecological stability; a greater variety of species can lead to more resilient ecosystems that are better able to withstand environmental stressors. Evenness is reflected in how evenly the individuals are distributed across different species. In this case, although there are many species represented, a few (like the Little Egret) dominate the population.

Table 3. Avifaunal diversity in the Magat Wetland areas.

Avifauna	Population Count	Proportion (pi)	p_i · ln(p_i)
Philippine duck	1954	0.0905	-0.0953
Tufted duck	504	0.0233	-0.0575
Little Egret	9489	0.4395	-0.0970
Intermediate Egret	3224	0.1493	-0.0733
Barn swallows	1030	0.0477	-0.0691
Common Kingfisher	49	0.0023	-0.0414
Grey Heron	834	0.0386	-0.0753
Great Egret	4249	0.1967	-0.0866
Great blue heron	203	0.0094	-0.0411
Osprey	3	0.0001	-0.0004
Pied Bushchat	7	0.0003	-0.0005
Blue Rock Thrush	2	0.0001	-0.0005
Emerald Dove	2	0.0001	-0.0005
Pied Triller	1	0.00005	-0.0005
Yellow-vented bulbul	4	0.00019	-0.0004
Black Winged Stilt	2	0.0001	-0.0005
Purple Heron	4	0.00019	-0.0004
Great Billed Heron	6	0.00028	-0.0005
Brahminy Kite	1	0.00005	-0.0005

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Avifauna	Population Count	Proportion (pi)	p_i · ln(p_i)
Chestnut Munia	1	0.00005	-0.0005
Philippine scops owl	1	0.00005	-0.0005
Olive Backed Sunbird	1	0.00005	-0.0005
Grey-Streaked Flycatcher	2	0.0001	-0.0005
White-throated Kingfisher	2	0.0001	-0.0005
Total	**21,575**	**1.0000**	**-1.6171**
Shannon-Wiener Index (H')			**1.62**

The lower representation of several species can indicate potential vulnerabilities in the ecosystem, as highly skewed distributions may make the ecosystem more susceptible to changes or threats (e.g., habitat loss, climate change). An H' value of **1.62** indicates a moderate level of biodiversity. Generally, values closer to **0** suggest low diversity (a few dominant species), while values approaching **3** or higher indicate high diversity and evenness (Table 3). This level of diversity is beneficial for ecosystem functionality, supporting services like pest control, pollination, and nutrient cycling. Given the diversity index, conservation efforts should focus on maintaining and enhancing habitats for less common species to promote greater evenness. Monitoring populations of dominant species, such as the Little Egret, is essential to ensure they do not outcompete others, leading to further declines in species diversity.

The existence of species with very low population counts increases concerns about their survival. Factors like habitat destruction, pollution, and climate change can significantly impact these vulnerable species. Conservation strategies could involve habitat restoration, protection of breeding grounds, and addressing anthropogenic pressures that threaten these species.

Although the index suggests a moderate level of diversity, it highlights the need for ongoing monitoring and conservation efforts to support both species richness and evenness. Nurturing a diverse avifaunal population is crucial for maintaining the health and resilience of the ecosystem as a whole. Future studies could focus on identifying specific threats to the less abundant species and developing targeted management strategies.

3.5. Sorensen's Index of Similarity for the Sto Domingo Site and Ambatali Site

In Table 4, the Similarity index is a valued tool for evaluating the degree of similarity between two ecological communities. In this case, the index was calculated for the avifaunal populations of the Sto Domingo Site and the Ambatali Site, yielding a value of **0.5**. This mark reflects a moderate level of similarity between the two sites, indicating both shared and unique species. Both sites have a total **of 24 species,** with **12 species** being common to both.

Table 4. Similarity index in the two sites.

Avifauna	Sto Domingo Site	Ambatali Site	Common (Yes/No)
Philippine duck	572	1382	Yes
Tufted duck	419	85	Yes
Little Egret	5651	3838	Yes
Intermediate Egret	1521	1703	Yes
Barn swallows	1030	0	No
Common Kingfisher	49	0	No
Grey Heron	655	179	Yes
Great Egret	1213	3036	Yes
Great blue heron	24	179	Yes
Osprey	0	3	No
Pied Bushchat	0	7	No

