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A BROAD OVERVIEW OF THE AVIFAUNA OF SECONDARY FORESTS IN PERUVIAN AMAZONIA

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ABSTRACT

In the Peruvian Amazon, we conducted an extensive survey of bird species in six secondary forests. We used the point count method and established 360 survey points (60 in each zone) at least 500 meters away from the others. These observations covered six zones across nine departments, including Loreto, Amazonas, San Martín, Ucayali, Huánuco, Pasco, Junín, Cusco, and Puno, at altitudes ranging from 96 to 2501 meters. We assessed these forests in both dry and rainy seasons with two consecutive days of observations at each point. Our findings revealed high species richness in every zone, with a total of 628 bird species identified, including one Endangered, and five Vulnerable according to the IUCN. Passeriformes was the order with the most species registered, while Tyrannidae and Thraupidae were the most species-rich families. Zones within protected areas exhibited higher species richness compared to adjacent unprotected zones. These results highlight the crucial role of secondary forests in conserving a significant number of bird species despite compositional changes.

KEYWORDS: Tropical rainforest, Aves, birds, point count method, conservation.

UN PANORAMA GENERAL DE LA AVIFAUNA DE LOS BOSQUES SECUNDARIOS DE LA AMAZONÍA PERUANA

RESUMEN

Se realizó un estudio exhaustivo de las especies de aves en seis bosques secundarios de la Amazonía peruana. Se utilizó el método de conteo por puntos, con un total de 360 puntos (60 en cada zona), separados como mínimo por 500 metros. Estas observaciones abarcan seis zonas en nueve departamentos, incluyendo Loreto, Amazonas, San Martín, Ucayali, Huánuco, Pasco, Junín, Cusco y Puno, en altitudes de 96 a 2501 metros. Las evaluaciones se realizaron tanto en la estación seca como en la lluviosa, con dos días consecutivos de observaciones en cada punto. Los resultados revelan una alta riqueza de especies en cada zona, con un total de 628 especies de aves, de las cuales una está En Peligro y cinco Vulnerables según la UICN. Passeriformes fue el orden con más especies registradas, mientras que Tyrannidae y Thraupidae fueron las familias más ricas en especies. Las zonas dentro de áreas protegidas exhibieron una mayor riqueza de especies en comparación con las zonas adyacentes no protegidas. Estos resultados subrayan el papel crucial de los bosques secundarios en la conservación de un número significativo de especies de aves a pesar de los cambios composicionales.

PALABRAS CLAVE: Bosque tropical lluvioso, Avifauna, conteo de puntos, Amazonía, conservación.

INTRODUCTION

The Peruvian Amazonia is an important hotspot of the world's biodiversity and harbors a remarkable number of bird species, making it an ideal area for research on avian biodiversity and its conservation (Ceballos & Ehrlich, 2006; Schulenberg *et al.*, 2010). However, extensive deforestation, caused by agriculture and human activities, has led to the formation of secondary forests in Peru, a trend that has been registered across the Amazon rainforest (Clavo *et al.*, 2022; Rutt *et al.*, 2019; Flores *et al.*, 2024). These forests are characterized by natural regeneration processes following significant disturbances, either human-induced or natural, to the original primary forests. They exhibit structural and compositional differences compared to undisturbed primary forests, often reflecting the intensity and type of disturbances as well as the time elapsed since regeneration began (Chokkalingam & De Jong, 2001; Mayhew *et al.*, 2019), these human disturbances include the construction of roads and houses that alter its environment. Given that they have become an important component of Amazonia, these forests provide valuable opportunities for studying the ecological effects of anthropogenic activities and identifying effective conservation strategies (Rutt *et al.*, 2019; Flores *et al.*, 2024; Piratelli *et al.*, 2008; Eyres *et al.*, 2017; Mayhew *et al.*, 2019).

