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Bird species in tropical forest fragments, at different altitudes, in the western Andes of Ecuador

Diana Karina VINUEZA-MORALES *[1], Victor Mario GARCÍA-MORA [2], Nataly CALO-CHANALUISA [1], Lorena del Carmen CHICAIZA-VILCACUNDO [1]

[1] Technical University of Cotopaxi, Latacunga, Ecuador.
[2] Faculty of Natural Resources, Escuela Superior Politécnica de Chimborazo, Riobamba, Ecuador.
*Email: diana.vinueza@utc.edu.ec

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ABSTRACT: In this research, the richness, diversity and similarity of bird species were evaluated in six fragments of tropical forests from 170 to 2100 meters above sea level in the western Andes, central Ecuador. The bird count was carried out in 2019 using the technique of counting birds by points, in the forest fragments: Las Cascadas, Ñunganan, Jardín de los Sueños, Los Laureles, Machay, and La Esperanza. The ecological parameters were evaluated by the Shannon Index, relative abundance, and Sorensen Index. The difference between forest fragments and ecological parameters was analyzed using the non-parametric statistical technique of Kruskal-Wallis ($p<0.05$) and comparison by post hoc. The comparison of the forest fragments was determined with the Mann-Whitney test, because the assumption of normality according to the Shapiro-Wilk test for the analysis of variance was not met. The results showed 219 species of birds belonging to 70 genera, 48 families, and 9 orders. The families with the highest wealth were Thraupidae (15.3%), Tyrannidae (12.7%), Fringillidae (5.4%), and Accipitridae (1.4%). The highest relative abundance of birds for La Esperanza was the species: *Anisognathus somptuosus* and *Streptoprocne rutila*; Ñunganan: *Pygochelidon cyanoleuca* and *Coragyps atratus*; Los Laureles: *Thraupis episcopus* and *Bubulcus ibis*; Machay: *Egretta thula* and *Arremon aurantiirostris*; and Las Cascadas: *Thraupis episcopus* and *Forpus coelestis*. For the components of bird species diversity in the six forest fragments, there are significant variations in species richness, abundance, and similarity ($p<0.05$); La Esperanza and Ñunganan being the least disturbed fragments, which presented a greater diversity of species and abundance of birds. These results highlight the importance of these forest fragments as refuges for bird biodiversity, despite the anthropogenic pressures they face.
Keywords: bird counting; forest fragment; habitat loss; relative abundance.

Espécies de aves em fragmentos de florestas tropicais, em diferentes cotas altitudinais, dos Andes ocidentais do Equador

RESUMO: Nesta pesquisa foi avaliada a riqueza, diversidade e similaridade de espécies de em seis fragmentos de florestas tropicais entre 170 a 2100 metros acima do nível do mar, na região ocidental dos Andes, centro do Equador. A contagem de aves foi realizada em 2019 pela técnica de contagem pontual de aves, nos seguintes fragmentos de floresta: Las Cascadas, Ñunganan, Jardín de los Sueños, Los Laureles, Machay e La Esperanza. A avaliação dos parâmetros ecológicos foi realizada utilizando o índice de Shannon, abundância relativa e índice de Sorensen. A diferença entre fragmentos florestais e parâmetros ecológicos foi analisada pela técnica estatística não paramétrica de Kruskal Wallis ($p<0,05$) e comparação post hoc por meio do teste de Mann Whitney. Para a comparação dos fragmentos florestais, eles foram determinados pelo teste isso porque o pressuposto de normalidade não foi atendido pelo teste de Shapiro Wilks para análise de variância. Os resultados mostraram 219 espécies de aves pertencentes a 70 gêneros, 48 famílias e 9 ordens. As famílias com maior riqueza foram Thraupidae (15,3%), Tyrannidae (12,7%), Fringillidae (5,4%) e Accipitridae (1,4%). As maiores abundâncias relativas de aves para La Esperanza foram as espécies: *Anisognathus somptuoso* e *Streptoprocne rutila*; Ñunganan: *Pygochelidon cianoleuca* e *Coragyps atrato*; Los Laureles: *Thraupis episcopus* e *Bubulcus ibis*; Machay: *Egreta Thula* e *Arremon aurantiirostris* e Las Cascadas: *Thraupis episcopus* e *Forpus coelestis*. Para os componentes da diversidade de espécies de aves nos seis fragmentos florestais, há variações significativas na riqueza, abundância e similaridade de espécies ($p<0,05$). Utilizando as espécies como bioindicadoras é possível inferir que La Esperanza e Ñunganan foram os fragmentos menos perturbados e apresentaram maior diversidade e abundância de aves. Estes resultados destacam a importância destes fragmentos florestais como refúgios para a biodiversidade de aves, apesar das pressões antrópicas que enfrentam.
Palavras-chave: contagem de aves; fragmento florestal; perda de habitat; abundância relativa.

1. INTRODUCTION

Mountain forests around the world are important centers of biodiversity and endemism (Salazar et al., 2020) and provide numerous ecosystem services, helping to retain water, stabilize soils, store carbon, and increase soil fertility (CARRIÓN-PALADINES et al., 2022). Unfortunately, due to their complex topographic location, these forests are highly threatened by fragmentation processes, due to anthropogenic activities (FASTRÉ et al., 2020), especially in the Andes.

Most of the planet's forests are home to birds, and they are excellent indicators of biodiversity or productivity, as well as environmental indicators to preserve and manage forests (ALEXANDRINO et al., 2016; MEKONEN, 2017; TERRIGEOL et al., 2022); that is, variation in bird numbers is associated with changes in the biodiversity of mountain ranges (KOVAŘÍK et al., 2021). In forested areas, the variation of birds at different levels of forest management intensity is evident (KLEEMANN et al., 2022b). Forest landscapes are affected by human activities mainly linked to agricultural development, livestock, forest fire and urbanization, developing a mosaic of forest fragments (CURTIS et al., 2018; NOH et al., 2022). This fragmentation gives rise to different environmental conditions, affects the distribution and survival of birds, and evidences the need to implement strategies to mitigate these effects (BOVO et al., 2018). As policies for the protection of fragments and secondary forests (AGYEMANG-DUAH et al., 2021; TONETTI et al., 2024), sustainable agricultural practices that reduce pressure on these habitats (JACOME et al., 2024), and the creation of biological corridors that connect forest fragments, facilitating the movement and dispersal of bird species (CHEN et al., 2021). However, there are studies in fragmented landscapes where it has been shown that the number of bird species decreases year after year after deforestation (DOS ANJOS et al., 2011; DOS ANJOS et al., 2024).

