El Hornero Volume 41 · Number 1 · August 2026
Article
doi.org/10.56178/eh.v41i1.1531

STATUS OF NEARCTIC AND AUSTRAL MIGRATORY BIRDS IN THE BRAZILIAN STATE OF ACRE, SOUTHWESTERN AMAZON: INSIGHTS FROM CITIZEN SCIENCE CONTRIBUTIONS

Alnizia Galdino Pereira[1], Kaylane de Oliveira Silva[1], Luana Alencar[1], Ighor Dienes Mendes[2] & Edson Guilherme[1,2]*

[1]Laboratório de Ornitologia, Centro de Ciências Biológicas e da Natureza, Universidade Federal do Acre, Rio Branco, Brazil
[2]Laboratório de Pesquisas Paleontológicas, Centro de Ciências Biológicas e da Natureza, Universidade Federal do Acre, Rio Branco, Brazil
*edson.guilherme@ufac.br

ABSTRACT: Migratory birds undertake seasonal movements between breeding and non-breeding areas in search of favorable climatic and food conditions. In South America, two major migratory systems are recognized: Nearctic and Austral. The Brazilian state of Acre, located in the southwestern Amazon, serves as a strategic stopover for both groups, yet increasing anthropogenic pressures threaten these corridors. Understanding migration dynamics is therefore essential for conservation planning. This study analyzed temporal patterns of Nearctic and Austral migratory bird species in Acre and assessed their degree of temporal overlap. Data was obtained from citizen science platforms, with photographic records filtered by species and month and visualized through heatmaps. Records were classified into reproductive and non-reproductive months, and differences tested using the non-parametric Mann-Whitney U test ($p < 0.05$). A total of 1554 images representing 61 migratory species (31 Nearctic and 30 Austral) were analyzed. Solitary Sandpiper (*Tringa solitaria*) showed the highest frequency of records among Nearctic migrants, whereas Vermilion Flycatcher (*Pyrocephalus rubinus*) prevailed within the Austral group. Phenological analysis revealed distinct seasonal windows: Nearctic migrants occurred mainly from September to March, whereas Austral migrants were recorded from March to September, with minimal overlap. Some species, such as Chivi Vireo (*Vireo chivi*) and Crowned Slaty Flycatcher (*Empidonomus aurantioatrocristatus*), were observed nearly year-round, suggesting complex strategies including partial migration or coexistence of resident and migratory populations. These findings highlight Acre's role as a dynamic migratory corridor and demonstrate the value of citizen science in monitoring avian biodiversity in remote regions, reinforcing its importance for conservation strategies.

KEYWORDS: *Amazonia, birds, citizen science, migratory route*

Migratory birds undertake seasonal movements between breeding and non-breeding areas, often spanning vast geographic distances and ecological zones. These movements are driven by the need to optimize access to resources such as food, shelter, and suitable climatic conditions (Saunders et al. 2025). In South America, two major migratory systems are recognized: the Nearctic and the Austral flyways (Sick 1983, Stotz et al. 1992, Chesser 1994, Jahn et al. 2004, Alves 2007). Nearctic migrants breed in North America, primarily in Canada, the United States, and northern Mexico and migrate southward to wintering grounds across Central and South America, including Brazil (Stotz et al. 1992, Valente et al. 2011, Humple et al. 2020). Conversely, Austral migrants originate from southern regions of South America, such as Argentina, Chile, and Uruguay, and travel northward during the austral winter to reach tropical and subtropical

Received: 25/11/2025 · **Accepted:** 19/02/206 · **Associate Editor:** Nicolás Adreani · **Format Reviewer:** Noelle Rivas-Ortiz · **English Editor:** Abigail Williams

zones (Sick 1983, Chesser 1994, Cestari 2015).

The Brazilian Amazon, particularly the state of Acre, serves as an important stopover and destination for both Nearctic and Austral migratory species (Guilherme 2012, 2016). These birds rely on a mosaic of habitats for resting, feeding, and refueling during their journeys. However, increasing anthropogenic pressures such as deforestation, urban expansion, and climate change pose significant threats to the integrity of these migratory corridors and the survival of the species that depend on them (Saunders et al. 2025).

Understanding the spatial and temporal dynamics of migratory routes is essential for developing effective conservation strategies. Migratory connectivity, which links breeding and non-breeding populations across regions, is a critical concept in identifying priority areas for habitat protection and restoration (Saunders et al. 2025).

Citizen science initiatives have become increasingly vital for monitoring migratory bird populations, particularly in regions with limited scientific coverage, while also enabling accurate predictions of migratory routes (Fuentes et al. 2023). Platforms such as eBird have generated extensive datasets that allow researchers to assess migration timing, distribution, and habitat use across remote areas in North America, Europe, Africa, Asia, and Oceania (Sullivan et al. 2014). For example, eBird data have been used to evaluate stopover ecology and migration phenology in boreal and Arctic regions of North America, where traditional surveys are logistically challenging (La Sorte et al. 2016). In Africa, citizen science records have contributed to the monitoring of Palearctic migrants in Kenya, providing insights into habitat use and changes in geographical distribution over time (Nussbaumer et al. 2024). In Oceania, citizen science has revealed a hidden migratory diversity in eastern Australia, far greater than previously recognized, including species with little legal protection (Shi et al. 2025). Collectively, these contributions demonstrate how citizen science can complement professional monitoring, enabling robust, large-scale assessments of population trends and habitat use in remote areas worldwide. Furthermore, citizen science initiatives have proven valuable for monitoring migratory bird populations in regions such as Acre, where formal scientific coverage may be limited (Guilherme 2012, 2016). These efforts help fill critical data gaps and support large-scale assessments of population trends and habitat use (Humple et al. 2020, Barbosa et al. 2021).

In this context, the primary objective of this study is to assess the seasonal dynamics of migratory flow of Nearctic and Austral bird species in the Brazilian State of Acre. Specifically, the study aims to determine the temporal patterns of occurrence of these migratory groups and to evaluate whether Nearctic and Austral species co-occur (sympatry) in the region or utilize the area during distinct periods, thereby revealing temporally segregated migratory strategies.