While several studies have analyzed the effect of human disturbance on bird communities in the Amazon rainforest (Ahmed *et al.*, 2014; Mahood *et al.*, 2012; Stouffer *et al.*, 2011), little attention has focused on the avian richness harbored by these forests across the Peruvian Amazonia or the effectiveness of Protected Areas conserving it. In this paper, we present a comparative analysis of species richness and composition of birds in six zones dominated by secondary forests in the Peruvian Amazonia. These forests were evaluated with consistent effort and methodology to determine their importance as habitats for Amazonian birds. Our study aims to demonstrate that these secondary forests harbor significant avian richness and to evaluate the Protected Areas effectiveness in the conservation of secondary forest's birdlife in the Peruvian Amazonia.

MATERIALS AND METHODS

This study was conducted in the secondary forests of the Peruvian Amazon, where six zones were examined (Figure 1): (1) Loreto, (2) Amazonas-San Martín, (3) Amazonas, (4) Ucayali-Huánuco, (5) Pasco-Junín and (6) Cusco-Puno (Figure 1, Table 1). These zones comprise secondary forests at different altitudes, ranging from 96 to 2501 meters, focusing primarily on closed and semi-closed canopy secondary forests. Zones Amazonas-San Martín (2) and Ucayali-Huánuco (4) correspond to areas protected by the Peruvian Government. To evaluate Protected Areas effectiveness in the conservation of avian richness in secondary forests, we compare two pairs of zones: Zone Amazonas-San Martín (protected) with zone Amazonas (not protected) and zone Pasco-Junín (protected) with zone Ucayali Huánuco (not protected).

(1) Zone Loreto: Situated within the Loreto department of Peru, this geographical location is demarcated by its association with the Iquitos-Nauta road, a pivotal land transportation route within the region, whose construction dates back to 1970. The landscape is mostly flat, with elevational ranging from 96 to 148 meters above sea level. The road passes through various indigenous communities, including the Cocama and Ikitu populations, as well as several densely populated urban centers. It is near the protective buffer zone of the Reserva Nacional

