Revista Cubana de Ciencias Forestales

Volume 13, issue 3; 2025, September-December

liberciencia
EDITORIAL CIENTÍFICA UNIVERSIDAD DE PINAR DEL RÍO

UNIVERSIDAD DE PINAR DEL RÍO
HERMANOS SAÍZ MONTES DE OCA

CFORES
REVISTA CUBANA DE CIENCIAS FORESTALES

ISSN: 2310-3469 RNPS: 2347
CFORES Journal, September-December 2025; 13(3): e898

Original article

Bird diversity associated with different forested areas of the Viñales Agroforestry Experimental Station

Diversidad de aves asociada a diferentes áreas boscosas de la Estación Experimental Agroforestal Viñales

Diversidade de aves associada a diferentes áreas florestais da Estação Experimental Agroflorestal de Viñales

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Received: *09/06/2025.*
Approved: *06/10/2025.*
Published: *06/11/2025.*

ABSTRACT

Pine-oak forests are among the most biodiverse ecosystems in the world, where the birds that inhabit them play a vital role in their functioning. This research was conducted at the Viñales Agroforestry Experimental Station to determine the bird diversity associated with different pine-oak forest areas, selecting two areas of *Pinus* Nineteen circular plots were established in total, each with a fixed radius of 15 m and distributed 100 m apart, in areas of *caribaea (natural and plantation) and two pine-oak forests (one more disturbed and*

the other less disturbed). Bird species present in each area were inventoried in May and October 2023. Diversity was determined by interpreting the relative abundance graph, rarefaction curves based on the number of samples, and cluster analysis. The Kruskal-Wallis test was performed to determine if there were differences in the richness and abundance of the birds detected between areas, months, and sampled strata. The Mann-Whitney U and Wilcoxon tests were also used to establish which strata differed. A total of 31 bird species were identified. These were grouped into 8 orders, 16 families, and 25 genera. Most were permanent residents, consuming insects and grains. There were no significant differences in species richness and abundance between areas and months, while there were differences between the upper, middle, and lower strata.

Keywords: birds, diversity, oak, pine.

RESUMEN

Los bosques de pino-encino son uno de los ecosistemas con más diversidad en el mundo, donde las aves que los habitan juegan un papel importante en su funcionamiento. Esta investigación se realizó en la Estación Experimental Agroforestal Viñales, para determinar la diversidad de aves asociada a diferentes áreas boscosas de pino-encino, seleccionándose dos áreas de *Pinus caribaea* (natural y plantación) y dos de pino-encino (una más perturbada y otra menos perturbada), se establecieron 19 parcelas circulares en total, con un radio fijo de 15 m cada una, distribuidas a 100 m unas de otras. Se inventariaron las especies de aves presentes en cada área, en mayo y octubre del 2023. Se determinó la diversidad mediante la interpretación del gráfico de abundancia relativa, las curvas de rarefacción basada en el número de muestras y un análisis de conglomerado. Se realizó la prueba de comparación de medias Kruskal-Wallis, para determinar si existían diferencias de la riqueza y abundancia de las aves detectadas, entre áreas, meses y los estratos muestreados; utilizándose, además, los Test de U de Mann-Witney y Wilcoxon para establecer entre quienes estaban las diferencias. Se identificaron un total de 31 especies de aves, las cuales se agruparon en 8 órdenes, 16 familias y 25 géneros. La mayoría fueron residentes permanentes, consumidoras de insectos y de granos, no hubo diferencias significativas con relación a la riqueza y

abundancia de especies entre las áreas y los meses, mientras que hubo diferencias entre el estrato alto con el estrato medio y bajo.

Palabras clave: aves, diversidad, encino, pino.