METHODS

Study area

The study focused on the territorial boundaries of the Brazilian state of Acre (Fig. 1). The state of Acre covers an area of 164,221.36 km², sharing international borders with Peru and Bolivia, and national borders with the states of Amazonas and Rondônia (Acre 2015). The territory is traversed by two major rivers: the Juruá, which flows through the western region and the Purus, which crosses the central area (Guilherme 2012, 2016). The climate is humid equatorial, with annual rainfall ranging from 1400 to 3000 mm, predominantly concentrated between November and April (Acre 2014). The predominant vegetation consists of dense *terra firme* forest, with areas dominated by bamboos (*Guadua* sp.) and palms, as well as seasonally flooded várzea forests that develop along the alluvial plains of the main rivers (Daly & Silveira 2008, Guilherme 2016). The eastern region of the state, where the capital Rio Branco is located, is the most densely populated and experiences the highest anthropogenic pressure, with significant impacts on natural ecosystems due to urban expansion, agriculture, and extractive activities (Acre 2015).

Data collection

The documentation of migratory birds within the state of Acre was conducted through the retrieval of species images from three major citizen science platforms: (a) iNaturalist (2025); (b) WikiAves (2025); and (c) eBird (2025). These platforms host thousands of photographs contributed by over 50,000 volunteers. For our survey, we employed the advanced search tools provided by each platform to filter images of Nearctic and Austral migratory bird species recorded in Acre. We restricted our search exclusively to photographs of specimens, while videos, audio recordings, and indirect evidence such as images of tracks or feathers were not screened. To ensure consistency with established records, we relied on the dataset presented in Table 3 by Guilherme (2016), which lists all Nearctic and Austral migratory species previously documented in the state of Acre over a 65-year period, between 1951 and 2016. By using this comprehensive reference, our image selection was restricted to the exact number of species reported in that study, thereby providing a reliable basis for analysis.

Data curation

The selected photographs were sorted chronologically, from the oldest to the most recent records. Subsequently, we screened the retrieved images to determine their eligibility for inclusion in our dataset. Each record's eligibility was established by the bird's confirmed presence, verified through photographic evidence within the state boundaries, supported by municipal-level location data. Each valid record was entered as a row in an Excel spreadsheet, which was later used to generate comparative graphs illustrating species presence across the state. Images were organized by species name and annotated with metadata including photo URL, source platform, contributor, date, municipality, specific locality, geographic coordinates, habitat type, and additional observations. Some images were excluded due to redundant information (identical contributor, date, and location). The earliest photographs retrieved date back to 2008 and extend through to July 2025. This temporal range provides a valuable longitudinal perspective on the occurrence and distribution of migratory bird species

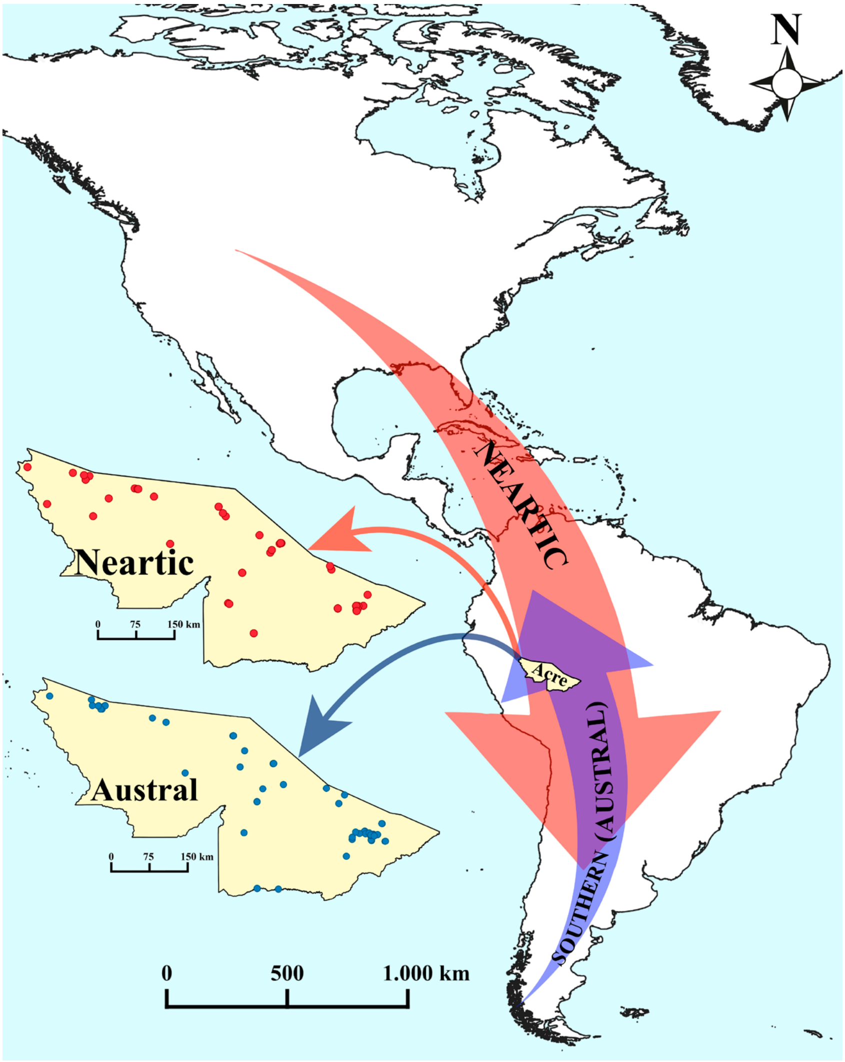

Figure 1. Geographic location of the Brazilian state of Acre in relation to the main migratory flyways of Nearctic and Austral bird species across The Americas. The detailed maps of Acre show the sites where at least one migratory species was recorded. Red points (Nearctic) and blue points (Austral) indicate the locations where at least one image of a migratory species was registered. Major arrows indicate the migratory flows between hemispheres, emphasizing Acre's strategic role as an ecological corridor for migratory birds.

within Acre, enabling the identification of patterns and potential shifts in migratory behavior over time, particularly among the most frequently photographed species across successive years. We surveyed 61 migratory species comprising 30 Austral and 31 Nearctic species (see Table 3 by Guilherme 2016). Scientific nomenclature follows that of AviList (AviList Core Team 2025).