In Ecuador, most of the primary Andean forests are part of the National System of Protected Areas (KLEEMANN et al., 2022a). However, most deforestation occurs in unprotected primary forests (MARIAN et al., 2020; RITCHIE; ROSER, 2021). According to the IUCN Red List of Threatened Species, the country is among the most threatened globally (MOUNCE et al., 2018). The main changes in land use are from natural forest to areas of grasslands, crops, and wood plantations (RÍOS-TOUMA et al., 2023), transformations that result in a mosaic of native forests, surrounded by extensive agricultural areas. These land-use change processes are one of the main drivers of biodiversity loss and the ecosystem services they provide (GUEVARA et al., 2021).

Although bird species are distributed throughout the country, their populations can vary in abundance and diversity over space and time due to variation in rainfall, resource changes, and habitat alteration (SHAW et al., 2013). Forest fragmentation and destruction have negatively affected their distribution and survival (BLAKE; LOISELLE, 2015). Information on bird diversity in forest fragments is essential to establish a knowledge base for monitoring, birdwatching activity, or as indicators of habitat quality (OCAMPO-PEÑUELA; WINTON, 2017). Given the pressures that forests endure, bird species' richness, diversity, and similarity were evaluated in six tropical forest fragments from 170 to 2,100 meters above sea level in the western Andes, central Ecuador.

2. MATERIAL AND METHODS

2.1. Study area

The research area is located in fragments of humid tropical forests on the Andean slopes of the canton of La Maná and Pujilí, with altitudinal ranges ranging from 170 to 2100 meters above sea level. These areas are part of the Guayas River Basin, with a Humid Megathermal Tropical climate, 18-26°C temperature, and rainfall from 950-2000 mm/year (ILBAY-YUPA et al., 2021). Part of the study area is within the Ilinizas Ecological Reserve (Figure 1).

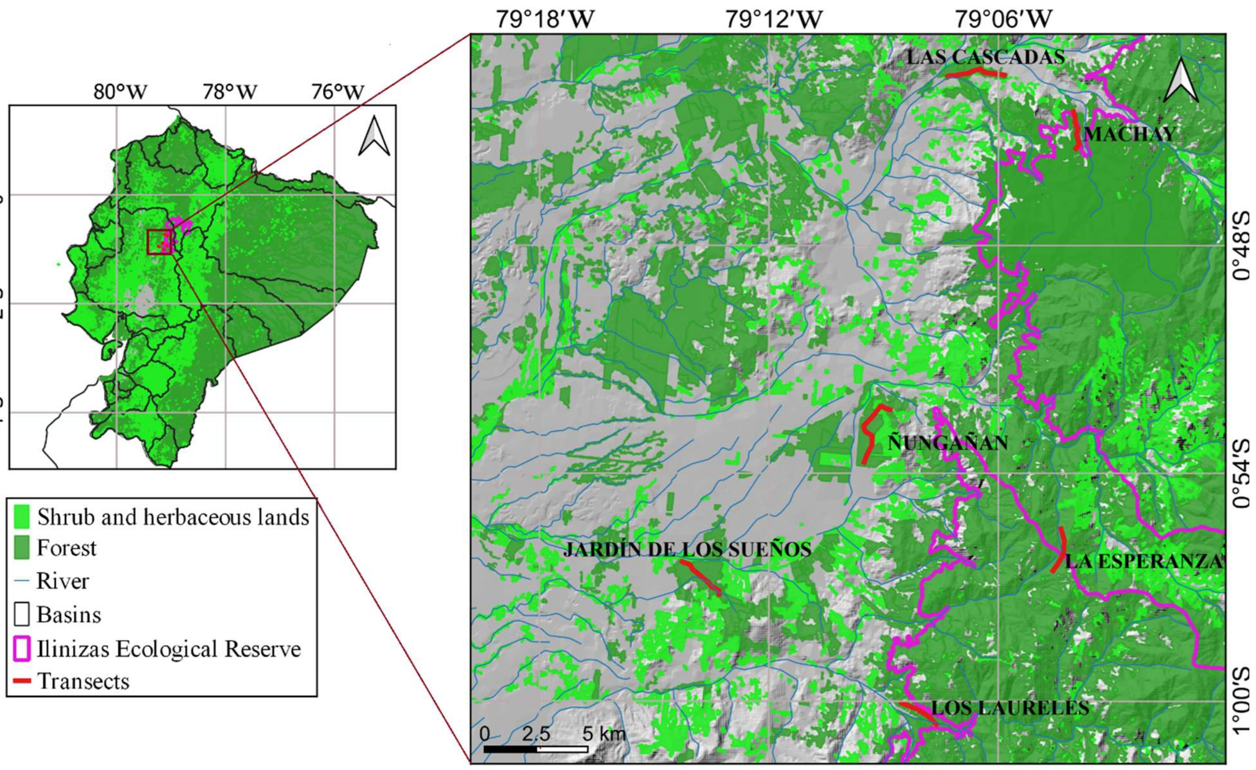

Figure 1. Spatial distribution of the six sampling areas in tropical forest fragments in the western Andes of Ecuador.
Figura 1. Distribuição espacial das seis áreas amostrais em em fragmentos de floresta tropical nos Andes ocidentais do Equador.

2.2. Bird count by points

This method is used to inventory and monitor bird populations worldwide (FONTÚRBEL et al., 2020). This count was carried out in six fragments of humid tropical forests on the western slopes of the Ecuadorian Andes, such as Las Cascadas (170-460 masl), Ñungañan (370-410 masl), Jardín de los Sueños (400-550 masl), Los Laureles (700-800 masl), Machay (900-1100 masl), and La Esperanza (1650-2100 masl); the latter area with a slope of 22% and is within the Illinizas. In each fragment, six strategic counting points were identified for a transect of ≈ 4 km (Figure 1). The weather conditions on the days of the count at strategic points were mostly sunny with a wind speed of 1.8 ± 0.65 m s^{-1}.

2.3. Species diversity and richness

Ecological parameters such as diversity and richness are essential to bird species diversity. Species richness was the total number of bird species observed for each area. The diversity of the species was calculated considering the Shannon Index (H ́), the calculation equation was (SOMARRIBA, 1999):

$$H' = -\sum_{i=1}^{S} fi * \log_2 pi \quad (01)$$

where: *fi* is the proportion of each species of birds in the population (relative abundance) and *S* is the species.

The relative abundance was calculated based on the following equation:

$$fi = \frac{NIOS}{TNIAS} \quad (02)$$

where: NIOS, Number of Individuals of one Species, and TNIAS, Total number of Individuals of all Species.

2.4. Calculation of the Sørensen index

Sorrensen's similarity coefficient was also calculated to compare the similarity of bird species in terms of richness and diversity (CUYCKENS et al., 2015) among the six zones with the presence of humid tropical forests; The following formula was used:

$$S = \frac{2C}{A} + B \quad (03)$$

where: C, common species between the areas; A, total number of species in areas A and B, total number of species in area B.