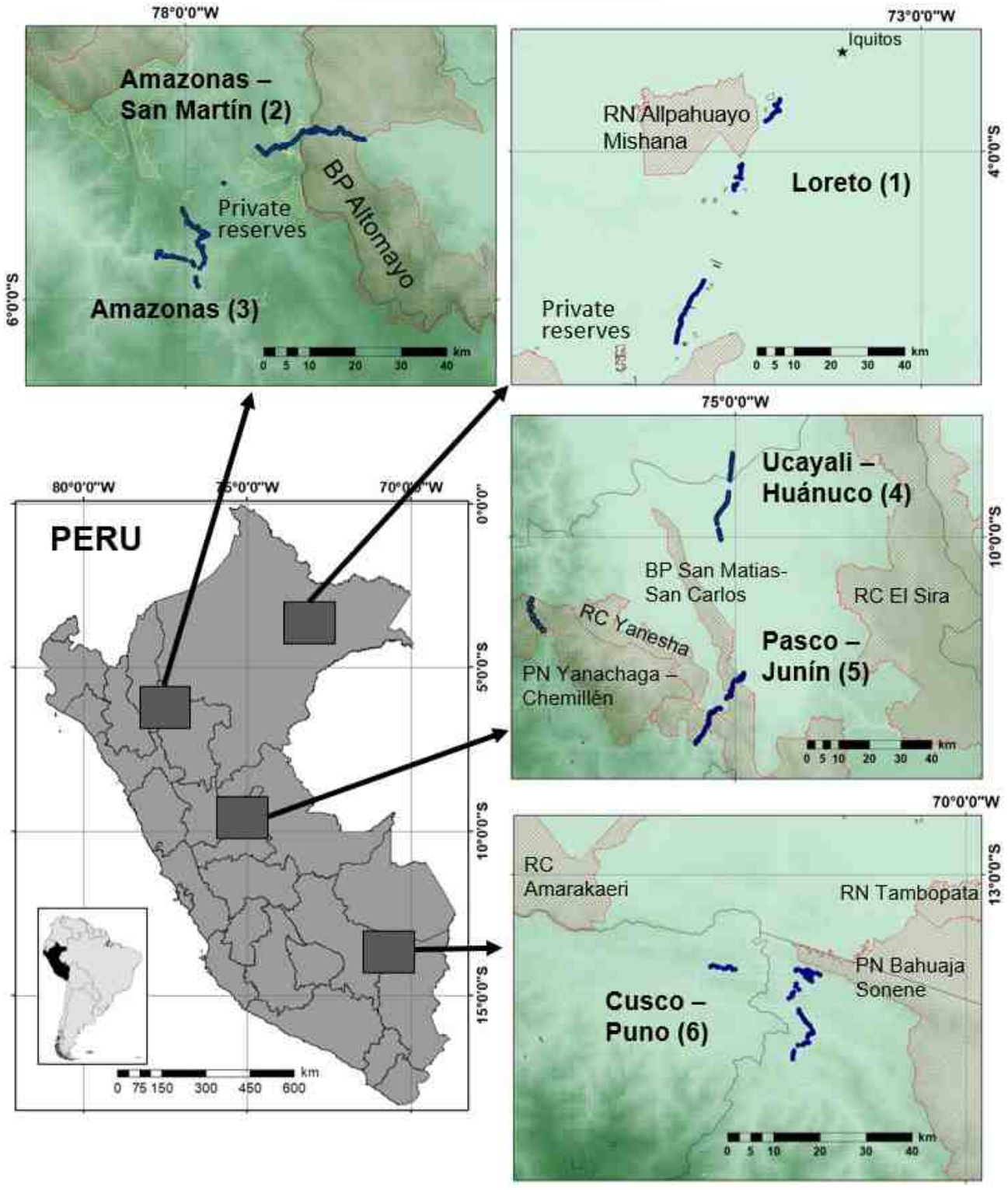

Figura 1. Distribution of count points in the six zones. The Peru department boundaries are shown in the map. Maps were constructed with shapefiles available in https://www.diva-gis.org/datadown and 30 arc-second DEM of South America (U.S. Geological Survey's Center for Earth Resources Observation and Science) available in https://databasin.org/datasets/d8b7e23f724d46c99db1421623fd1b4f/.

Table 1. Summary of the departments covered by each zone and the range of altitude.

Zones	Departments	Altitude Range
Zone 1	Loreto	96 – 148 m
Zone 2	Amazonas, San Martín	1074 – 2322 m
Zone 3	Amazonas	1079 – 2501 m
Zone 4	Ucayali, Huánuco, Pasco	210 – 272 m
Zone 5	Pasco, Junín	290 – 1021 m
Zone 6	Cusco, Puno	399 – 637 m

Allpahuayo-Mishana, a conservation area. The Iquitos-Nauta road serves as a crucial link between the urban center of Iquitos, its ports and the strategically positioned city of Nauta along the Marañon River. The surrounding landscape consists of white sand forests, low-hill forests, flood-prone alluvial forests, non-floodable terrace forests, and palm swamps (MINAM, 2019).

(2) Zone Amazonas-San Martín: This area is located in the Amazonas (Bogará province) and San Martin (Rioja province) departments, along the Fernando Belaunde Terry Road, which was constructed in 1963, between the Abra Pardo Miguel pass and Aguas Verdes town, near the Serranuyacu river. It is close to the Abra Patricia pass, Alto Nieva and the Bosque de Protección Alto Mayo, a protected area. Parts of this area overlap with Ashaninka communities. The landscape is diverse, with elevations ranging from 1074 to 2322 m. This zone is near to premontane Yunga forest, montane Yunga forest and high montane Yunga wet forest (MINAM, 2019).

(3) Zone Amazonas: This zone is situated in the Amazonas department, between the Utcubamba province (Bagua Grande and Naranjitos towns) and Bongara province (Pedro Ruiz Gallo, Florida Pomacocha and Oso Perdido towns). The sampling points were established along the Fernando Belaunde Terry road, with the Utcubamba river influencing the area. The elevation ranges from 1079 to 2501 m. The surrounding landscapes consist of high montane Yunga wet forest, montane Yunga forest, and premontane Yunga forest (MINAM, 2019).