Data processing

Phenology: To visualize and gain a general understanding of the temporal distribution of Nearctic and Austral migrants in Acre, a heatmap was constructed using RStudio software (version 12.1; R Core Team. 2024). We visualized the occurrence of different species across the months over the past 16 and a half years (2008 to July 2025). The data were organized into a record matrix, representing the number of monthly images for each species. The chronological ordering of months was manually defined to ensure temporal consistency. The heatmap was generated using a dedicated function, which was employed to represent each cell of the matrix. The fill scale was defined using a color palette ranging from light tones (indicating minimum records counts) to dark tones (indicating maximum records counts). The interpolated gradient allowed for a smooth transition between minimum and maximum values, enhancing the visual perception of intensity patterns. All images of each species obtained within the state were classified into reproductive and non-reproductive months to evaluate seasonal variation in species occurrence. The categorization of migratory species into reproductive and non-reproductive periods was based on Birds of the World (Billerman et al. 2026). This classification enabled the identification of months associated with documented reproductive activity versus those without evidence of breeding. Statistical differences in the number of images recorded during reproductive and non-reproductive months were tested using the non-parametric Mann-Whitney U test, with a threshold of $p < 0.05$ considered significant (Nachar 2008). The analysis was conducted for 45 species represented in the heatmap, ensuring comprehensive coverage of the migratory taxa included in the dataset. The statistical procedures were performed using the software PAST version 3.24 (Hammer et al. 2001). The dataset used in this study is available on the Mendeley Data platform (Pereira et al. 2026).

Minimizing bias in long-term time series: Species presence and absence can allow for inferring migratory patterns within the region (Somveille et al. 2013, Dennis et al. 2025). However, incorporating the number of photographic records per month adds a valuable dimension, potentially reflecting fluctuations in the relative abundance of individuals throughout the year. While we acknowledge the inherent bias in citizen science data, particularly the opportunistic nature of observations that may increase during periods of heightened field activity (Zhang et al. 2025), for example, during the dry season in Acre when rural areas become more accessible via roads, we consider that long-term datasets can mitigate these effects and allow for the detection of robust ecological trends (Strien et al. 2013, Kelling et al. 2019, Johnston et al. 2021). Moreover, comparative analyses between platforms such as eBird and iNaturalist have demonstrated consistent seasonal patterns of bird occurrence, despite differences in user profiles and data collection methods (Carroll et al. 2025). Therefore, graphical representations of monthly records for migratory species are likely to reflect actual population dynamics rather than merely observer effort (Koh & Opitz 2024). This approach strengthens our ability to identify cycles of arrival, residency, and departure, and highlights potential temporal overlap between Austral and Nearctic migrants in Acre.

RESULTS

A total of 1554 images were screened (1540 included and 14 excluded). Of the included images, 495 (32.1%) were taken between November and April, corresponding to the rainy season, whereas 1045 (67.9%) were taken between May and October, corresponding to the dry season. The dataset comprised 675 Nearctic migrants and 879 Austral migrants. Among the 31 Nearctic migratory species previously recorded in Acre, 10 (Blue-winged Teal, *Spatula discors*; Baird's Sandpiper, *Calidris bairdii*; Least Sandpiper, *Calidris minutilla*; Grey-cheeked Thrush, *Catharus minimus*; Black-billed Cuckoo, *Coccyzus erythropthalmus*; Connecticut Warbler, *Oporornis agilis*; Barn Swallow, *Hirundo rustica*; Laughing Gull, *Leucophaeus atricilla*; Wilson's Phalarope, *Phalaropus tricolor*; and Sand Martin, *Riparia riparia*) had no images recorded on any of the platforms. Three species (Swainson's Hawk, *Buteo swainsoni*; Stilt Sandpiper, *Calidris himantopus*; and Olive-sided Flycatcher, *Contopus cooperi*) were recorded exclusively on one platform (WikiAves), while Broad-winged Hawk (*Buteo platypterus*), Buff-breasted Sandpiper (*Calidris subruficollis*), and Summer Tanager (*Piranga rubra*) were found on only Wikiaves and iNaturalist platforms. Among the 31 Nearctic migrant species analyzed, 14 showed low or no representation across the platforms. Of these, six species had no records at all: Sick's Swift (*Chaetura meridionalis*), Southern Tropical Pewee (*Contopus cinereus*), Scissor-tailed Nightjar (*Hydropsalis torquata*), Greenish Elaenia (*Myiopagis viridicata*), Subtropical Doradito (*Pseudocolopteryx acutipennis*), and Blue-and-white Swallow (*Pygochelidon cyanoleuca*). Three species (Nacunda Nighthawk, *Chordeiles nacunda*; White-crested Elaenia, *Elaenia albiceps*; and Pantanal Snipe, *Gallinago paraguaiae*) were recorded on only Wikiaves platform, and five (Small-billed Elaenia, *Elaenia parvirostris*; Bran-colored Flycatcher, *Myiophobus fasciatus*; Southern Martin, *Progne elegans*; White-throated Kingbird, *Tyrannus albogularis;* and Ash-colored Cuckoo, *Coccycua cinerea*) were found only on Wikiaves and eBird platforms.

Most Frequently Photographed Species

The photographic records of migratory birds in Acre show that among the Nearctic migrants, Solitary Sandpiper (*Tringa solitaria*) was the most photographed, with 157 images, recorded year-round but more frequent from August to December (Fig. 2A). Pectoral Sandpiper (*Calidris melanotos*) had 89 records, present from August to December (Fig. 2B). Eastern Wood Pewee (*Contopus virens*) appeared in nearly all months, peaking in November with 83 images (Fig. 2C). Finally, Eastern Kingbird (*Tyrannus tyrannus*) had 80 records, occurring from September to May and absent from June to August (Fig. 2D). Among the Austral migrants, Vermilion Flycatcher (*Pyrocephalus rubinus*) was the most photographed, with 239 images, occurring from April to October (Fig. 2E). Fork-tailed Flycatcher (*Tyrannus savana*) had 100 records, present during the rainy season (Jan-Apr) and the dry season (Jul-Oct; Fig. 2F). Crowned Slaty Flycatcher (*Empidonomus aurantioatrocristatus*) accounted for 96 images, occurring from February to November and absent only in Dec-Jan (Fig. 2G). Chivi Vireo (*Vireo chivi*) totaled 80 records, present from March to November and in January, absent in Dec-Feb (Fig. 2H).

Phenology

The heatmap revealed a distinct migratory pattern with some overlap between Nearctic and Austral migratory bird species (Fig. 3). Nearctic species typically arrive in the state of Acre during the second half of the year, between September and October, and depart by March. In contrast, Austral species begin arriving in March and April, remaining until September or October (Fig. 3). The Mann-Whitney U test revealed statistically significant differences in temporal occurrence patterns for 47.6% of Nearctic migrants (Fig. 3). In contrast, among austral migrants only 8.3% showed significant differences, although two species (Variegated Flycatcher, *Empidonomus varius,* and Chivi Vireo) were at the threshold of statistical significance (Fig. 3).