RESUMO

As florestas de pinheiros e carvalhos estão entre os ecossistemas mais biodiversos do mundo, onde as aves que as habitam desempenham um papel vital em seu funcionamento. Esta pesquisa foi conduzida na Estação Experimental Agroflorestal de Viñales para determinar a diversidade de aves associada a diferentes áreas de floresta de pinheiros e carvalhos. Foram selecionadas duas áreas de *Pinus caribaea* (natural e plantada) e duas áreas de pinheiros e carvalhos (uma mais perturbada e outra menos perturbada). Um total de 19 parcelas circulares foram estabelecidas, cada uma com raio fixo de 15 m, distribuídas a 100 m de distância umas das outras. As espécies de aves presentes em cada área foram inventariadas em maio e outubro de 2023. A diversidade foi determinada pela interpretação do gráfico de abundância relativa, curvas de rarefação baseadas no número de amostras e análise de agrupamento. O teste de Kruskal-Wallis foi utilizado para comparar as médias e determinar se havia diferenças na riqueza e abundância das aves detectadas entre as áreas, meses e estratos amostrados. Os testes de Mann-Whitney U e Wilcoxon também foram utilizados para identificar os grupos entre os quais existiam diferenças. Um total de 31 espécies de aves foram identificadas, agrupadas em 8 ordens, 16 famílias e 25 gêneros. A maioria era residente permanente, alimentando-se de insetos e grãos. Não houve diferenças significativas na riqueza e abundância de espécies entre as áreas e os meses, enquanto diferenças foram observadas entre os estratos superior, médio e inferior.

Palavras-chave: aves, diversidade, carvalho, pinheiro.

INTRODUCTION

Pine-oak forest ecosystems depend heavily on the ecological functions of birds, making it crucial to maintain genetic diversity and reproduction across a broad geographic area of the ecosystem. Among the diverse birdlife in oak-pine forests are pollinating and seed-dispersing species (Şekercio ğ lu, 2006). These forests support a wide variety of flora and fauna, many of which are beneficial to agriculture. For example, certain birds can act as pest controllers by feeding on insects harmful to crops or as pollinators (Martin *et al*., 2021).

In birds, their mobility, easy location, observation and monitoring allow for the creation of species lists that, when analyzed ecologically, reveal the environmental conditions of a given area, which allows for the establishment of recommendations on the protection of their habitat (Herrando *et al*., 2014) cited by Moreno *et al*. (2023).

Several national authors have conducted research contributing to the understanding of the overall composition and evaluation of bird assemblages inhabiting pine and oak forest ecosystems. Among them are Pérez *et al*. (2016) and Ortega *et al*. (2021), who have made contributions in this area at different sites within the Pinar del Río province. Therefore, this research aimed to determine the bird diversity associated with different pine-oak forest areas of the Viñales Agroforestry Experimental Station.

MATERIALS AND METHODS

Characteristics of the study area

The present study was carried out in the mountain formation known as Alturas de Pizarras in central Pinar del Río, located in the Guaniguanico mountain range, specifically four areas: a natural pine forest of *Pinus Caribbean* Morelet var. caribaea Barret and Golfari (PnPc), with 10% in a mixture with *Pinus tropicalis* Morelet, which has an area of 1.2 ha; a 35-year-old plantation of *Pinus Caribbean* The var. *caribaea* (PPc) was planted with three thinnings, covering an area of 1.4 ha, in two natural pine-oak forests: one less disturbed (PEMEP), selected based on criteria of low nearby human activity,

distance from the road and areas with high pedestrian traffic, and another with greater human impact (PEMAP), due to its potential effect on birds, and therefore located near the road to Viñales and areas cultivated by farmers. These areas are part of the forest heritage of the Viñales Agroforestry Experimental Station (EEAFV).

Inventory of birds

For bird counting and taking into account the surface area in each of the areas, 19 circular plots (count points) were established with a fixed radius of 15 m each: 4 in PPc, 4 in PnPc, 4 in PEMAP, and 7 in PEMEP. These plots had a fixed radius of 15 m because the abundance of vegetation in the shrub layer makes it difficult to see and detect the birds. They were distributed at a minimum distance of 100 m from each other to avoid double counts.

Bird observations were conducted in 2023 during the spring (March) and autumn (October) migration periods to observe the behavior of bird diversity during these two periods. Each sampling began with the arrival of the observer at the center of the counting point, and birds flying away from the point upon the observer's arrival were considered present (Hutto *et al.*, 1986).

Quantitative sampling was limited to terrestrial forest birds; therefore, species flying above the forest canopy were not included. Counts were conducted in the early morning until approximately 11:00 AM, under favorable conditions: no rain, fog, or cloud cover. In each sampling unit, all birds seen or heard during a 10-minute period were inventoried across three strata: lower (0–2 m), middle (2–6 m), and upper (6 m and above).