(4) Zone Ucayali-Huánuco: The area covers the region from the Alexander von Humboldt Urban Center in the Padre Abad province of Ucayali, including the Federico Basadre road initiated in 1943. It connects this urban center to Puerto Zungaro, Ciudad Constitución, and Puerto Bermudez, spanning the Ucayali, Huánuco, and Pasco departments. The road in this area has been progressively paved with asphalt since 2013, with completion scheduled for 2031. This route passes secondary forests, pastures, and agricultural zones, with a mostly flat topography and elevations ranging from 210 to 272 meters above sea level. The road intersects various hamlets, including Puerto Zungaro, Ciudad Constitución, El Porvenir, Lorencillo Quimpirari, Siria, and Chirichiari. Surrounding landscapes include low hill forest and high hill forests (MINAM, 2019). The area is influenced by the Palcazu, Pachitea, Pichis and Huitoyacu rivers.

(5) Zone Pasco-Junín: This area includes the Yanachaga-Chemillén National Park and the Bosque de Protección San Matías San Carlos, located in the province of Oxapampa, Department of Pasco. Elevations in this zone range from 290 to 1021 meters above sea level and it is influenced by the Cacazú and Palcazú rivers. The landscape is home to indigenous communities, including the Campa, Asháninka, and Amuesha peoples. The landscape encompasses premontane Yunga forest, high hill forest and low hill forest (MINAM, 2019).

(6) Zone Cusco-Puno: This area includes the Interoceanic Highway sections Urco Inambari (from Quincemil to Puerto Leguía) and Inambari-Azángaro (Puerto Leguía to Ollachea town). The altitude in this area ranges from 399 to 637 meters above sea level. This area is influenced

by the Araza River in Cusco and the San Gaban River in Puno. The landscape surrounding this area includes premontane Yunga forest and high hill forest (MINAM, 2019).

We established 60 count points along roads, ensuring a minimum separation of 500 m between them. A total of 360 points were surveyed (Supp. Data 1), covering nine departments across Peru. We utilized the unlimited-distance point-count method (Bibby *et al.*, 1992; Awai & Saviour, 2023), which has been proven effective in various terrains and habitats. This method allows for a more comprehensive and accurate assessment of bird diversity in similar forests (Volpato *et al.*, 2009). To ensure a comprehensive assessment of the bird species in each study area, two surveys were conducted during the dry season (June to October) and the rainy season (December to May), corresponding to the seasonality of rivers in the Amazon region. This approach was adopted to account for variations in plant phenology and bird reproduction across seasons (Madigosky & Vatnick, 2000).

Each point was evaluated for 15 minutes to obtain a significant quantity of observations. To reduce any bias in the sampling method, the observations were carried out during periods of high bird activity, starting 30 minutes after sunrise and lasting for approximately three hours, as suggested by Cavarzere *et al.* (2013). The following day, each point was revisited, so each point was studied four times in total (two per season).

Working groups consisted of two people per team. The observer focused on detecting and identifying as many species as possible, while the recorder documented detailed information about the environment, the bird's behavior, and recorded sounds. We used ¨Birds of Peru¨ (Schulenberg *et al.*, 2010) for field identification, and verified identifications using the ¨Handbook of the Birds of the World Alive¨ (del Hoyo *et al.*, 2019), ¨Birds of the World¨ (Billerman *et al.*, 2022), and the ornithological collection of Museo de Historia Natural of the Universidad Nacional Mayor de San Marcos. Sound recordings were validated using Macaulay Library and Xeno-canto. Taxonomy and nomenclature followed the South American Classification Committee (Remsen *et al.*, 2023), and the status of endemic species in Peru was obtained from the List of Birds from Peru (Plenge *et al.*, 2023), supplemented by range information from Salinas *et al.* (2021) and ¨Birds of the World ¨ (Billerman *et al.*, 2022). Conservation status information was obtained from IUCN (2023). Additionally, we gathered data about migration patterns from ¨Birds of Peru¨ (Schulenberg *et al.*, 2010), ¨Birds of the World¨ (Billerman *et al.*, 2022), and Cunha *et al.* (2022).

Maps were created using ArcGIS 10.3 and shapefiles available at https://www.diva-gis.org/datadown, and 30 arc-second DEM of South America (U.S. Geological Survey's Center for Earth Resources Observation and Science) available in https://databasin.org/datasets/d8b7e23f724d46c99db1421623fd1b4f/. UpSet plots (Lex *et al.*, 2014) were generated with the R package UpSetR (Conway *et al.*, 2017).