DISCUSSION

Migratory birds from both Austral and Nearctic regions exhibit seasonal movements toward northern South America, including the state of Acre, in response to favorable climatic and ecological conditions. This explains their year-round presence in the region. During the Austral autumn and winter, southern South America experiences colder temperatures and reduced food availability, prompting Austral species to move northward (Joseph 1996, Jahn et al. 2004). Similarly, Nearctic species depart from temperate North America during its fall and winter months, seeking warmer climates and richer foraging grounds in the tropics (Silveira et al. 2021, El Hindi et al. 2023). The investigation of this phenomenon in the Neotropical region has been greatly facilitated by the extensive databases provided by citizen science platforms, which enable research across large geographic areas without major logistical challenges or high operational costs (Schubert et al. 2019, Jahn et al. 2020). Results have revealed consistent migratory patterns for birds across different regions of South America similar to those observed in the present study (Schubert et al. 2019, Barbosa et al. 2021, Thibaudier et al. 2025). Although a potential bias of working with images in Acre is that more birdwatchers visit the state during the drier months, reflected in the fact that greater than 50% of the images were obtained in this period, it was nevertheless possible to detect a clear migratory pattern of Nearctic species, which occur in the state during the rainy season. We believe this was feasible because the dataset encompassed a long sampling period of more than 15 years, as previously discussed regarding the biases inherent to citizen science data. An additional bias in our study may explain why Vermilion Flycatcher and Fork-tailed Flycatcher accounted for the highest number of photographs. Both species are migratory birds associated with open habitats and are known to use urban and peri-urban environments during their seasonal movements (Jahn et al. 2016, Thibaudier et al. 2025). This ecological behavior increases their visibility and accessibility to observers, thereby facilitating the documentation and acquisition of images compared to species that remain restricted to forested habitats.

Among Nearctic birds, Solitary Sandpiper was the only Scolopacidae species recorded in Acre throu-

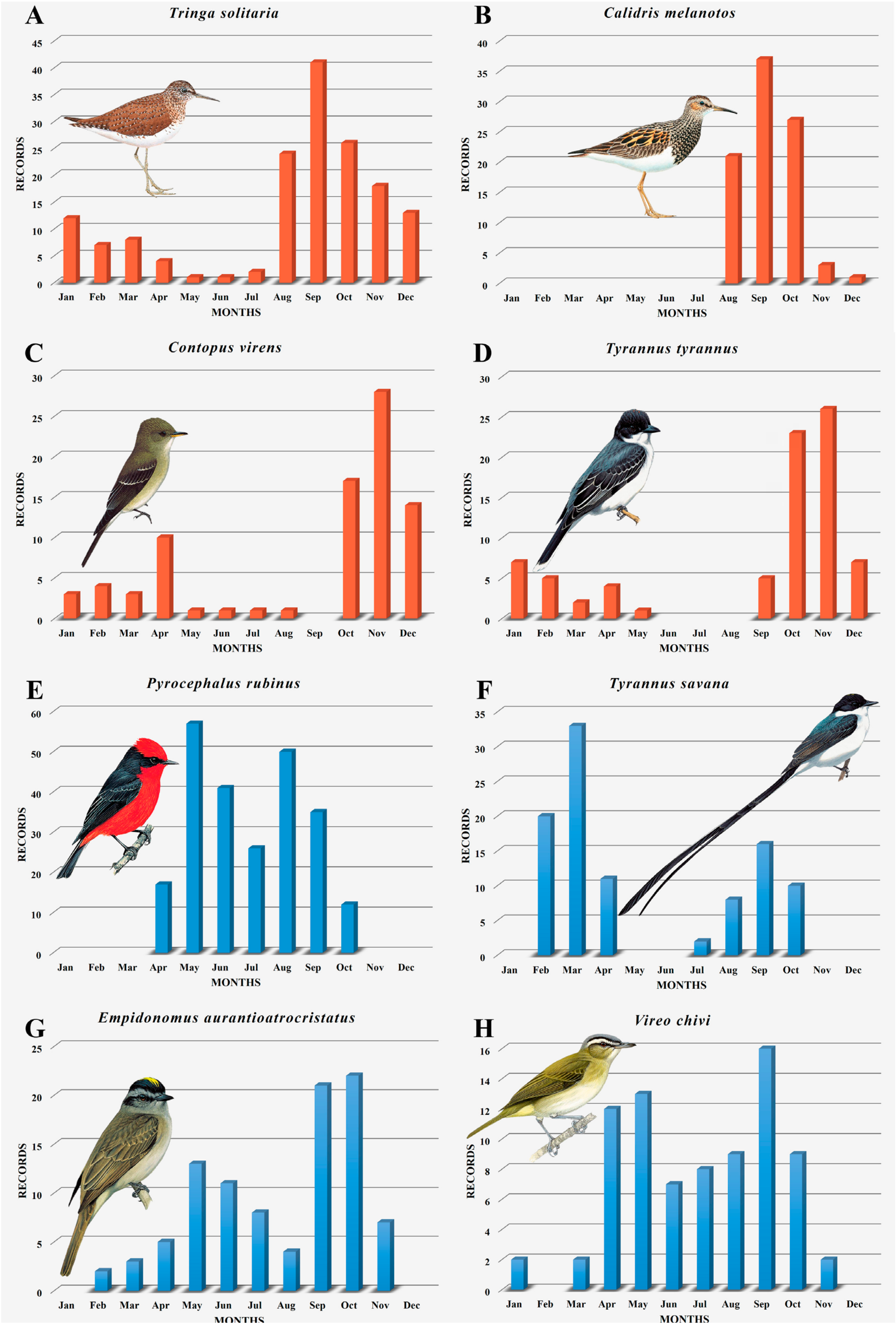

Figure 2. Temporal distribution of the four most frequently photographed Austral and Nearctic migratory bird species in the state of Acre between 2008 and July 2025. Records for A-D Nearctic and E-H Austral birds. Credits for bird illustrations: Farmer et al. (2020), Jahn & Tuero (2020), Kirwan (2020), Moskoff (2020), Murphy & Pyle (2020), Robb (2020), Watt et al. (2020), and Ellison et al. (2021).