The recorded species were classified according to their status of presence using the categories of partially migratory, resident and winter transient, summer resident, and permanent resident; endemism and threat criteria were also considered, as proposed by Navarro (2024). In addition, they were classified according to trophic guild using Kirkconnell 's criteria. *et al.* (1992).

Data analysis

For the study of diversity, the relative abundance graph or Whittaker curves, proposed by Feinsinger (2004), were used due to their simplicity and effectiveness compared to diversity indices.

Smoothed accumulation curves of observed species richness were also obtained for each area (sample-based rarefaction curves) to assess the representativeness of the sampling. EstimateS software version 9 was used for this purpose. To evaluate the similarity in species composition between areas, a cluster analysis was performed using PC-ORD software, version 4.17, with the quantitative Sorensen distance measure (Bray-Curtis).

The vertical distribution of birds was characterized considering the strata mentioned above. Species richness was determined in each stratum, as well as the frequency of observation of individuals within them.

Given that the analyzed data do not follow a normal distribution, the Kruskal-Wallis test of mean comparison was performed to determine if there were differences between the values of richness and abundance of the birds detected between the areas, months and the sampled strata; in addition, the Mann-Witney U and Wilcoxon tests were used to establish between whom the differences were, all these analyses were done using the statistical software IBM SPSS Statistics for Windows, version 22.0.

RESULTS AND DISCUSSION

In the areas studied, a total of 317 bird individuals were recorded, belonging to 31 species, distributed as follows: 17 in the PnPc, 20 in the PPc, 18 in the PEMAP and 19 in the PEMEP; These were grouped into 8 orders, 16 families, and 25 genera. The order Passeriformes and the family Parulidae were the best represented in terms of species richness. Most of the recorded species were permanent residents, followed by migratory birds. González (2002) notes that permanent resident birds sing systematically to maintain their territory and are thus relatively easy to detect in counts.

Fourteen trophic groups were identified, with the trunk-feeding insectivore being the most prevalent, followed by the perching insectivore, soil and foliage granivore, frugivore, boring trunk-feeding insectivore, and hanging perching insectivore. Most species consumed insects and grains, consistent with Kirkconnell 's findings. *et al* . (1992) in which Cuban land birds (resident and migratory) are primarily insectivorous, although the vast majority supplement their diet with fruits and seeds.

Three of the eight endemic genera of Cuba were recorded, represented by the species: *Teretristis fernandinae, Phonipara canora* and *Xiphidiopicus percussus*. These are joined by 12 other endemic species, either at the species or subspecies level, for Cuba or the Caribbean, representing 48% of the total number of Cuban endemic species reported by Navarro (2024). Of the species recorded in the areas, According to the classification based on the degree of threat (Navarro, 2024), *Setophaga pityophila* is found in the Vulnerable species category, while *Melopyrrha nigra* as Near Threatened.

Figure 1 shows the abundance for the areas studied. It is observed that the shapes of the curves are quite similar, which means that equality, or its inverse, numerical dominance, was similar among the areas.

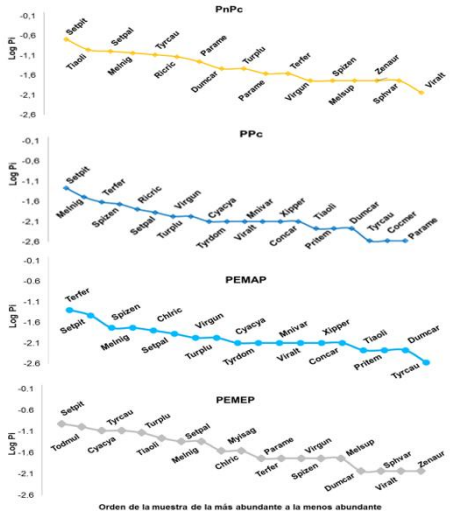

Figure 1 *- Whittaker curves or abundance range for the studied areas*

Acronyms of the species: *Setophaga pityophila* (Setpit), *Teretistris fernandinae* (Terfer), *Vireo gundlachii* (Virgun), *Spindalis Zena* (Spizen), *Cyanerpes cyaneus* (Cacya), Melopyrrha nigra (Melnig), *Setophaga palmarum* (Setpal), *Mniotilta varia* (Mnivar), Riccordia ricordii (Ricric), *Turdus plumbeus* (Turplu), *Myiarchus*