Species accumulation curves were generated using EstimateS v9.1.0 and plotted in R. The resulting data and plots are provided as Supplementary Data (Supp. Data 3 & 4).

RESULTS

We documented a total of 628 bird species in six zones of secondary forest (Supp. Data 2). Among these species, 401 (63,85%) fall under the taxonomic order Passeriformes, 101 species (16,08%) in the Thraupidae family and 95 species (15,13%) in the Tyrannidae family (Figure 2).

The number of species varies across the study zones. Zone 1 (Loreto) presented 184 bird

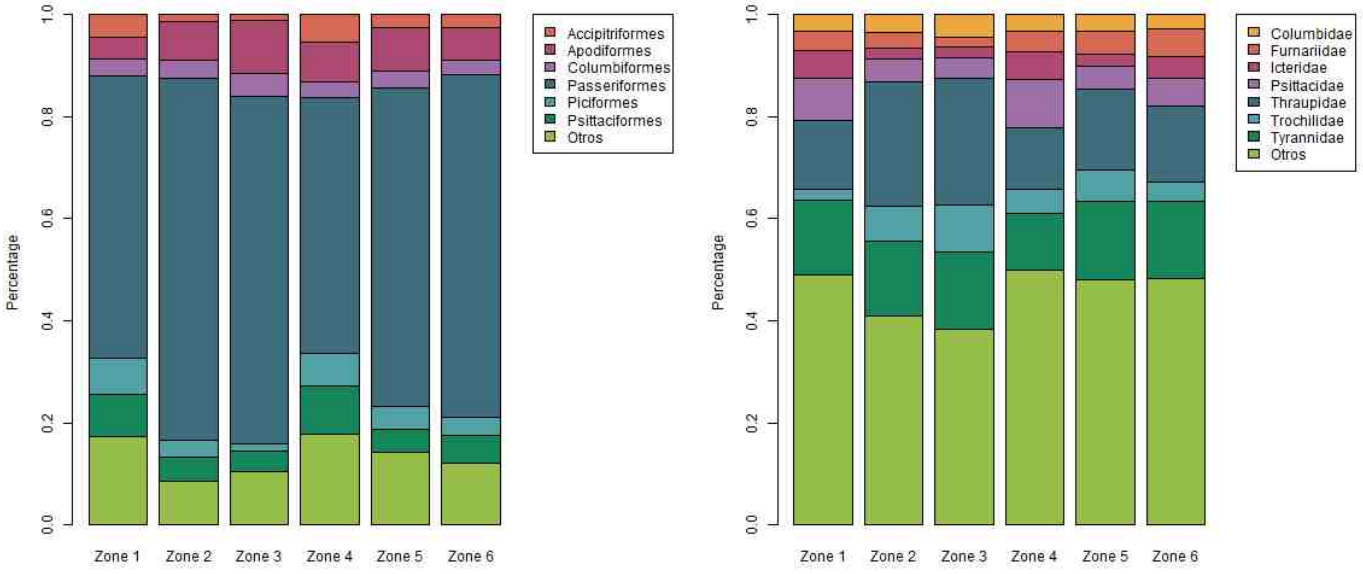

Figura 2. Proportion of species by taxonomic order and family for each zone. Passeriformes account for more than 50% of the recorded species in each zone. Thraupidae and Tyrannidae are the taxonomic families with the highest number of recorded bird species in each zone.

species, the lowest species richness registered; while zone 6 (Cusco-Puno) registered 290 species, the highest species richness registered. Likewise, in Amazonas-San Martín (zone 2) we recorded 35 species that were not registered in any other area (Figure 3). In Pasco-Junín (zone 5) and Cusco-Puno (zone 6), we found 52 and 62 species found exclusively in these zones, respectively (Figure 3). These three zones have the highest number of species found exclusively in one area. We found 45 species that are present in all zones (Figure 3).