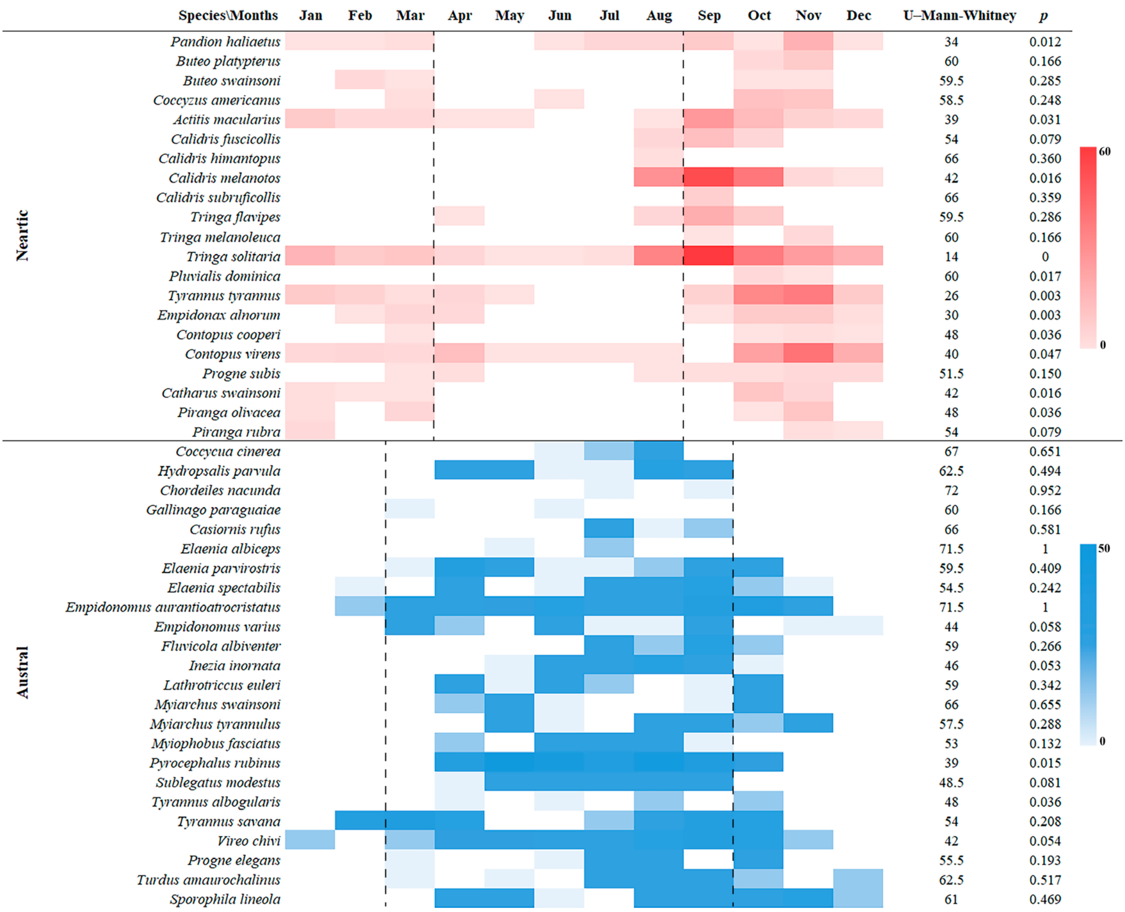

Figure 3. Heatmap of the migratory phenology of Nearctic and Austral bird species in the state of Acre between 2008 and July 2025. Color intensity represents the monthly frequency of photographic records for each species. Dashed lines indicate periods of minimal temporal overlap between Nearctic and Austral migratory species, highlighting distinct seasonal patterns of occurrence in the region. The last two columns show the Mann-Whitney U test statistics and the corresponding *P*-value.

ghout all months of the year. Nevertheless, its migratory pattern proved to be statistically significant, given that during the breeding months of May and June (Moskoff 2020) only a single image was documented in each month within the boundaries of Acre over the past 17 years, in sharp contrast to the considerably higher number of records obtained during the non-breeding months (Fig. 3). This shorebird is commonly seen on the Campus of the Federal University of Acre, foraging along the edges of ponds either alone or in small flocks (Guilherme 2001, 2016). Color-banded individuals observed on campus in subsequent years suggest that they remain locally for more than one summer (EG pers. obs.). These birds breed in high-latitude regions of the Northern Hemisphere and, for the most part, migrate along coastal areas, where sites with large concentrations of individuals are found (Campos et al. 2008, Valente et al. 2011, Somenzari et al. 2018). The Spotted Sandpiper (*Actitis macularius*) was present in Acre throughout 10 months, except for June and July, which correspond to the peak breeding season of the species in temperate North America, particularly in the United States (Reed et al. 2020). The other shorebirds (e.g., *Calidris* sp.) were present in Acre only during the expected wintering period in Brazil, between the months of August and December (Fig. 3; Valente et al. 2011, Somenzari et al. 2018). The Eastern Wood Pewee migrates from eastern North America, through Central America, to winter in the western Amazon (Watt et al. 2020) and may also reach regions in Central Brazil (Somenzari et al. 2018). Watt et al. (2020) identifies two migration periods: one in spring and the other in autumn, which explains its presence in Acre during almost every month of the year, except September (Fig. 3). The Eastern Kingbird breeds in the northern United States and Canada and migrates to the forests of South America during the boreal winter (Murphy & Pyle 2020). This species undergoes both spring and autumn migrations (Murphy & Pyle 2020), like the Eastern Wood Pewee, which explains its presence in Acre from January to April and from September to December, with a peak in records during October and November, coinciding with the winter months in the breeding sites.

Some species, such as Vermilion Flycatcher, occupy a wide range across South, Central, and North America, encompassing 12 subspecies, some of which are resident while others are migratory (Carmi et al. 2016). The Austral migrant that reaches the state of Acre is the nominal subspecies: *P. r. rubinus* (Carmi et al. 2016, Canassa 2022, Thibaudier et al. 2025). According to Sick (1983), *P. r. rubinus* initiates its migratory activity around mid-January, departing from Argentina towards northern South America. Recent citizen science data indicate that this species winters between May and August, with northward migration occurring in March and April, and southward return migration between September and October (Thibaudier et al. 2025). The presence of Vermilion Flycatcher in the state of Acre from April to October is consistent with these findings. Among austral migrant species, this was the one that exhibited the clearest migratory pattern, with records in Acre restricted to the wintering months (Fig. 3). Data indicated that the Southern Fork-tailed Flycatcher migrates to Acre during two distinct seasons: the rainy season and the dry season (Fig. 2F). According to Jahn et al. (2016), individuals of this species exhibit two main migratory periods: an autumnal migration involving birds that breed in southeastern Brazil and migrate to northern South America, and a spring migration involving individuals that breed in Argentina and migrate to northwestern South America. This dual pattern helps explain the two migratory waves observed in Acre: one occurring from February to April, and another from July to October, corresponding to the timing of post-breeding and pre-breeding movements within South America (Jahn et al. 2013, Jahn et al. 2016). These intra-tropical migrations reflect the broader diversity of migratory strategies among Neotropical Austral migrants, which often winter north of their breeding areas and may use multiple stopover or overwintering sites (Chesser 1994, Jahn et al. 2004). The Crowned Slaty Flycatcher and Chivi Vireo have been photographed in the state of Acre throughout nearly the entire year (Fig. 3). According to Jahn et al. (2004), the Crowned Slaty Flycatcher exhibits a type of migration known as leapfrog partial migration, in which some individuals of the population are migratory while others are resident. We believe that this pattern also explains the year-round presence of Chivi Vireo in Acre.