2.5. Statistical analysis

To compare the richness and diversity of the forest fragments under study, the Shapiro-Wilk normality test was executed, which is necessary for the performance of the analysis of variance, to reduce statistical error (KNIEF; FORSTMEIER, 2021). It was carried out according to the expression:

$$w = \frac{\left(\sum_{i=1}^{n} a_i \gamma_{(i)}\right)^2}{\sum_{i=1}^{n} (\gamma_i - \bar{\gamma})^2} \quad (04)$$

where: w: corresponds to the test statistic, which varies from 0 to 1, to denote that, according to H_0, there is not enough statistical evidence to reject the assumption of normality, with an alpha of 0.05; n: is the size of the bird samples observed; $\gamma_{(i)}$: absolute value obtained from the difference between the lowest and the last value, from the data ordered from lowest to highest; γ_i: represents each of the observations; $\bar{\gamma}$: is the average of the data; a_i: coefficients of the quantiles of the standard normal distribution.

The number of birds does not follow a Gaussian distribution due to considerable outliers, whose data require a critical analysis for an in-depth study within the biological sequences (GUPTA et al., 2014). Therefore, a non-parametric analysis was carried out, t according to the Kruskal-Wallis test, to determine if there are differences between groups or fragments of forests, based on H_0 that each group is the same and H_1 that at least one of the groups is different, using the following expression:

$$H = \left[\frac{12}{N(N+1)} \sum_{j=1}^{k} \frac{R_j^2}{n_j}\right] - 3(N+1) \quad (05)$$

where: H: is the test statistic that follows a χ^2 (chi-square) distribution with k-1 degrees of freedom; N: is the total number of birds in all forest fragments; k: is the number of forest fragments; R_j: is the sum of the ranges obtained from bird observations in each of the forest fragments; n_j : is the number of birds present in each fragment of forest.

To determine the difference between groups, H was compared with the critical value of $\alpha = 0.05$, therefore, if $p \leq 0.05$, H_0 is rejected, in which case the Post-hoc comparison was made, using Dunn's test, commonly used since it corrects the type I error, adjusting the p-value by Banferroni's method (ARMSTRONG, 2014).

Dunn's test is based on calculating the standard normal Z to obtain the comparison of the sum of the ranges, given by the following expression.

$$Z_{ij} = \frac{R_i - R_j}{\sqrt{\left(\frac{N(N+1)}{12}\right)\left(\frac{1}{n_i} + \frac{1}{n_j}\right)}} \quad (06)$$

where: R_i y R_j : is the sum of the ranges of birds observed in forest fragment i and j; n_i y n_j: is the number of birds in the forest fragment i and j.

This same method was used to compare bird species that coincide in the same groups, suggesting that they are more adaptable to the conditions presented by each forest fragment.

Because the analysis of forest fragments was also performed in pairs, to determine whether the richness and diversity of birds is different or not, the Mann Whitney test was performed, which is a non-parametric test commonly used to compare two independent groups, under the assumption that normality is not met (LE CESSIE et al., 2020), as follows:

$$U_i = n_i \times n_j + \frac{n_i(n_i+1)}{2} - R_i \quad (07)$$

$$U_j = n_i \times n_j + \frac{n_j(n_j+1)}{2} - R_j \quad (08)$$

where: U is the test statistic obtained from the minimum value between Ui and Uj which, when compared with the critical value between ni and nj with $\alpha = 0.05$, determines whether there is a difference between the groups under the hypothesis H_0 that the medians of both groups are the same or vice versa fo H_1, according to $p \leq 0.05$ of significance. determines whether there is a difference between the groups under the hypothesis H_0 that both groups are equal or H_1 different, according to $p \leq 0.05$ of significance.

3. RESULTS

3.1. Statistical analysis of bird richness and diversity

We recorded 19 orders, 48 families, 70 genera, and 219 species, for a total of 1849 birds; the families with the highest abundance were Thraupidae with 283 individuals, followed by Tyrannidae with 234, Fringillidae with 99, and Accipitridae with 25. In the fragment of tropical forest La Esperanza, the abundance was 635 individuals, followed by Ñungañan (375), Jardín de los Sueños (243), Los Laureles (225), Machay (186), and Las Cascadas (185).

The Kruskal-Wallis test shows significant differences ($p \leq 0.05$) between the number of bird species in each forest fragment. According to the Bonferroni test, two groups could be established. The differences between groups are shown in Table 1: between La Esperanza and the sites: Jardín de los Sueños, Machay, Los Laureles, and Las Cascadas. On the other hand, Ñungañan was differentiated from the Garden of Dreams, Machay, Los Laureles, and Las Cascadas sites.

Table 1. Statistical significance of forest fragments according to the Bonferroni test, where ** = 0.01 and *** = 0.001
Tabela 1. Significância estatística dos fragmentos florestais segundo o teste de Bonferroni, onde ** = 0,01 e *** = 0,001.

	Jardín de los sueños	La esperanza	Las Cascadas	Los Laureles	Machay
La esperanza	0.001***				
Las cascadas	1.000	0.002**			
Los Laureles	1.000	0.014**	1.000		
Machay	1.000	0.000***	1.000	1.000	
Nunganan	0.005**	1.000	0.008**	0.047*	0.001***

Figure 2 shows that the number of birds observed was significantly equal for La Esperanza and Ñungañan, which we call group one; on the other hand, the forest fragments of Jardín de los Sueños, Los Laureles, Machay, and Las Cascadas are significantly the same, so we call group two, because they are different from the previous group, with a smaller number of birds observed. It is worth mentioning that, in the forest fragment made up of group one, with the highest number of observations, there is the largest number of atypical data, with different species observed in a greater quantity than others, with observations of 20 to 60 individuals, which contrasts with group two, whose outliers do not exceed 18 observed individuals of the same species. This peculiarity may mean a preference for a certain group of birds in these forest spaces. these differences between forest fragments may be influenced by anthropogenic pressures, occurring in genetic drift and little gene flow, decreasing diversity, finding more forceful effects in fragments over 50 years of age than those more recent, as revealed by the analysis carried out by SCHLAEPFER et al. (2018), which although it depends a lot on poorly understood factors typical of the behavior of the species.