It is worth noting that Cusco-Puno (zone 6) is situated near significant conservation areas and includes a diverse forest with different environmental features, such as bamboo stands (Grilli & Berkunsky, 2021). Similarly, Amazonas-San Martín (zone 2) is located within the Abra Patricia and Altomayo Protection Forest. The importance of the effect of protected areas becomes evident when we compare the number of species found in Amazonas-San Martín (zone 2 - 288 species) with Amazonas (zone 3 - 250 species), the latter having no nearby protected area. Furthemore, in Pasco-Junín (zone 5 - 287 species), which is close to Bosque de Protección San Matías-San Carlos and Yanachaga-Chemillén National Park, we found more species than in Ucayali-Huánuco (zone 4 - 190), which lacks nearby protected areas despite geographical proximity.

The study area also hosted threatened bird species from various taxonomic families. Below is a comprehensive list of threatened bird species documented during the study, organized according to their respective taxonomic families.

FAMILY TINAMIDAE

1.*Tinamus tao* (Temminck, CJ 1815): The Grey Tinamou was observed in Puno during the study and is currently classified as Vulnerable on the IUCN Red List of Threatened Species. One individual from this species was recorded in Puno (zone 6).

FAMILY TROCHILIDAE

2. *Loddigesia mirabilis* (Bourcier, J 1847): The

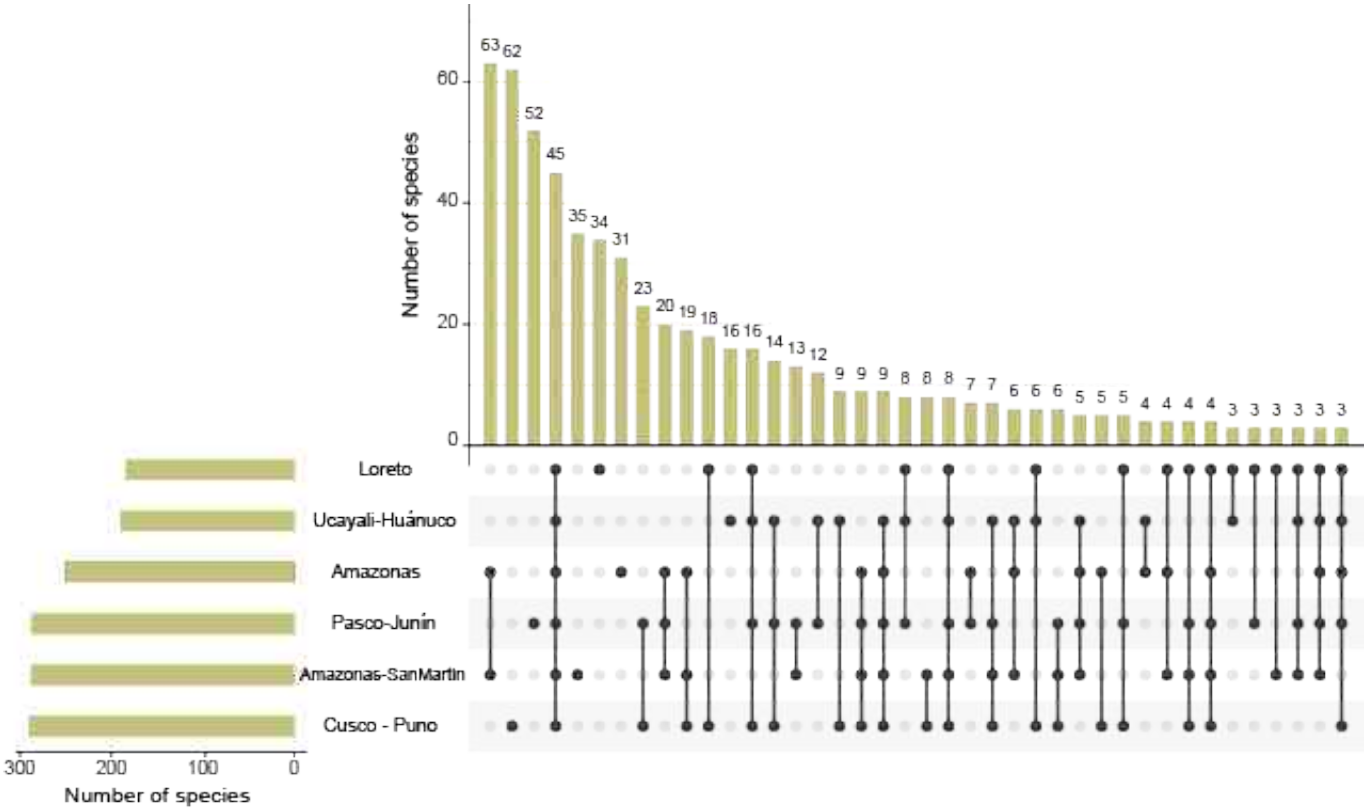

Figura 3. UpSet plot of the number of shared species through all the combinations of zones. The total number of species for each zone is indicated in the horizontal barplots and intersections are depicted in the vertical barplots.