Phenology

This long-term dataset allowed us to identify distinct seasonal windows of occurrence for each migratory group, with some overlap in their periods of peak activity. Nearctic migrants typically arrive in Acre during the second half of the year, with a concentration of records between September and October. These species remain in the region until March, after which their presence declines sharply. This pattern aligns with their migratory routes from North America to South America during the boreal winter. In contrast, Austral migrants begin arriving in Acre in March and April, coinciding with the end of the rainy season, and remain until September or October. Their migratory cycle reflects movements within South America, often between southern breeding grounds and northern non-breeding areas.

Seasonal statistical differences were more evident among Nearctic species. This indicates a clear migratory pattern in the study region, where the likelihood of observing these species increases significantly during non-breeding months. For certain Nearctic species in which no significant pattern was detected, we attribute this outcome to the low number of available records in the surveyed platforms, such as Swainson's Hawk, Stilt Sandpiper, Buff-breasted Sandpiper, Greater Yellowlegs (*Tringa melanoleuca*), and Summer Tanager, all represented by fewer than ten images during the sampling period. Among austral species, no significant seasonal differences were observed for most taxa. In some cases, this was also due to limited sampling, as with Pantanal Snipe, Nacunda Nighthawk, Ash-colored Cuckoo, White-crested Elaenia, and Rufous Casiornis (*Casiornis rufus*). However, the absence of seasonal statistical differences may be more convincingly explained by the presence of resident populations that remain in the region year-round, as documented for Chivi Vireo and Crowned Slaty Flycatcher (Jahn et al. 2004, Schulenberg et al. 2007, Somenzari et al. 2018), or by species that exhibit more complex migratory patterns, such as two distinct migratory periods, as observed in Fork-tailed Flycatcher (Jahn et al. 2016). Another plausible explanation relates to the physical condition of individuals: juveniles or weakened birds may be unable to initiate return migration after the breeding season, remaining longer in the area to feed and accumulate energy reserves. These individuals typically resume migration in the following season once they are physically prepared. Confirmation of this pattern will require systematic field studies capable of monitoring both migratory populations and individuals that fail to return to breeding areas. If validated, such behavior would have important implications for migratory ecology and conservation strategies, highlighting the need to protect habitats used beyond traditional migratory windows (Jahn et al. 2020).

CONCLUSION

The state of Acre serves as a seasonal refuge and strategic corridor for migratory birds, sustaining ecological connectivity across The Americas. Nearctic migrants, particularly shorebirds, use the Amazon Basin's rivers and floodplains as vital stopover and wintering sites during their southward journeys (Linscott et al. 2024), while Austral migrants from southern South America depend on Acre's forests and wetlands during the non-breeding season. Acre's warm and humid climate corresponds to the ecological requirements of some Austral migrant species adapted to tropical lowland conditions (Joseph 1996), reinforcing its role as a refuge within the Amazon Basin (Valente et al. 2011, Guilherme 2012, 2016). The alternating presence of these two migratory groups, with limited temporal overlap, reduces interspecific competition and highlights Acre's dual importance as a hemispheric convergence zone. The degradation of Acre's wetlands, riparian zones, floodplain forests, and *terra firme* upland forests would simultaneously affect both Nearctic and Austral migratory systems, underscoring the urgency of integrating Acre into transnational conservation frameworks that safeguard biodiversity and ecological resilience across the continent. Acre's conservation is therefore fundamental not only for sustaining migratory connectivity but also for ensuring the long-term resilience of the Amazon as a whole (Leal Filho et al. 2025).

ACKNOWLEDGMENTS

A. G. Pereira and K. O. Silva acknowledge the support of CNPq and the Pró-Reitoria de Pesquisa e Pós-Gradução of the Universidade Federal do Acre (UFAC) for granting undergraduate research fellowships; I. D. Mendes acknowledges the support of CNPq for granting a visiting specialist fellowship. The authors also thank Prof. Dr. Eder F. Morato (UFAC) for the discussions on the statistical treatment of the data.

REFERENCES

Acre, Governo do Estado (2014) Caderno das Unidades de Gestão de Recursos Hídricos do Acre / Secretária de Estado do Meio Ambiente. Rio Branco: SEMA

Acre, Governo do Estado (2015) Zoneamento Ecológico-Econômico do Estado do Acre, Fase II. Rio Branco: SEMA

Alves MAS (2007) Sistemas de migrações de aves em ambientes terrestres no Brasil: exemplos, lacunas e propostas para o avanço do conhecimento. Revista Brasileira de Ornitologia 15(2):231-238

AviList Core Team. 2025. AviList: The Global Avian Checklist, v2025. https://doi.org/10.2173/avilist.v2025

Barbosa KVC, Develey PF, Ribeiro MC, Jahn AE (2021) The contribution of citizen science to research on migratory and urban birds in Brazil. Ornithology Research 29:1-11. https://doi.org/10.1007/s43388-020-00031-0

Billerman SM, Keeney BK, Kirwan GM, Medrano F, Sly ND, Smith MG (2026) Birds of the World. Cornell Laboratory of Ornithology, Ithaca, NY, USA. https://doi.org/10.2173/bow

Campos CEC, Naiff RH, Araújo AS (2008) Censo de aves migratórias (Charadriidae e Scolopacidae) da Porção Norte da Bacia Amazônica, Macapá, Amapá, Brasil. Ornithologia 3:38-46

Canassa GG (2022) Migração austral do Príncipe (*Pyrocephalus rubinus*: Aves): uma avaliação através da ciência cidadã. Universidade Estadual Paulista, Rio Claro. [URL: http://hdl.handle.net/11449/216499]

Carmi O, Witt CC, Jaramillo A, Dumbacher JP (2016) Phylogeography of the Vermilion Flycatcher species complex: multiple speciation events, shifts in migratory behavior, and an apparent extinction of a Galápagos-endemic bird species. Molecular Phylogenetics and Evolution 102:152-173. https://doi.org/10.1016/j.ympev.2016.05.029