Avifauna	Sto Domingo Site	Ambatali Site	Common (Yes/No)
Blue Rock Thrush	0	2	No
Emerald Dove	2	0	No
Pied Triller	0	1	No
Yellow-vented bulbul	1	3	Yes
Black Winged Stilt	0	2	No
Purple Heron	1	3	Yes
Great Billed Heron	1	5	Yes
Brahminy Kite	0	1	No
Chestnut Munia	0	1	No
Philippine scops owl	0	1	No
Olive Backed Sunbird	0	1	No
Grey-Streaked Flycatcher	1	1	Yes
White-throated Kingfisher	0	2	No
Total Species	**24**	**24**	**Common Species** = 12

The existence of shared species, such as the *A luzonica*, *E. garzetta*, and *A. cinerea*, suggests that these species are adaptable or suited to the environmental conditions present in both areas. The **common species** account for 50% of the total species identified, which indicates that while there are shared ecological traits or habitats, there are also unique factors influencing species dispersal at each site. A similaity index of **0.5** suggests a moderate level of similarity, which may indicate shared environmental conditions or habitat types that support similar bird populations (Table 4). Nevertheless, the presence of numerous unique species in each location hints at differing ecological conditions, such as variations in habitat structure, food availability, or human influence.

3.6. Menhinick's Richness Index for the Avifaunal Populations at the Sto Domingo Site and Ambatali Site

The richness index in Table 5 provide as a measure of species richness in ecological studies. It provides insights into the diversity of species in relation to the total number of individuals in a community. The calculated index value of **0.163** for the avifaunal populations at the Sto Domingo Site and Ambatali Site indicates a moderate level of species richness. An index value of **0.163** suggests that while there is a diversity of species, it may not be exceedingly high when considering the total number of individuals present. This could indicate that a few species may dominate the community, while others are less prevalent. The value reflects the balance between the number of species and the overall population size. A lower value could imply that the ecosystem is less diverse or potentially facing environmental pressures that limit species abundance.

Table 5. Avifaunal richness in the two sites.

Metric	Value
Total Number of Species (S)	24
Total Number of Individuals (N)	21575
Square Root of N	147.1
Menhinick's Richness Index (R)	**0.163**

3.7. Avian Populations and Forest Cover Dynamics in Ifugao

Figure 3 shows the avian populations and forest cover loss in Ifugao from 2013 to 2024, it reveals a generally positive trend in avian numbers, increasing from 4,702 in 2013 to 11,134 in 2024, despite notable fluctuations, particularly in 2016 and 2017. Forest cover loss varies significantly, peaking at 39% in 2016 and 40% in 2017, but shows a decreasing trend from 2021 onwards, suggesting potential improvements in conservation efforts. This raises the question of a possible inverse relationship between avian populations and forest cover loss, indicating that habitat degradation could negatively impact bird populations. However, the increase in avian numbers amidst fluctuating forest loss points to the effectiveness of conservation initiatives and the need for ongoing habitat preservation.

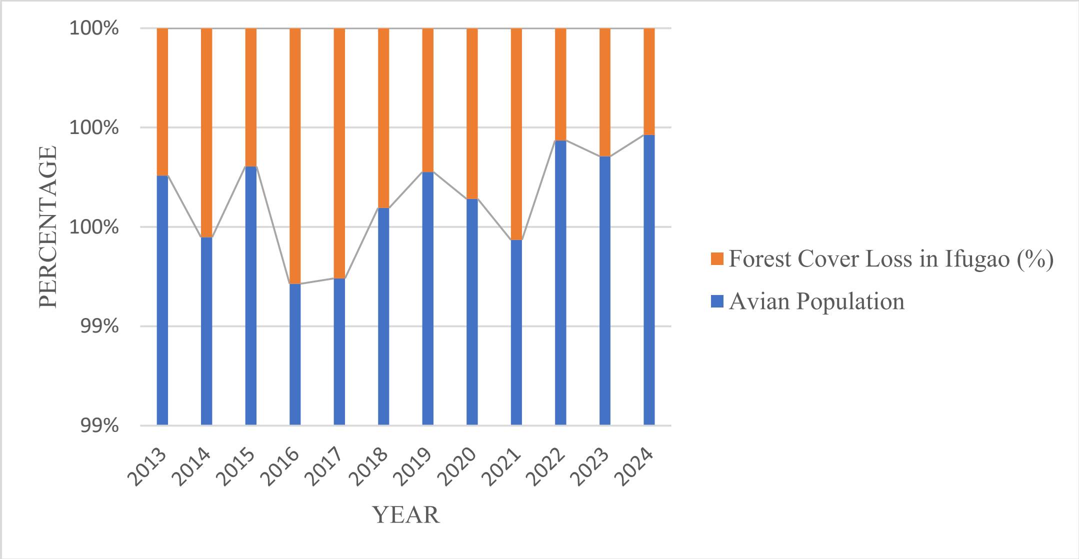

Figure 3. Forest cover loss and avifaunal population for the past 13 years.