Marvelous Spatuletail is an endangered species (IUCN, 2023), endemic to a very restricted range in northeastern Peru, specifically in the Department of Amazonas (Billerman et al., 2022). Three individuals were observed near Pomacochas lake during this study in Amazonas (zone 3). It is an uncommon species, and its habitat is threatened by slash-and-burn agriculture and cattle ranching (Billerman et al., 2022; IUCN, 2023).

FAMILY PSITTACIDAE

3. *Ara militaris* (Linnaeus, C 1766): The Military Macaw was observed in Loreto during the study. It is currently categorized as Vulnerable on the IUCN Red List of Threatened Species. The species is threatened by habitat loss, hunting, and capture for the pet trade, and its populations have declined significantly in recent years. Two members of this species were recorded within Loreto (zone 1), along the Iquitos-Nauta highway. While these macaws were observed in the wild, their presence may be explained by escape from captivity, as this region lies outside their known natural range.

4. *Pionites leucogaster* (Kuhl, H 1820): The White-bellied Parrot has been observed in Pasco during the study. Currently, it is classified as Vulnerable on the IUCN Red List of Threatened Species. There is one record sighting of this species within Pasco (zone 5, Bosque de Protección San Matías San Carlos).

5. *Primolius couloni* (Sclater, PL 1876): The Blue-headed Macaw has been observed in Huánuco during the study. It is currently classified as Vulnerable by the IUCN. One record of individuals was taken in Huánuco (zone 4).

FAMILY THRAUPIDAE

6. *Stilpnia argyrofenges* (Sclater, PL; Salvin, O 1876): The Green-throated Tanager is a bird species that is considered a permanent resident in its habitat (Schulenberg et al., 2010). It has been observed in Amazonas, Peru during the study. The species is currently classified as Vulnerable on the IUCN Red List of Threatened Species, indicating that its population is at risk of decline due to various threats such as habitat loss and fragmentation, as well as capture for the pet trade (BirdLife International, 2018). Two individuals from this species were recorded within Amazonas-San Martín (zone 2, Abra Patricia pass) and six were recorded within Amazonas (zone 3).

DISCUSSION

Our study in six different areas in the Peruvian Amazonia provides valuable insights into the richness and composition of bird communities in neotropical secondary forests. These forests undergo significant changes in composition due to human or natural disturbances, resulting in variations in forest structure and canopy species composition (Chokkalingam & De Jong, 2001). Although these forests are often considered damaged, they have been shown to support a high proportion of bird species compared to primary forest (Peh *et al.*, 2005; Latta *et al.*, 2017; Hughes *et al.*, 2020). However, as noted by Socolar *et al.* (2019), secondary forests may contribute to biotic homogenization across landscapes, which highlights the importance of managing them to preserve regional diversity.

As anticipated, a significant number of species that we report belong to the Passeriformes order, known for its global species richness (Gill *et al.*, 2023). The taxonomic families Thraupidae and Tyrannidae showed the highest species counts. These families are known by males displaying striking plumages and varying in body size from small to medium (Price-Waldman *et al.*, 2020; Meneses-Giorgi & Cadena, 2021). A consistent pattern emerged across all evaluated zones, showing similarities in taxonomic family and order compositions.

We found 45 species present across all zones (Figure 2), predominantly common and widespread in the Peruvian Amazonia (Billerman *et al.*, 2022). The Rufous-collared Sparrow (*Zonotrichia capensis*), known for its coastal and Andean distribution in Peru, was recorded in all zones, aligning with recent reports in Loreto and San Martin, within the Peruvian Amazonia (Ugarte & Lavalle Valdivia, 2018).