3.2. Abundance and Frequency of Birds

The bird species that were most frequently found ($fi \geq 0.02$) are described in Figure 3. The most common species in the La Esperanza forest fragment are: *Anisognathus somptuosus, Streptoprocne rutila, Pygochelidon cyanoleuca, Patagioenas fasciata, Streptoprocne zonaris* and *Tangara arthus*; in Ñungañan: *Pygochelidon cyanoleuca, Coragyps atratus* and *Bubulcus ibis*; Jardín de los Sueños: *Pygochelidon cyanoleuca*; in Los Laureles: *Thraupis episcopus, Bubulcus ibis, Coragyps atratus, Ramphocelus flammigerus* and *Cathartes aura*; in Machay: *Egretta thula;* and in Las Cascadas: *Thraupis episcopus, Forpus coelestis, Dives warczewiczi, Pygochelidon cyanoleuca* and *Tyrannus melancholicus*. The genus *Pygochelidon* is common in most places, and *Bubulcus ibis* is in Ñungañan and Los Laureles. The presence and frequency of birds vary from fragment to fragment. This may be due to environmental factors, predation intensity, habitat heterogeneity, food resources, and nesting sites (BIBI; ALI, 2013; GUEVARA et al., 2021).

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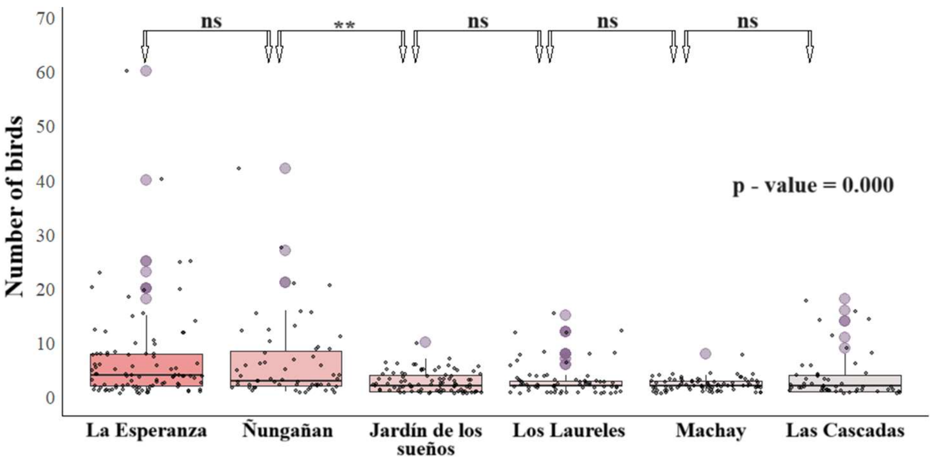

Figure 2. Comparison of richness between tropical forest fragments, according to the Bonferroni post hoc test; ns = insignificant, ** = significant at 0.01. The small dots represent each observation, while the larger dots are the outliers.
Figura 2. Comparação da riqueza entre fragmentos de floresta tropical, segundo teste post hoc de Bonferroni; ns = não significativo, ** = significativo a 0,01. Os pontos pequenos representam cada observação, enquanto os pontos maiores são os valores discrepantes.

It was possible to determine the bird species that coincide in all the forest fragments: *Amazilia tzacatl, Coragyps atratus, Cathartes aura, Dives warczewiczi, Molothrus bonariensis, Ramphocelus flammigerus, Thraupis episcopus, Turdus maculirostris,* and *Tyrannus melancholicus*, which did not show any difference between them ($p=0.110$), according to the Kruskal-Wallis test with $p \leq 0.05$. These birds have in common that they are native to various areas of Latin America, in tropical and subtropical regions.

3.3. Bird Diversity

Table 1 shows the range of the Shannon diversity index, which was from 0.72 to 1.20 for the six forest fragments; that is, all values were less than 2, corresponding to a low diversity of birds in the forest fragments of the western Andes of Ecuador. When comparing these results with protected tropical forests (DICKINSON et al., 2015; HOHNWALD, 2021), these results reflect impoverished diversity, probably because these forests have undergone moderate alteration, and also in Las Cascadas, Los Laureles, and part of Machay, there is a great agricultural development in their surroundings.

3.4. Similarity of bird species

The similarity evaluated with the Sorensen Index in the six forest fragments during 2019 generated two groups: Group 1, formed by Ñungañan and Machay, areas that presented similar floristic environments with large trees and steeply inclined slopes (20-35%), and Group 2, made up of the forest fragments of Los Laureles, Jardín de los Sueños, La Esperanza, and Las Cascadas (Figure 4). However, it should be considered that the level of similarity of bird species in the two groups was 41-60% between 170-2100 masl. This indicates that each patch of forest within each group has a medium level of species similarity. This may be because the bird species found were relatively similar in richness and diversity (PATTINASARANY et al., 2021).

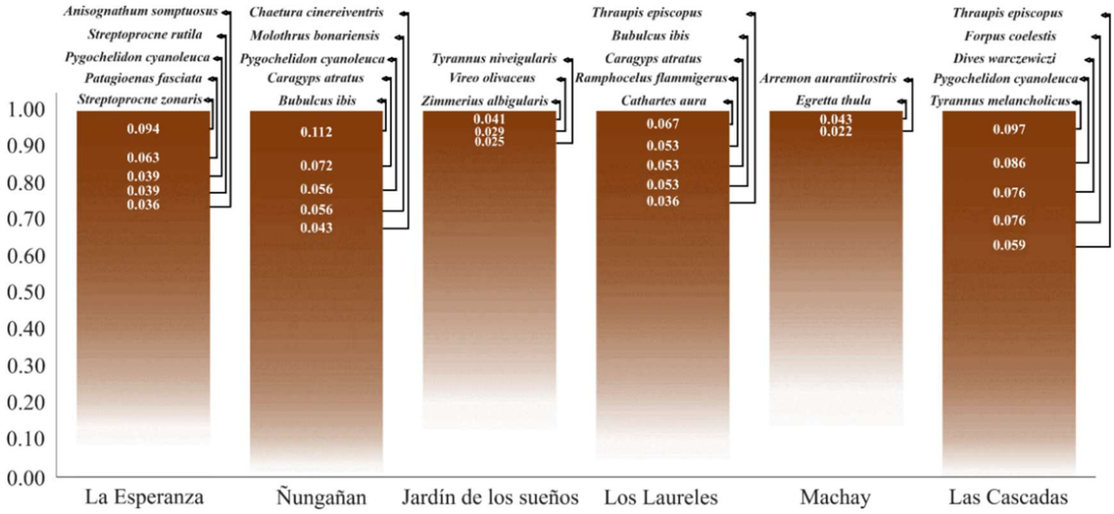

Figure 3. Relative frequency of the number of birds of different species observed in the six forest fragments, with those having greater abundance in the upper part.
Figura 3. Frequência relativa do número de aves de diferentes espécies observadas nos seis fragmentos florestais; sendo aqueles com maior abundância na parte superior.

Table 1. Bird diversity in tropical forest fragments of the western Andes of Ecuador.
Tabela 1. Diversidade de aves em fragmentos de floresta tropical dos Andes ocidentais do Equador.