Carroll C, Furrow RE, Gerhart LM (2025) Consistency and Validity of Participatory Science Data: A Comparison of Seasonality Patterns of Northern California and Nevada Birds Across eBird and iNaturalist. Citizen Science: Theory and Practice 10(1):1-14. https://doi.org/10.5334/cstp.825

Cestari C (2015) Coexistence between Nearctic-Neotropical migratory shorebirds and humans on urban beaches of the Southern Hemisphere: a current conservation challenge in developing countries. Urban Ecosystems 18:285-291. https://doi.org/10.1007/s11252-014-0399-3

Chesser RT (1994) Migration in South America: an overview of the austral system. Bird Conservation International 4(2-3):91-107. https://doi.org/10.1017/S0959270900002690

Daly DC, Silveira M (2008) Primeiro catálogo da flora do Acre, Brasil. Editora da Universidade Federal do Acre – Edufac. Rio Branco, Acre. Pp. 42

Dennis EB, Diana A, Matechou E, Morgan BJ (2025) Efficient statistical inference methods for assessing changes in species' populations using citizen science data. Journal of the Royal Statistical Society Series A: Statistics in Society 188(3):641-657. https://doi.org/10.1093/jrsssa/qnae105 eBird (2025) eBird: An online database of bird distribution and abundance (web application). eBird, Cornell Lab of Ornithology, Ithaca. [URL: http://www.ebird.org]

El Hindi TS, Jahn AE, Tuero DT, Pizo MA, Silveira NSD (2023) Projected population- and season-dependent impacts of climate change on a migratory songbird in South America. Frontiers in Bird Science 2:1214458. https://doi.org/10.3389/fbirs.2023.1214458

Ellison KS, Wolf BO, Jones SL (2021) Vermilion Flycatcher (*Pyrocephalus rubinus*), version 1.1. In: Poole AF (ed) Birds of the World. Cornell Lab of Ornithology, Ithaca, NY, USA. https://doi.org/10.2173/bow.verfly.01.1

Farmer A, Holmes RT, Pitelka FA (2020) Pectoral Sandpiper (*Calidris melanotos*), version 1.0. In: Billerman SM (ed) Birds of the World. Cornell Lab of Ornithology, Ithaca, NY, USA. https://doi.org/10.2173/bow.pecsan.01

Fuentes M, Van Doren BM, Fink D, Sheldon D (2023) BirdFlow: Learning seasonal bird movements from eBird data. Methods in Ecology and Evolution 14(3):923-938. https://doi.org/10.1111/2041-210X.14052

Guilherme E (2001) Comunidade de Aves do Campus e Parque Zoobotânico da Universidade Federal do Acre, Brasil. Tangara 1(2):57-73

Guilherme E (2012) Birds of the Brazilian state of Acre: Diversity, zoogeography, and conservation. Revista Brasileira de Ornitologia 20(4):393-442. [URL: http://www.revbrasilornitol.com.br/BJO/article/view/0149]

Guilherme E (2016) Aves do Acre. Editora da Universidade Federal do Acre – Edufac. Rio Branco, Acre. Pp. 897

Hammer Ø, Harper DA (2001) Past: paleontological statistics software package for education and data analysis. Palaeontologia Electronica 4(1):1-9. [URL: http://palaeo-electronica.org/2001_1/past/issue1_01.htm]

Humple DL, Cormier RL, Richardson TW, Burnett RD, Seavy NE, Dybala KE, Gardali T (2020) Migration tracking reveals geographic variation in the vulnerability of a Nearctic-Neotropical migrant bird. Scientific Reports 10:5483. https://doi.org/10.1038/s41598-020-62132-6

iNaturalist (2025) iNaturalist: an online social network of people sharing biodiversity information to help each other learn about nature. [URL: https://www.inaturalist.org/] (10/09/2025)

Jahn AE, Levey DJ, Smith KG (2004) Reflections across hemispheres: Austral migration is key to a system-wide approach to New World bird migration. The Auk 121(4):1005-1013. https://doi.org/10.1093/auk/121.4.1005

Jahn AE, Levey DJ, Cueto VR, Ledezma JP, Tuero DT, Fox JW, Masson D (2013) Long-distance bird migration within South America revealed by light-level geolocators. The Auk 130(2):223-229. https://doi.org/10.1525/auk.2013.12077

Jahn AE, Seavy NE, Bejarano V, Benavides Guzmán M, Provinciato ICC, Pizo MA, MacPherson M (2016) Intra-tropical migration and wintering areas of Fork-tailed Flycatchers (*Tyrannus savana*) breeding in São Paulo, Brazil. Revista Brasileira de Ornitologia 24(2):116-121

Jahn AE, Cueto VR, Fontana CS, Guaraldo AC, Levey DJ, Marra PM, Ryder TB (2020) Bird migration within the Neotropics. The Auk 137(4):ukaa033. https://doi.org/10.1093/auk/ukaa033

Jahn AE, Tuero DT (2020) Fork-tailed Flycatcher (*Tyrannus savana*), version 1.0. In: Schulenberg TS (ed) Birds of the World. Cornell Lab of Ornithology, Ithaca, NY, USA. https://doi.org/10.2173/bow.fotfly.01

Johnston A, Hochachka WM, Strimas-Mackey ME, Gutierrez VR, Robinson OJ, Miller ET, Auer T, Kelling ST, Fink D (2021) Analytical guidelines to increase the value of community science data: An example using eBird data to estimate species distribution. bioRxiv:574392. Diversity and Distributions 27:1265-1277. https://doi.org/10.1111/ddi.13271

Joseph L (1996) Preliminary climatic overview of migration patterns in South American austral migrant passerines. Ecotropica 2(2):185-193

Kelling S, Johnston A, Bonn A, Fink D, Ruiz-Gutierrez V, Bonney R, Fernandez M, Hochachka WM, Julliard R, Kraemer R, Guralnick R (2019) Using semistructured surveys to improve citizen science data quality. BioScience 69(3):170-179. https://doi.org/doi/10.1093/biosci/biz010

Kirwan GM (2020) Chivi Vireo (*Vireo chivi*), version 1.1. In: Schulenberg TS, Keeney BK, Billerman SM, Rodewald PG (eds) Birds of the World. Cornell Lab of Ornithology, Ithaca, NY, USA. https://doi.org/10.2173/bow.chivir1.01.1

Koh J, Opitz T (2024) Extreme-value modelling of migratory bird arrival dates: Insights from citizen science data. Journal of the Royal Statistical Society Series A: Statistics in Society 188(3):674-699. https://doi.org/10.1093/jrsssa/qnae108