In the Peruvian Amazonia, numerous inventories have been conducted to identify bird species in various localities (Hornbuckle, 1999; Patterson *et al.*, 2006; Álvarez Alonso *et al.*, 2012; Salinas *et al.*, 2021). However, comparing results proves challenging due to variations in methods and effort levels. Here, we present comparisons with prior studies descriptively, providing a contextual overview of avian diversity rather than inferential conclusions. Data from publications that exclusively conducted inventories in localities with sampling durations not exceeding one month were useful for these comparisons.

We documented a substantial number of 628 distinct bird species across the six zones of secondary forests, representing approximately 41.7% of the 1,506 avian species recorded across all habitats in the Peruvian Amazon, including both primary and secondary forests of varying soil types (Arana *et al.*, 2024), indicating a high species richness in these forests. We identified 184 bird species in Loreto (zone 1). While comparisons with other studies are challenging due to differences in sampling methods, we consider this count in the context of studies with si-

milar sampling durations. For example, this number is comparable to less diverse areas within the Cordillera Escalera Regional Conservation Area and Matsé National Reserve in Loreto, both of which are protected and experience less disturbance than the analyzed secondary forests. However, our findings fall short of reports from pristine areas in the same department, recording over 220 species (Field Museum, 2004; Field Museum, 2013). While Loreto is a highly diverse department (Salinas *et al.*, 2021), the values recorded in our study in Loreto (zone 1) did not reflect this.

In Amazonas-San Martín (zone 2), we documented 288 species, and in Amazonas (zone 3), we found 250 species, exceeding the count in the Tabaconas Namballe National Sanctuary in the Amazonian part of the neighboring department of Cajamarca. The sanctuary, situated between 1600 and 2700 m altitude, reported 132 to 208 species (Salazar & Mena, 2018).

Ucayali-Huánuco (zone 4) recorded 190 species in our study, aligning with the range reported by Moncrieff *et al.* (2020) for the Ucayali region (72 to 298 species) at different altitudes (140 to 1100 meters). This count surpasses that of the Cerros El Sira Communal Reserve forests (110 to 121 species, Gonzalez, 1998). In the Pasco-Junín zone (zone 5), we documented 287 species, surpassing counts in various locations within the Yanachaga Chemillen National Park (67 to 152 species) between 419 to 3400 meters altitude (Gonzalez, 1998). In the Cusco-Puno zone (zone 6), we found 290 species, which is lower than the reported 350 species in lowland forests of Madre de Dios within National Parks (Patterson *et al.*, 2006). However, it exceeds counts in areas under forest management and at higher altitudes (Patterson *et al.*, 2006; Campos-Cerqueira *et al.*, 2019).

These comparisons show that the avifauna in Peruvian Amazon secondary forests maintains a substantial species richness despite anthropogenic impact. The evaluated zones also harbor threatened species, including six identified in the results (IUCN, 2023). Thus, the inclusion of these forests in Amazonia conservation plans is imperative.

Our findings also highlight that zones hosting conservation areas exhibit higher species richness compared to geographically close zones lacking such areas. For instance, Zone 2 surpassed Zone 3 in species count, and Zone 5 exceeded Zone 4, which may be related to conservation regulations in these areas. Protected Areas have proven to be effective in maintaining freshwater bird biodiversity in the Peruvian Amazonia (Barocas *et al.*, 2023). Moreover, it has been proposed that proximity to primary forest is a key factor in secondary forests avian richness because primary forests nearby can act as sources of colonizing dispersers (Gilroy & Edwards, 2017). Therefore, the higher bird richness registered at Protected Areas may be a result of a reduction of human disturbances such as current deforestation or poaching, and of the higher proximity to primary forests within the core of the Protected Areas.

Building upon previous research on Peruvian avifauna, our study significantly contributes to understanding the remarkable bird diversity in diverse habitats within the region. This research addresses knowledge gaps in bird richness, specifically focusing on secondary forests. It employs an evaluation design that encompasses both protected and non-protected areas in Peru. Finally, despite the perceived damage and alterations caused by activities such as the construction of roads and houses, these secondary forests can retain substantial value in terms of bird species richness.

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