3.8. The Relationship Between Forest Cover Loss and Avian Population Metrics

The value of 5525.39 as shown in Table 6 is the expected value of the avian population when all independent variables (Forest Cover Loss, Similarity, Richness, Diversity) are at zero. In practice, this value mainly serves as a baseline and is not particularly meaningful in this context, as forest cover loss and other factors are unlikely to be zero. For each 1% increase in forest cover, the avian population is expected to increase by about 84 individuals, holding other factors constant. This variable has a p-value of 0.004, indicating it is statistically significant ($p < 0.05$).

Table 6. Statistical summary of the Avifaunal different variables.

Variable	Coefficient	Std. Error	t-value	p-value	95% Confidence Interval
Constant	5525.3883	34400	0.160	0.877	-73900, 84900
Forest Cover Loss (%)	84.4219	21.423	3.941	0.004	35.019, 133.824
Similarity	-171100	85100	-2.011	0.079	-367000, 25100
Richness	44660	41900	1.066	0.318	-52000, 141000
Diversity	199300	148000	1.344	0.216	-143000, 541000

***F-statistic**: 51.05 ($p = 0.0000146$), showing overall model significance.

The confidence interval (35.02, 133.82) does not cross zero, reinforcing its reliability. Forest cover loss is the only variable with a clear, statistically significant impact on avian population in this model. Higher similarity is associated with a reduction in avian population. Although the coefficient suggests a strong negative relationship, the p-value of 0.079 ($p > 0.05$) indicates that this result is not statistically significant. This relationship could indicate that higher similarity (greater homogeneity of avifauna) correlates with lower overall population, though the data does not confirm this definitively. Richness, or the number of unique species, shows a positive relationship with avian population. However, with a p-value of 0.318, this effect is statistically insignificant, meaning the impact of richness on the avian population cannot be reliably concluded from this model alone. Diversity appears to have a positive impact on avian population, with a high coefficient suggesting substantial influence. However, its high p-value (0.216) and wide confidence interval mean this relationship is not statistically significant in this dataset (Table 6).

The Table indicates that 95% of the variation in avian population is explained by this model, suggesting a strong fit overall. However, the reliability of individual coefficients is limited due to potential multicollinearity among the variables (as noted in the warnings). The F-statistic (51.05, p <

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0.001) indicates that the model is significant as a whole, meaning that at least one of the independent variables is predictive of the avian population.

Overall, the model suggests that forest cover loss has a significant effect on the avian population, likely due to habitat changes impacting species density and distribution. While similarity, richness, and diversity show potential relationships with the population, they lack statistical significance.

3.8.1. Forest Cover Loss (%) vs Avian Population

The Figure 4 in the graph shows the relationship between forest cover loss and avian population likely exhibits an inverse correlation. As the percentage of forest cover loss increases, the avian population is expected to decrease. This pattern is consistent with ecological principles, where habitat destruction—such as deforestation—leads to fragmentation and loss of habitats essential for various bird species. A decrease in forest cover typically results in reduced nesting sites, food availability, and increased vulnerability to predators, all contributing to a decline in avian populations.