Forest fragment	Shannon Index (H´)
Esperanza	1.15
Ñungañan	1.20
Jardín de los Sueños	0.95
Los Laureles	0.93
Machay	0.84
Las Cascadas	0.72

When comparing only similar species and their count between forest fragments using the Mann Whitney ($p \leq 0.05$), highly significant differences were shown between La Esperanza and Machay ($p = 5.12x10^{-5}$), with a greater number being found in La Esperanza, particularly previously described as the forest fragment with the highest number of observations of the same species. On the other hand, Ñungañan is superior to Jardín de los Sueños ($p = 0.024$), Machay ($p = 0.002$), and Las Cascadas ($p = 0.017$). Finally, Jardín de los Sueños was superior to Machay ($p = 0.002$). However, the rest of the forest fragments did not show significant differences (Figure 5).

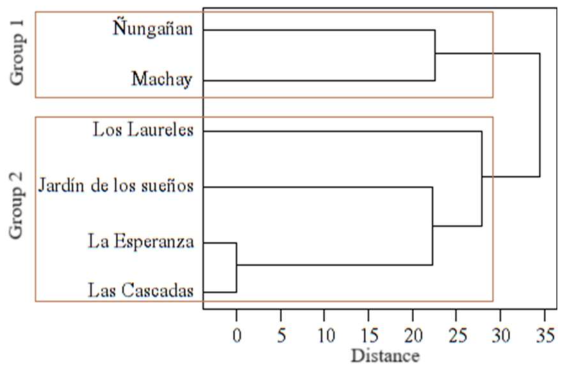

Figure 4. Hierarchical grouping of the Bird Similarity Index in tropical forest fragments.
Figura 4. Agrupamento hierárquico do Índice de Similaridade de Aves em fragmentos de floresta tropical.

The distribution of birds varies widely between 170 and 2100 masl in the different forest fragments; however, in

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certain fragments, their distribution is restricted to steep slopes. This is because these forests are maintained with less human intervention due to the difficulty of access and use of the land, and therefore, birds have greater availability of food resources (UGALDE-LEZAMA et al., 2010; VACCARO & BELLOCQ, 2019).

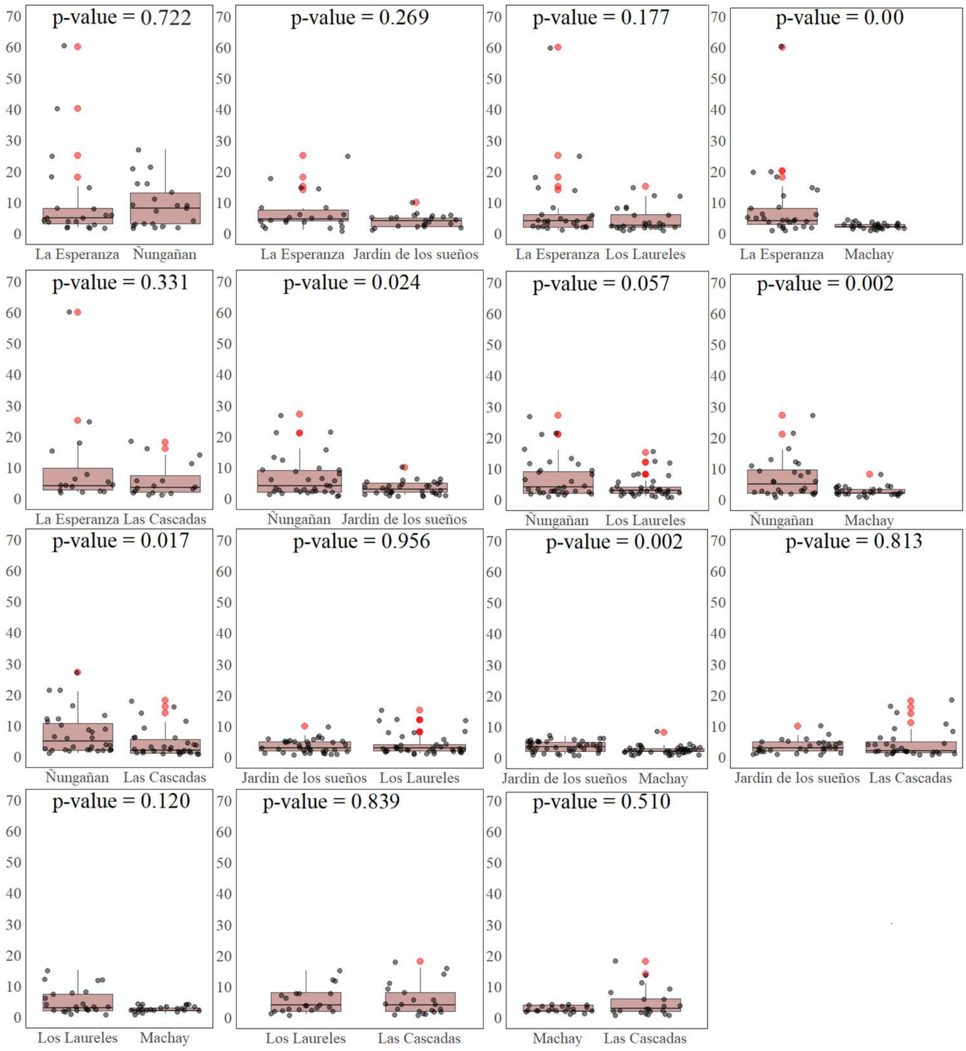

Figure 5. Number of birds for the Pairwise comparison of bird richness and diversity in tropical forest fragments, according to the Mann-Whitney test with $p \leq 0.05$. The small dots represent each observation, while the larger dots are the outliers.
Figura 5. Número de aves para comparação pareada da riqueza e diversidade de aves em fragmentos de floresta tropical, segundo o teste de Mann Whitney com $p \leq 0,05$. Os pontos pequenos representam cada uma das observações, enquanto os pontos maiores são os valores discrepantes.

4. DISCUSSION

Certain forest fragments seem to be able to host more birds, perhaps due to specific environmental factors. However, a study conducted in Colombia suggests that the ecological connection of some bird species is linked to large areas that can span from the Andes to the Amazon (LINERO-TRIANA et al., 2023). Therefore, restoring areas affected by human action should increase and promote forest growth (ANDERSON; JENKINS, 2006), which benefits the birdlife in the protected area corridor.

In the six forest fragments, there is a certain richness of bird species, resident and migratory species, and characteristics of the different stages of conservation of the fragments. Thus, the forest fragments still have an environment with enough vegetation cover and food resources to house some native birds (MORALES et al., 2022).