sagrae (Myisag), *Parula Americana* (Parame), *Todus multicolor* (Todmul), *Colaptes auratus* (Colaur), *Contopus caribaeus* (Concar), *Tyrannus dominensis* (Tyrdom), *Tyrannus caudifasciatus* (Tyrcau), *Xiphidiopicus percussus* (Xippen), *Priotelus temnurus* (Pritem), *Vireo altiloquus* (Viralt), *Dumetella carolinensis* (Dumcar), *Melanerpes superciliaris* (Melsup), *Tiaris olivaceus* (Tiaoli) and *Zenaida aurita* (Zenaur)

It can be seen that the most abundant species were in the PnPn *S. pityophila* followed by *Tiaris olivacea;* in the PPc the dominant species was also *S. pityophila* followed by *M. nigra;* in the PEMAP they were *T. fernandinae* and *S. pityophila*; while in the PEMEP the dominant species turned out to be *S. pityophila* followed by *T. multicolor*. The dominance of these species in these areas could be due to: *S. Pityophila* is a specialist species of pine forests according to González *et al*. (2002), and is therefore abundant in these areas. Furthermore, these sites can offer favorable conditions for all these species to carry out their vital functions: feeding, shelter, and reproduction. The presence of several flowering and fruiting plant species was observed; moreover, the first month of monitoring falls within the reproductive period of most species in our country, making them easier to detect.

When analyzing species richness in the studied areas using rarefaction curves based on the number of samples (Figure 2), it can be observed that the number of samples differs for the PEMEP area, which exhibits significantly greater richness. Therefore, statistical comparisons should be made based on the community with the lowest N value, which in this case is comparable to the other areas.

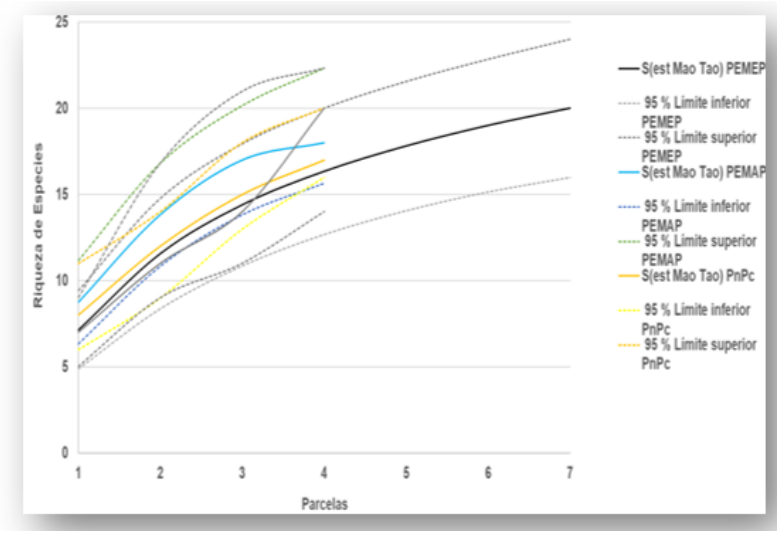

Figure 2. *- Rarefaction curves based on the number of samples for each area studied.*

Since the 95% confidence intervals for average species richness overlap between the studied areas, there are no significant differences in bird richness among them. This result is corroborated by the Kruskal-Wallis test (Table 1), which indicates that there are no significant differences between the monitored areas in terms of the abundance and richness of species present.

Table 1. - *Kruskal Wallis mean comparison test, grouping variable: area*

	Abundance	**Wealth**
Chi-square	,864	,429
Gl	3	3
Asymptotic Sign	1,000	,614

When analyzing the abundance of birds by strata in the studied areas, the Kruskal-Wallis test (Table 2) indicates that there are significant differences between the strata occupied by birds in the studied areas in relation to the abundance of the species present in them.