La Sorte FA, Fink D, Hochachka WM, Kelling S (2016) Convergence of broad-scale migration strategies in terrestrial birds. Proc. R. Soc. B 283: 20152588. http://dx.doi.org/10.1098/rspb.2015.2588

Leal Filho W, Dinis MAP, Canova MA, Cataldi M, Silva da Costa GA, Enrich-Prast A, Symeonakis E, Brearley FQ (2025) Managing ecosystem services in the Brazilian Amazon: the influence of deforestation and forest degradation in the world's largest rain forest. Geoscience Letters 12:24. https://doi.org/10.1186/s40562-025-00391-9

Linscott JA, Basso E, Bathrick R et al. (2024) The Amazon Basin's rivers and lakes support Nearctic-breeding shorebirds during southward migration. Ornithological Applications 126(4):duae034. https://doi.org/10.1093/ornithapp/duae034

Moskoff W (2020) Solitary Sandpiper (*Tringa solitaria*), version 1.0. In Birds of the World (A. F. Poole, Editor). Cornell Lab of Ornithology, Ithaca, NY, USA. https://doi.org/10.2173/bow.solsan.01

Murphy MT, Pyle P (2020) Eastern Kingbird (*Tyrannus tyrannus*), version 1.0. In: Rodewald, P.G. (Ed.). Birds of the World. Cornell Lab of Ornithology, Ithaca, NY, USA. https://doi.org/10.2173/bow.easkin.01

Nachar N (2008) The Mann-Whitney U: A test for assessing whether two independent samples come from the same distribution. Tutorials in quantitative Methods for Psychology 4(1):13-20. https://doi.org/10.20982/tqmp.04.1.p013

Nussbaumer R, Nussbaumer A, Guchu S et al. (2024) Historical bird atlas and contemporary citizen science data reveal long-term changes in geographic range of Kenyan birds. Diversity and Distributions 31:e13935. https://doi.org/10.1111/ddi.13935

Pereira A, Silva K, Alencar L, Mendes I, Guilherme E (2026) Migratory Birds in the Brazilian State of Acre. Mendeley Data:1. https://doi.org/10.17632/f43sxybs93.1

R Core Team. 2024. R: A Language and Environment for Statistical Computing. R Foundation for Statistical Computing, Vienna, Austria

Reed JM, Oring LW, Gray EM (2020) Spotted Sandpiper (*Actitis macularius*), version 1.0. In: Poole AF (ed) Birds of the World. Cornell Lab of Ornithology, Ithaca, NY, USA. https://doi.org/10.2173/bow.sposan.01

Robb R (2020) Crowned Slaty Flycatcher (*Empidonomus aurantioatrocristatus*), version 1.0. In: Schulenberg TS (ed) Birds of the World. Cornell Lab of Ornithology, Ithaca, NY, USA. https://doi.org/10.2173/bow.croslf1.01

Saunders SP, DeLuca WV, Bateman BL et al. (2025) Multispecies migratory connectivity indicates hemispheric-scale risk to bird populations from global change. Nature Ecology & Evolution 9:2575-2583. https://doi.org/10.1038/s41559-024-02575-6

Schubert SC, Manica LT, Guaraldo AC (2019) Revealing the potential of a huge citizen-science platform to study bird migration. Emu - Austral Ornithology 119:4, 364-373. https://doi.org/10.1080/01584197.2019.1609340

Schulenberg TS, Stotz DF, Lane DF, O'Neill JP, Parker III TA (2007). Birds of Peru. Princeton University Press, New Jersey. Pp. 664

Shi X, Clarke RH, Simmonds JS, Kerswell A, Holden W, Chapman JW, Fuller RA (2025) Characterising Migratory Bird Assemblages in Understudied Regions by Integrating Radar and Citizen Science Data. Global Ecology and Biogeography 34(8):e70104. https://doi.org/10.1111/geb.70104

Sick H (1983) Migrações de aves na América do Sul Continental. Publicação Técnica no. 2. CEMAVE – Instituto Brasileiro de Desenvolvimento Florestal, Brasília, DF

Silveira NSD, Vancine MH, Jahn AE, Pizo MA, Sobral-Souza, T (2021) Future climate change will impact the size and location of breeding and wintering areas of migratory thrushes in South America. Ornithological Applications 123(2):duab006. https://doi.org/10.1093/ornithapp/duab006

Somenzari M, Amaral PP, Cueto VR et al. (2018) An overview of migratory birds in Brazil. Papéis Avulsos de Zoologia 58:e20185803. https://doi.org/10.11606/1807-0205/2018.58.03

Somveille M, Manica A, Butchart SHM, Rodrigues ASL (2013) Mapping Global Diversity Patterns for Migratory Birds. PLoS ONE 8(8): e70907. doi:10.1371/journal.pone.0070907

Stotz DF, Bierregaard RO, Cohn-Haft M, Petermann P, Smith J, Whitney BM, Whittaker A (1992) The status of North American migrants in central Amazonian Brazil. The Condor 94(3):608-621. https://doi.org/10.2307/1369246

Strien AJ, Van Swaay CAM, Termaat T (2013) Opportunistic citizen science data of animal species produce reliable estimates of distribution trends if analyzed with occupancy models. The Journal of Applied Ecology 50(6):1450-1458. https://doi.org/10.1111/1365-2664.12158

Sullivan BL, Aycrigg JL, Barry JH, ..., Yu J, Kelling S (2014) The eBird enterprise: an integrated approach to development and application of citizen science. Biological Conservation 169:31-40. https://doi.org/10.1016/j.biocon.2013.11.003

Thibaudier J, Lopes LE, Cunha FC (2025) Unveiling the migratory patterns of scarlet flycatchers using citizen science databases. Ornithology Research 33:20. https://doi.org/10.1007/s43388-025-00225-4

Valente RM, Silva JMC, Straube FC, Nascimento JLX (2011) Conservação de aves migratórias neárticas no Brasil. Brasília: Conservação Internacional. Pp. 400

Watt DJ, McCarty JP, Kendrick SW, Newell FL, Pyle P (2020) Eastern Wood-Pewee (*Contopus virens*), version 1.0. In: Rodewald PG (ed) Birds of the World. Cornell Lab of Ornithology, Ithaca, NY, USA. https://doi.org/10.2173/bow.eawpew.01

Wikiaves (2025) A Enciclopédia das Aves do Brasil [URL: https://www.wikiaves.com.br/] (10/10/2025)

Zhang L, Kang J, Kubo T (2025) Long-term monitoring of citizen science: driving factors and pandemic impacts. International Journal of Sustainable Development & World Ecology 32 (2):177-185. https://doi.org/10.1080/13504509.2024.2423085