Studies say that fragmented tropical forests affect the diversity and abundance of birds (HARIHARAN; RAMAN, 2022; SIEGEL et al., 2024; SIMAMORA et al., 2021). This information is consistent with what was obtained in this study, due to the abundance and diversity of the forest fragments.

In a study in Indonesia, the record of 244 dissimilar species of birds showed that 80% preferred intact forests, with 6% being those species that have been sighted in cultivated areas (SIMAMORA et al., 2021). Another study also demonstrated similar characteristics (JONES et al., 2021). This allows us to understand that there are species adapted to human conditions and therefore the presence of birds of the same species in specific sites of the forest fragments in this study. It is plausible to use agroforestry systems as an alternative for the recovery of fragmented areas with mixed tree species, typical of the area (ASTIANI; RIPIN, 2016; MARJOKORPI; RUOKOLAINEN, 2003). This is added because it is worrying that in Ecuador, 4% of deforestation occurs in protected areas, 25% in buffer zones, which includes the Ilinizas ecological reserve (Kleemann et al., 2022b), which comprises part of the transects in this research.

Pygochelidon cyanoleuca is a species denoted by its repeated presence in the various forest fragments; therefore, an important adaptability is assumed in Ecuador. On the other hand, the expansion of *Bubulcus ibis* in Ñungañan and Los Laureles reveals its capacity to adapt and coexist with anthropogenic activities. This is logical, given that this species adapts to multiple locations, in regions of the world with tropical, subtropical, and warm temperate climates (SALEM et al., 2023). With climates similar to its origin in sub-Saharan Africa, it is also an indicator of altered areas.

This pattern would be ideal with a larger number of native species; however, Ecuador ranks second in the number of threatened species, with 102 birds, due to various human activities (IUCN RED LIST, 2024), confirmed by Kleemann et al. (2022a), in whose review it is shown that the greatest negative effect on biodiversity and ecosystem services that directly affect birds in Ecuador corresponds to human activities rather than the effect of climate change.

According to the count obtained in this study, it has been possible to determine the low diversity of birds; this is because the existence of a variety of habitats favors the number of species, richness and uniformity, understanding that forest lands significantly increase these variables (TU et al., 2020). Forest cover is crucial for increasing the number of bird species. Increasing forest cover can reduce fragmentation and improve connectivity between habitats, facilitating the colonization and survival of more bird species (BASILE et al., 2021). Although there are no extensive studies that denote in general the effect of sustainability in the areas of our interest, which affect the entire ecological system of an area, in La Esperanza there is variability in production systems with divergences of technologies and access to different services and with weak environmental sustainability (JÁCOME et al., 2024). Another factor to consider is the influence of steep slopes, where forest fragments are maintained with less human intervention, due to the difficulty of access and land use, and therefore birds have greater availability of food resources (UGALDE-LEZAMA et al., 2010; VACCARO; BELLOCQ, 2019).

We understand that the national system of protected areas of Ecuador (SNAP) categorizes ecological reserves, as is the case with Iliniza, with little or no human activity (MAATE, 2024). The diversity of birds could be because most of the observations were at the limits of the reserve and not in the interior, which would be ideal to show a better perspective of bird diversity. Still, it was important to note that increased human activity and decreased protected areas are aggravating factors.

5. CONCLUSIONS

Studying the six fragments of Tropical Forests of the western Andes of Ecuador reveals important findings about birds' richness, abundance, and diversity. 219 species of birds belonging to 70 genera, 48 families, and 9 orders were recorded. The families with the highest wealth were Thraupidae (15.3%), Tyrannidae (12.7%), Fringillidae (5.4%), and Accipitridae (1.4%). The highest relative abundance of birds for the La Esperanza was the species Anisognathus somptuosus and Streptoprocne rutila; Ñungañan: Pygochelidon cyanoleuca and Coragyps atratus; Los Laureles: Thraupis episcopus and Bubulcus ibis; Machay: Egretta thula and Arremon aurantiirostris, and in Las Cascadas: *Thraupis episcopus and Forpus coelestis*. Bird diversity, as measured by the Shannon index, was low in all fragments, reflecting an impoverishment of diversity due to moderate forest disturbance. On the other hand, the similarity analysis shows two main groups, with a medium level of similarity among species.

The statistical analysis shows significant variations in the richness, abundance and similarity of bird species between forest fragments ($p<0.05$). La Esperanza and Ñungañan are the least disturbed forest fragments, the ones that presented a greater diversity of species and abundance, which underlines the importance of conserving these habitats, through an integral and sustainable management of tropical forest fragments in the western Andes of Ecuador, to preserve bird biodiversity and the ecosystem services that these forests provide.

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Data availability: The study data are in the annexes; they can be sent if more details are required. This information corresponds to completed research work.

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ANNEX

Annex 1. List of fragments, their altitude and bird species
Anexo 1. Lista de fragmentos, sua altitude e espécies de aves.

Forest fragments	Altitude (masl)	Bird species	Number of bird species
La Esperanza	1650 - 2100	*Streptoprocne zonaris*	60
		Patagioenas fasciata	40
		Streptoprocne rutila	25
		Pygochelidon cyanoleuca	25
		Anisognathus somptuosus	23
		Colibri cyanotus	20
		Synallaxis azarae	20
		Tangara arthus	20
		Coragyps atratus	18
		Pionus sordidus	15
		Tyrannus melancholicus	15
		Myioborus miniatus	14
		Adelomyia melanogenys	12
		Elaenia pallatangae	12
		Zonotrichia capensis	12
		Myiothlypis coronata	12
		Semnornis ramphastinus	10
		Vireo leucophrys	10
		Turdus fuscater	10
		Chaetura cinereiventris	8
		Grallaria ruficapilla	8
		Thripadectes holostictus	8
		Mecocerculus poecilocercus	8
		Contopus fumigatus	8
		Pheugopedius euophrys	8
		Sporophila luctuosa	8
		Tangara ruficervix	8
		Dives warczewiczi	8
		Lepidocolaptes lacrymiger	7
		Cyanolyca turcosa	6
		Troglodytes aedon	6
		Henicorhina leucophrys	6
		Tangara vassorii	6
		Thraupis episcopus	6
		Leptotila verreauxi	5
		Chaetocercus mulsant	5
		Amazilia tzacatl	5
		Aulacorhynchus	5
		Setophaga pitiayumi	5
		Cathartes aura	4
		Andigena laminirostris	4
		Mionectes striaticollis	4
		Myiodynastes	4
		Rupicola peruvianus	4
		Vireo olivaceus	4
		Cantorchilus nigricapillus	4
		Diglossa albilatera	4
		Ramphocelus flammigerus	4
		Thlypopsis ornata	4
		Coereba flaveola	4
		Pipraeidea melanonota	4
		Arremon brunneinucha	4
		Molothrus bonariensis	4
		Colibri coruscans	3
		Calliphlox mitchellii	3
		Geranoaetus polyosoma	3
		Pyrrhomyias	3
		Sayornis nigricans	3
		Cinclus leucocephalus	3
		Turdus serranus	3
		Patagioenas plumbea	2
		Systellura longirostris	2
		Heliodoxa rubinoides	2
		Rupornis magnirostris	2
		Parabuteo leucorrhous	2
		Margarornis squamiger	2
		Cranioleuca erythrops	2
		Elaenia albiceps	2
		Zimmerius albigularis	2
		Ochthoeca	2
		Turdus maculirostris	2
		Tachyphonus rufus	2
		Sporophila corvina	2
		Piranga leucoptera	2
		Pheucticus chrysogaster	2
		Euphonia laniirostris	2