Table 2.- *Kruskal Wallis mean comparison test, grouping variable: stratum*

	Abundance
Chi-square	17,200
Gl	2
asymptotic significance	,001

According to the non-parametric Mann-Whitney U test (Table 3), the abundance of species differed significantly between the high, middle, and low strata in each area. This could be due to variations in vegetation density within each stratum, which in turn affects bird presence.

This result coincides with that reported by Espinosa *et al.* (2020) in different types of forests and conditions , the upper stratum was the most used by the bird community for foraging, followed by the middle-upper stratum and the understory-middle stratum).

Table 3.- *Mann -Whitney U test for strata in relation to species abundance*

Test statistics	Strata		
	low-medium	medium-high	high-low
Mann-Whitney U	183,000	130,400	57,000
Wilcoxon's W	444,000	380,500	323,000
Z	-1,182	-2,533	-3,678
Next	,321	,006	,003

The previous result is corroborated by analyzing the frequency of observation of the species detected in each stratum (Figure 3). The distribution of birds in the vertical strata of the vegetation followed a pattern of behavior, with most bird species being detected in greater proportion in the upper stratum, followed by the middle and, lastly, the lower stratum.

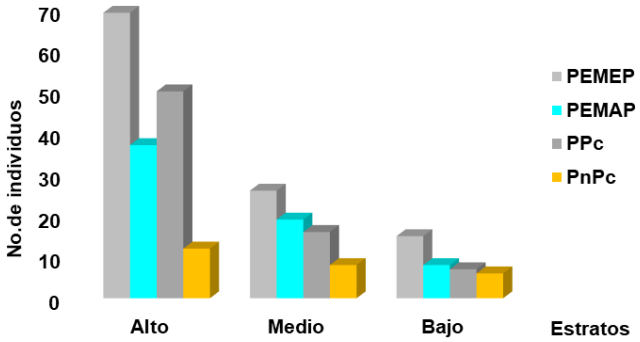

Figure 3. *- Observation frequency (FO) of birds in each stratum in the studied areas*

Greenberg (1981) argued that undisturbed mature tropical forests exhibit a greater number of individuals of different bird species in the canopy, while fewer individuals and species are found in the lower strata. In contrast, habitats with a moderate degree of disturbance allow for a greater number of individuals of different species and exhibit a more homogeneous distribution of these species across the different strata; that is, most birds in this type of forest generally do not limit themselves to any particular stratum, but rather become more flexible in their use of them (García *et al.* 1998; Bojorges and López, 2006; Ugalde *et al*. 2009).

In the areas studied, the avifauna was not restricted to a single stratum; it was observed that bird species can visit one or more strata, depending on the vegetation and habitat characteristics, which is related to what was found by Salas-Correa and Mancera (2018), in which vegetation variables have an influence on species composition.

The Kruskal- Wallis test (Table 4) indicates that there are also significant differences between the strata occupied by birds in the studied areas in relation to the richness of species present in them.

Table 4. *- Kruskal Wallis mean comparison test, grouping variable: stratum*

	Wealth
Chi-square	12,588
Gl	2
asymptotic significance	,003

Furthermore, the high, middle, and low strata also differ significantly for each area in relation to the richness of the species present in them, according to the non-parametric Mann-Whitney U test performed (Table 5).

MacArthur *et al* . (1962), cited by Ugalde *et al*. (2009), indicate that heterogeneity in forest strata influences the horizontal and vertical distribution of bird communities, which in turn can be indicators of the state of certain ecosystems. According to Espinosa *et al*. (2020) The modification in the canopy (larger clearings), the heterogeneity and architecture of the vegetation, influence diversity, giving rise to mechanisms that favor the coexistence of bird species.

Table 5. *- Mann-Whitney U test for strata in relation to species richness*

Test statistics	Strata		
	low-medium	medium-high	high-low
Mann-Whitney U	219,400	124,500	102,500
Wilcoxon's W	457,500	394,500	332,500
Z	-,432	-2,405	-3,278
Next	,510	,006	,003

The above result is corroborated by analyzing the behavior of the species richness detected in each stratum (Figure 4).