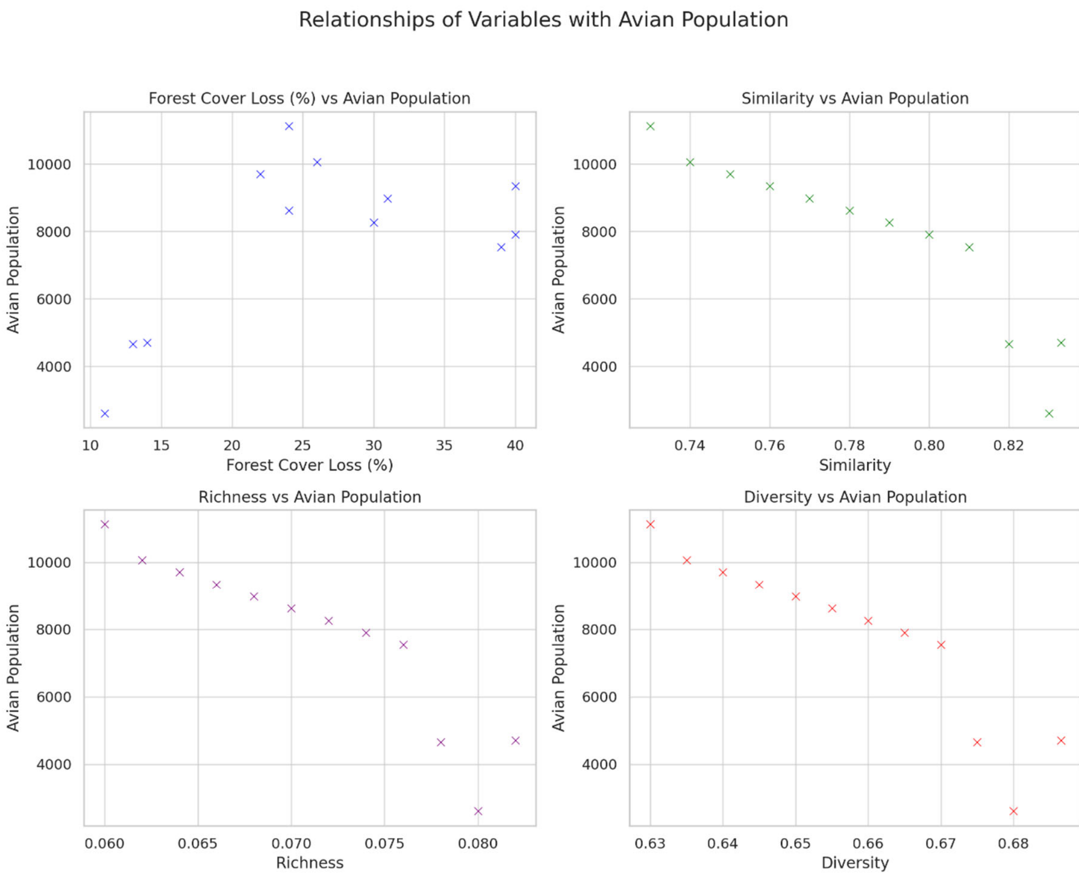

Figure 4. Mutiple linear regression analysis.

3.10. Current Status of the Wetland Areas

In Figure 5, the Municipal Tourism Office of Alfonso Lista, Ifugao, has developed a bird-watching site. Based on the researcher's observations, the crowd creates sound pollution that disturbs the avifaunal environment in the area. A study must be conducted to determine the carrying capacity of the site and its long-term impact on bird habitats. Therefore, further research on the long-term effects of various ecological factors should include a visual spatial analysis of land use cover to achieve sustainable management and conservation of the different avifaunal species thriving in the area.

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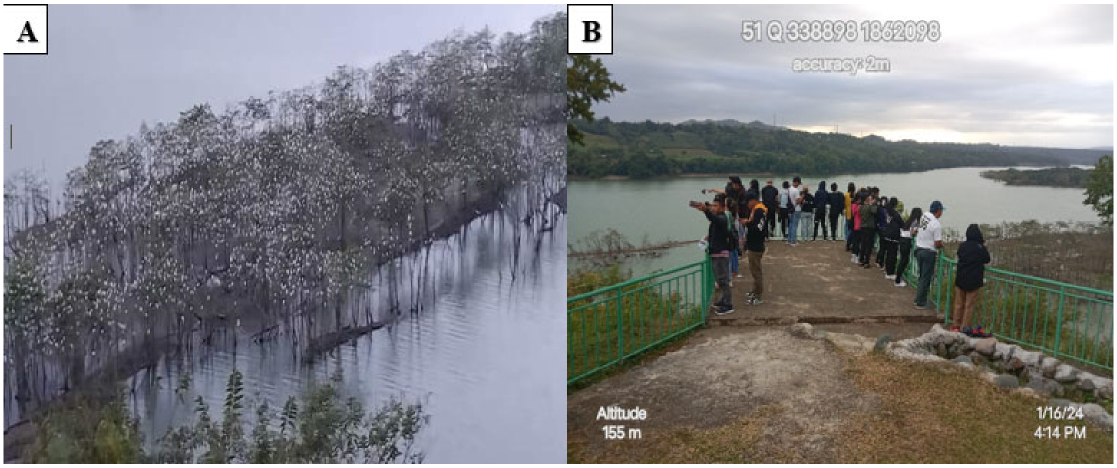

Figure 5. The bird watching site (B), flocks of bird in the patches of of Bangkal (*N. orientalis*) forest stand (A).