		Merganetta armata	1
		Chamaepetes goudotii	1
		Nyctibius griseus	1
		Uropsalis lyra	1
		Schistes geoffroyi	1
		Heliangelus strophianus	1
		Coeligena torquata	1
		Amazilia franciae	1
		Tyto alba	1
		Ciccaba albitarsis	1
		Pharomachrus auriceps	1
		Veniliornis dignus	1
		Colaptes rivolii	1
		Diglossa sittoides	1
		Chlorornis riefferii	1
		Tangara nigroviridis	1
		Thraupis cyanocephala	1
		Euphonia cyanocephala	1
		Euphonia xanthogaster	1
Machay	900 - 1100	*Egretta thula*	8
		Streptoprocne zonaris	4
		Furnarius leucopus	4
		Sayornis nigricans	4
		Fluvicola nengeta	4
		Stelgidopteryx ruficollis	4
		Ramphocelus flammigerus	4
		Thraupis palmarum	4
		Arremon aurantiirostris	4
		Dives warczewiczi	4
		Bubulcus ibis	3
		Coragyps atratus	3
		Touit dilectissimus	3
		Synallaxis azarae	3
		Myiotriccus ornatus	3
		Tyrannus melancholicus	3
		Pachyramphus	3
		Cantorchilus nigricapillus	3
		Sicalis flaveola	3
		Tachyphonus rufus	3
		Sporophila corvina	3
		Sporophila nigricollis	3
		Chlorospingus canigularis	3
		Arremonops conirostris	3
		Myiothlypis fraseri	3
		Molothrus oryzivorus	3
		Spinus xanthogastrus	3
		Euphonia saturata	3
		Euphonia laniirostris	3
		Euphonia xanthogaster	3
		Aburria aburri	2
		Patagioenas subvinacea	2
		Leptotila verreauxi	2
		Zenaida auriculata	2
		Crotophaga ani	2
		Tapera naevia	2
		Piaya cayana	2
		Amazilia tzacatl	2
		Laterallus albigularis	2
		Ardea alba	2
		Cathartes aura	2
		Ciccaba nigrolineata	2
		Pharomachrus auriceps	2
		Pionus chalcopterus	2
		Synallaxis brachyura	2
		Camptostoma obsoletum	2
		Myiozetetes similis	2
		Myiarchus tuberculifer	2
		Troglodytes aedon	2
		Turdus maculirostris	2
		Turdus chiguanco	2
		Saltator maximus	2
		Coereba flaveola	2
		Pipraeidea melanonota	2
		Tangara parzudakii ü	2
		Tangara arthus	2
		Thraupis episcopus	2
		Zonotrichia capensis	2
		Myiothlypis fulvicauda	2
		Myioborus miniatus	2
		Icterus mesomelas	2
		Patagioenas cayennensis	1
		Phaethornis yaruqui	1
		Lesbia victoriae	1
		Elanus leucurus	1
		Aulacorhynchus	1
		Pteroglossus torquatus	1
		Picoides fumigatus	1
		Colaptes rubiginosus	1
		Dryocopus lineatus	1
		Herpetotheres cachinnans	1
		Taraba major	1
		Lepidocolaptes souleyetii	1
		Cranioleuca erythrops	1
		Contopus fumigatus	1
		Myiodynastes	1
		Cephalopterus penduliger	1
		Pachyramphus albogriseus	1
		Cyclarhis gujanensis	1
		Tangara gyrola	1
		Molothrus bonariensis	1
Los Laureles	700 - 900	*Cathartes aura*	15
		Bubulcus ibis	12
		Coragyps atratus	12
		Ramphocelus flammigerus	12
		Psittacara erythrogenys	8
		Tyrannus melancholicus	8
		Pygochelidon cyanoleuca	8
		Thraupis episcopus	8
		Pionus chalcopterus	7
		Streptoprocne zonaris	6
		Molothrus bonariensis	6
		Patagioenas cayennensis	4
		Columbina buckleyi	4
		Megarynchus pitangua	4
		Stelgidopteryx ruficollis	4
		Mitrospingus cassinii	4
		Patagioenas plumbea	3
		Leptotila pallida	3
		Crotophaga ani	3
		Piaya cayana	3
		Ardea alba	3
		Ramphastos brevis	3
		Pionus menstruus	3
		Zimmerius albigularis	3
		Sayornis nigricans	3
		Myiozetetes similis	3
		Atticora tibialis	3
		Tachyphonus rufus	3
		Sporophila funerea	3
		Sporophila corvina	3
		Amazilia tzacatl	2
		Forpus coelestis	2
		Myrmotherula pacifica	2
		Hafferia zeledoni	2
		Furnarius leucopus	2
		Cranioleuca erythrops	2
		Fluvicola nengeta	2
		Myiozetetes cayanensis	2
		Myiodynastes	2
		Querula purpurata	2
		Troglodytes aedon	2
		Polioptila plumbea	2
		Cinclus leucocephalus	2
		Chlorophanes spiza	2
		Sporophila nigricollis	2
		Coereba flaveola	2
		Setophaga pitiayumi	2
		Icterus mesomelas	2
		Dives warczewiczi	2
		Spinus xanthogastrus	2
		Euphonia laniirostris	2
		Euphonia xanthogaster	2
		Eutoxeres Aquila	1
		Heliothryx barroti	1
		Heliomaster longirostris	1
		Harpagus bidentatus	1
		Morphnarchus princeps	1
		Rupornis magnirostris	1
		Buteo nitidus	1
		Megaceryle torquata	1
		Nystalus radiatus	1
		Melanerpes pucherani	1
		Veniliornis kirkii	1
		Colaptes rubiginosus	1
		Dryocopus lineatus	1
		Formicarius nigricapillus	1
		Turdus maculirostris	1
		Saltator atripennis	1