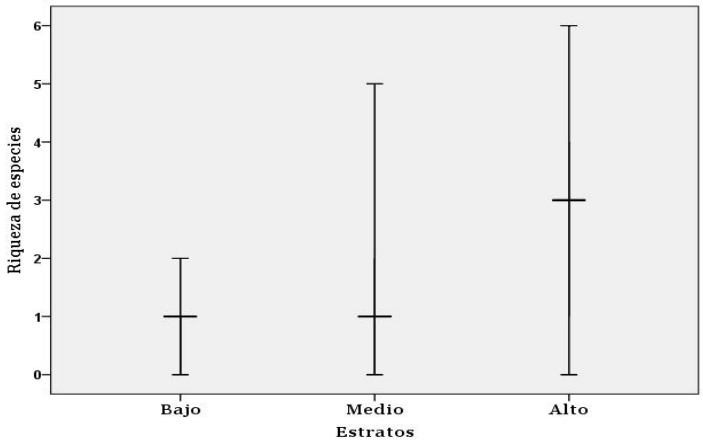

Figure 4. *- Species richness detected in each stratum in the studied areas*

Miranda *et al*. (2010) proposed that vegetation plays a crucial role among the factors influencing habitat selection by birds (interspecific and intraspecific competition, habitat size and distribution, food availability, predator and parasitism density, anthropogenic factors, etc.). The physiognomy and floristic composition of the vegetation shape the structure of bird communities at a local scale. However, the usefulness of these traits in identifying suitable areas for birds can be influenced by other factors, such as altitude, climate, and landscape structure at a regional scale. These factors operate at large spatial scales (along latitudinal gradients) but also at smaller scales (mountainous regions).

Figure 5 shows the richness and abundance of the monitored birds during the monitoring period. It can be seen that both parameters did not differ significantly. The months surveyed belong to two different periods (Summer Residence and Winter Migration); however, most of the species detected were permanent residents, which may have influenced the previous result. During these periods, the forests host some species, including summer migrants and permanent residents. Neotropical migrants are also present in the second period (with fewer species and individuals detected compared to other studies), resulting in a relatively stable number of species.

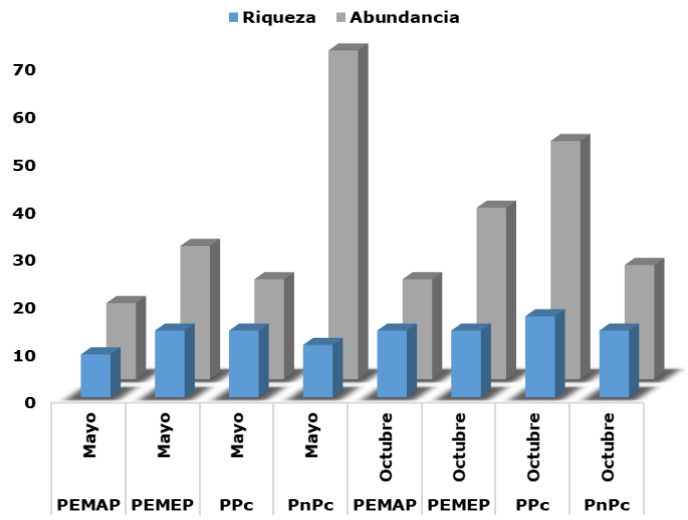

Figure 5. *- Monthly variation in bird richness and abundance in the areas studied*

The above analysis is corroborated by the results presented using the Kruskal-Wallis test (Table 6), which indicates that there are no significant differences between the months monitored for each area studied in relation to the abundance and richness of species present in them.

Table 6. *- Kruskal Wallis mean comparison test, grouping variable: month*

	Abundance	Wealth
Chi-square	8,708	9,904
Gl	1	1
Asymptotic Sign	,532	,392

The months surveyed belong to two different periods (Summer Residence and Winter Migration); however, most of the species detected were permanent residents, which may have influenced the previous result. During these periods, the forests are home to some species, including summer migrants and permanent residents. Neotropical migrants are also present in the second period (with fewer species and individuals detected compared to other studies); therefore, the number of species remained relatively stable.

CONCLUSIONS

A total of 31 bird species were identified in the studied areas, most of which were permanent residents and fed on insects and grains. There were differences in species richness and abundance between the upper, middle, and lower strata, but no differences were observed between areas or months.

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Conflicts of interest:

The authors declare no conflicts of interest.

Authors' contribution:

The authors have participated in the writing of the work and analysis of the documents.