4. Discussion

The study revealed that the relationship between richness and the predicted variable seems strong, suggesting that the multiple linear model is effective in predicting outcomes. In the context of biodiversity studies, this implies that while richness significantly contributes to ecological outcomes, other factors such as habitat quality, climate conditions, or interspecies interactions could also be contributing. The Magat Wetland ecosystem is threatened due to the rapid increase of anthropogenic activities such as commercial-scale fish farming, hunting, and agricultural conversion of forest. The birds in the site are one of the attractions for local tourists; indeed, birds frequently serve as focal points in biodiversity and ecosystem research due to their visibility and heightened sensitivity to environmental shifts, making them excellent bioindicators of ecosystem health [2,4,22,23,25].

Rapid and unplanned urbanization often leads to homogeneous, dense, artificial environments dominated by exotic species of fauna [26]. This extensive land conversion, labeled as "development," poses significant threats to the migratory patterns of avifauna [27]. Globally, many Palearctic populations are fully migratory, dispersing widely between September and October post-breeding and returning to breeding grounds in February [28]. The conservation priorities for these species are critical [29], with established theories linking species richness to island area [30]. The International Union for Conservation of Nature states that 12% of birds and 38% of the world's trees are at risk of extinction, with the number of threatened tree species more than twice that of threatened bird, mammal, reptile, and amphibian species combined [31].

Among Philippine birds, a strong correlation exists between endemic species richness and island area, enabling predictions regarding species richness for islands of a given size. Such insights emphasize that, beyond a certain area, certain species are likely to dominate the avifaunal landscape. Therefore, the interplay between bird sightings, nesting behaviors, and various environmental indicators suggests that endemic and migratory birds are adapting to the presence of human populations in the area and its surroundings. This confirms the study by Encarnacion et al. [32], which concluded that the river's water quality is significantly impacted by human activities, adversely affecting the diversity of organisms. Consequently, they recommend continuous monitoring and assessment of avifaunal diversity, along with the strict enforcement of conservation regulations.

Bird populations face severe risks of extinction due to both natural and human-induced factors that drive forest deforestation. This loss of habitat reduces available wildlife areas, significantly decreasing bird populations [33]. Studies consistently show a positive link between vegetation and bird diversity [34,35]. Research on the Magat Wetland, despite its marginal forest classification, indicates that even small protected landscapes support relatively high bird diversity, including restricted-range species and those with high conservation priority. This underscores the importance of conserving even small forest fragments, as they provide valuable habitats crucial for bird conservation [36]. Continuous forest cover loss has been observed in Ifugao Province [37], which in the long term affects the population status of the birds as revealed in this study. In the Philippines, much research has concentrated on large protected areas, but the vital role of smaller protected areas in conserving biodiversity is often overlooked, highlighting a specific gap for further study [38].

Contrasting their larger counterparts, smaller protected areas tend to support fewer species and are more vulnerable to intensified threats from land-use changes and ecological isolation [39–41]. This overlooks the significance of smaller protected areas such as the Magat Wetland areas, including their impact on the ecological conservation of avifaunal populations. Ultimately, the findings highlight the complexity of avian ecology and the need for adaptive management strategies that consider both the immediate and long-term impacts of environmental changes.

By integrating scientific research with conservation practices, we can better address the challenges posed by habitat loss and promote the resilience of avian communities in the face of ongoing ecological pressures. Future research should expand the range of variables considered, including habitat quality, food availability, and the presence of invasive species, to develop a more comprehensive model. Additionally, employing longitudinal studies will provide insights into temporal changes in avian populations and the effects of ongoing environmental changes.

5. Conclusions

The study expounds the ecological significance of the Magat Wetland areas as critical habitats for both resident and migratory avifauna. Findings indicate a moderate level of avian biodiversity, with notable species such as the Little Egret and the Philippine Duck contributing substantially to the avifaunal population.

Despite the challenges posed by deforestation, habitat conversion, and climate-related changes, local conservation initiatives have helped mitigate biodiversity loss. The study emphasizes the need for continuous habitat preservation and stricter implementation of conservation policies to maintain the wetland's ecological health.

It also recommends engaging local communities and establishing structured monitoring to track population dynamics and assess the impacts of human activities. Future research should focus on understanding habitat quality, availability of food resources, and specific threats to underrepresented species, as well as the long-term effects of urbanization on biodiversity. By fostering sustainable management practices, the study suggests that Magat Wetland can serve as a model for balancing ecological preservation with community involvement, underscoring the importance of small but biodiverse areas in conserving the Philippines' natural heritage.

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Data Availability Statement: All relevant data are included in the paper

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