		Myioborus miniatus	1
Jardín de los	400 – 550	*Pygochelidon cyanoleuca*	10
		Pionus chalcopterus	7
		Poliocrania exsul	6
		Ramphocelus flammigerus	6
		Thraupis episcopus	6
		Thraupis palmarum	6
		Euphonia laniirostris	6
		Euphonia xanthogaster	6
		Amazilia tzacatl	5
		Bubulcus ibis	5
		Ramphastos brevis	5
		Camptostoma obsoletum	5
		Tyrannus melancholicus	5
		Stelgidopteryx ruficollis	5
		Troglodytes aedon	5
		Turdus maculirostris	5
		Coereba flaveola	5
		Coragyps atratus	4
		Lophotriccus pileatus	4
		Fluvicola nengeta	4
		Myiarchus tuberculifer	4
		Cantorchilus nigricapillus	4
		Tangara cyanicollis	4
		Myiothlypis fulvicauda	4
		Dives warczewiczi	4
		Euphonia saturata	4
		Crotophaga ani	3
		Phaethornis yaruqui	3
		Pteroglossus torquatus	3
		Lepidocolaptes souleyetii	3
		Synallaxis brachyura	3
		Myiozetetes similis	3
		Megarynchus pitangua	3
		Tyrannus niveigularis	3
		Vireo olivaceus	3
		Sporophila corvina	3
		Saltator maximus	3
		Setophaga pitiayumi	3
		Myiothlypis fraseri	3
		Leptotila verreauxi	2
		Leptotila pallida	2
		Panyptila cayennensis	2
		Heliothryx barroti	2
		Discosura conversii	2
		Cathartes aura	2
		Baryphthengus martii	2
		Momotus subrufescens	2
		Ramphastos ambiguus	2
		Thamnophilus atrinucha	2
		Furnarius leucopus	2
		Myiopagis viridicata	2
		Capsiempis flaveola	2
		Zimmerius albigularis	2
		Todirostrum cinereum	2
		Cyclarhis gujanensis	2
		Cyanerpes caeruleus	2
		Sporophila luctuosa	2
		Tangara icterocephala	2
		Molothrus bonariensis	2
		Tinamus major	1
		Crypturellus	1
		Patagioenas cayennensis	1
		Piaya cayana	1
		Nyctidromus albicollis	1
		Phaethornis striigularis	1
		Butorides striata	1
		Egretta thula	1
		Chondrohierax uncinatus	1
		Buteo nitidus	1
		Buteo albonotatus	1
		Ciccaba virgata	1
		Picumnus olivaceus	1
		Melanerpes pucherani	1
		Campephilus	1
		Herpetotheres cachinnans	1
		Taraba major	1
		Myrmotherula pacifica	1
		Dendrocincla fuliginosa	1
		Phylloscartes ophthalmicus	1
		Myiotriccus ornatus	1
		Myiozetetes cayanensis	1
		Myiodynastes maculatus	1
		Attila spadiceus	1
		Querula purpurata	1
		Manacus manacus	1
		Pachyramphus	1
		Microcerculus Marginatus	1
		Polioptila plumbea	1
		Myioborus miniatus	1
Ñungañan	370 – 410	*Bubulcus ibis*	42
		Coragyps atratus	27
		Pygochelidon cyanoleuca	21
		Molothrus bonariensis	21
		Chaetura cinereiventris	16
		Cathartes aura	16
		Phalacrocorax brasilianus	15
		Ramphocelus flammigerus	13
		Furnarius leucopus	12
		Stelgidopteryx ruficollis	12
		Streptoprocne zonaris	11
		Tangara icterocephala	10
		Tyrannus melancholicus	9
		Turdus maculirostris	9
		Euphonia laniirostris	9
		Thraupis episcopus	8
		Patagioenas fasciata	7
		Thraupis palmarum	7
		Patagioenas cayennensis	6
		Egretta thula	6
		Myiozetetes similis	6
		Tangara cyanicollis	6
		Colaptes rubiginosus	5
		Saltator atripennis	5
		Ardea alba	4
		Zimmerius albigularis	4
		Polioptila plumbea	4
		Patagioenas plumbea	3
		Crotophaga ani	3
		Amazilia tzacatl	3
		Todirostrum nigriceps	3
		Megarynchus pitangua	3
		Myiarchus tuberculifer	3
		Sporophila funerea	3
		Dives warczewiczi	3
		Leptotila verreauxi	2
		Tapera naevia	2
		Piaya cayana	2
		Rupornis magnirostris	2
		Megaceryle torquata	2
		Momotus subrufescens	2
		Eubucco bourcierii	2
		Melanerpes pucherani	2
		Camptostoma obsoletum	2
		Sayornis nigricans	2
		Myiozetetes cayanensis	2
		Machaeropterus deliciosus	2
		Troglodytes aedon	2
		Cantorchilus nigricapillus	2
		Chlorophanes spiza	2
		Tangara gyrola	2
		Phaethornis striigularis	1
		Heliothryx barroti	1
		Heliomaster longirostris	1
		Gampsonyx swainsonii	1
		Pulsatrix perspicillata	1
		Chloroceryle americana	1
		Herpetotheres cachinnans	1
		Dacnis lineata	1
Las Cascadas	170 – 460	*Tyrannus melancholicus*	18
		Pygochelidon cyanoleuca	16
		Forpus coelestis	14
		Dives warczewiczi	14
		Thraupis episcopus	11
		Stelgidopteryx ruficollis	9
		Pionus chalcopterus	8
		Coragyps atratus	6
		Sayornis nigricans	6
		Myiozetetes cayanensis	6
		Melanerpes pucherani	4
		Sicalis flaveola	4
		Ramphocelus flammigerus	4
		Sporophila corvina	4
		Tangara icterocephala	4
		Cathartes aura	3
		Tangara gyrola	3
		Molothrus bonariensis	3
		Patagioenas subvinacea	2
		Piaya cayana	2
		Amazilia tzacatl	2

Rupornis magnirostris	2
Momotus subrufescens	2
Campephilus	2
Furnarius leucopus	2
Camptostoma obsoletum	2
Tityra semifasciata	2
Vireo olivaceus	2
Turdus maculirostris	2
Myiothlypis fulvicauda	2
Cacicus uropygialis	2
Icterus mesomelas	2
Patagioenas cayennensis	1
Columbina buckleyi	1
Streptoprocne zonaris	1
Ardea alba	1
Egretta thula	1
Chloroceryle americana	1
Baryphthengus martii	1
Eubucco bourcierii	1
Glyphorynchus spirurus	1
Lepidocolaptes souleyetii	1
Zimmerius albigularis	1
Leptopogon superciliaris	1
Myiozetetes similis	1
Megarynchus pitangua	1
Pachyramphus	1
Sporophila nigricollis	1
Saltator maximus	1
Mitrospingus cassinii	1
Arremon aurantiirostris	1
Cacicus cela	1