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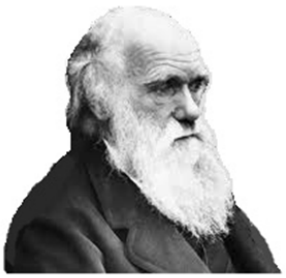

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Vertical stratification of birds in Dense Ombrophilus Forest remmant in Brazil

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ABSTRACT

The composition of life in the forest is altered as changes occur in vegetation that directly interferes with the population structure of the avifauna. The integrity and complexity of a forest are the factors that influence the composition, abundance, and probably the functions of the assembly of different bird species. In that way, in forest environments, where a vertical stratification of resources occurs, these species are distributed occupying a high diversity of trophic niches. This study realized in forest fragments of Atlantic Forest in a metropolitan area of São Paulo, Brazil, was to analyze the bird's distribution in trophic guilds, according to vertical stratification to different ecological successional stages of vegetation. The forest fragment in an advanced stage of secondary regeneration showed the highest number of bird species and was better distributed in trophic guilds and in the vertical structure of the forest, which indicates a better quality status in comparison to the other forest fragments in an initial and medium stage of ecological succession.

***Keywords*:** biodiversity trophic structure, ecological succession, forest fragments, Brazilian birds

1. INTRODUCTION

The Atlantic Forest is one of the most important biodiversity hotspots; originally covering over 1.3 million km^2, distributed along the Brazilian coastal, and is the most threatened

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Brazilian biome. After 500 years of exploitation and destruction, the Atlantic Forest has been reduced to less than 8% of its original cover [1]. This important biome harbors a high diversity of bird species, with several endemic and threatened species [2]. The Brazilian Atlantic Forest sensu lato is classified as an area that comprises different types of forests: Dense Ombrophilous forests, Deciduous and Semi-deciduous forests from the South and Southern regions, and Mixed Ombrophilous forests, also known as Araucaria forests from Southern Brazil [3, 4].

The Atlantic Forest has an extremely diverse and unique mix of vegetation and forest types. It has spectacular bird diversity, with over 930 species, about 15 percent of which are found nowhere else. This avifauna is a highly endangered community: 68 % of the species are rare and there are 23 endemic genera [5]. Because most of the region's forests have been cleared during centuries of exploitation, many species are now threatened, and future extinctions seem inevitable [6, 7].

Among the many factors thought to contribute to the high bird species richness in the Atlantic Forest is the high diversity of habitat and microhabitat types, some of which are unique to tropical regions [8]. The increase in structural complexity of the vegetation on various vertical levels makes new forms of occupancy of the environment possible [9, 10]. Thus, the increase in the number of bird species is principally due to the increase of both the new food guilds and the number of species in the existing guilds [11]. Stratification of habitats allows the coexistence of bird species exploiting the same resources due to reduced interference competition [12].

Tropical forests are characterized by stratification and vertical distribution of plant biomass through the trunks and branches of the trees, leaves, fruits, and flowers, creating habitats and resources for avian communities [13]. The habitat heterogeneity is fundamental in result more species richness because it leads to greater spatial variability of habitat physical conditions, and therefore permits greater niche specialization [14].

Vegetation is one of the most important characteristics of the environment because it supports animal life, through two key attributes: food and shelter. The structure of the forest directly interferes with the population structure of the birds. This fact can be realized by the alterations in the diversity and density of birds species, principally among specialist species [15]. The main objective of this study was to know the composition of birds existing in forest fragments of Dense Ombrophilous forest at Atlantic Forest and to analyze the birds' distribution in trophic guilds, according to vertical stratification to different ecological successional stages of vegetation.

2. MATERIALS AND METHODS

2. 1. Study site

The study was conducted in forest fragments of Dense Ombrophilous forest at Atlantic Forest, situated in the western metropolitan area of São Paulo, Brazil, between the latitude 23°29'S to 23°34'S and longitude 46°51'W to 46°58'W, between 750 and 850 meters of altitude (Figure 1). The climate of the region is the Cwa type according to Köppen's classification. The annual average rainfall is over 1,400 mm, concentrated in the summer. The annual medium temperature range is 20 °C.

Different natural environments were studied, according to different ecological successional stages of vegetation. The forest fragments in the initial stage of ecological

succession have only one stratum with trees varying in height between two and eight meters. Six fragments were studied with areas varying between 0.2 and 4.6 hectares. The estimated basal area was 9.57 $m^2 \cdot ha^{-1}$ and densities ranging from 900 to 1,100 $trees \cdot ha^{-1}$. Low species diversity was observed, H = 2.91 nats ind^{-1}, and few significant differences between the fragments. In general, the composition of the trees is formed mainly by early pioneer species like Alchornea glandulosa, Lithraea molleoides, Trema micrantha, Cecropia pachystachya, Myrsine ferruginea, Croton floribundus, and Anadenanthera colubrina.

Figure 1. Localization of the studied area, situated in the metropolitan area of São Paulo, Brazil.

In the forest fragments in a medium stage of secondary regeneration are recognizable two vertical strata of the vegetation: understorey and canopy stratum. The canopy stratum is composed of the crowns of large-sized trees, with sparse trees varying in average height between 8 and 14 meters. Nine fragments were studied with areas varying between 1.2 and 12.4 hectares. The estimated basal area was 21.18 $m^2 \cdot ha^{-1}$ and densities ranging from 1,100 to 1,300 $trees \cdot ha^{-1}$. A high species diversity was observed, H = 3.56 nats ind^{-1}, with few significant differences between the fragments. The composition of the trees is formed mainly by early pioneer and secondary species like Piptadenia gonoacantha, Anadenanthera colubrina, Cupania vernalis, Casearia sylvestris, Guarea guidonia, Luehea divaricata, Zanthoxylum riedelianum, Inga edulis, Lonchocarpus guilleminianus, Ocotea puberulla, and Tapirira guianensis. The understorey vegetation is characterized by shrubs (0.40 to 2.00 meters tall).

In the forest fragment in an advanced stage of secondary regeneration are recognizable three vertical strata of the vegetation: understorey, under canopy, and canopy stratum. The canopy stratum is composed of the crowns of large-sized trees, with sparse trees varying in average height between 18 and 22 meters. The understorey is composed of trees varying in average height between 8 and 14 meters. Only a fragment with approximately 26 hectares was studied in this stage of ecological succession. The estimated basal area was 32.13 $m^2 \cdot ha^{-1}$ and densities ranging from 700 to 900 $trees \cdot ha^{-1}$. A high species diversity was observed, H = 3.87 nats ind^{-1}. The most important arboreal species in density and relative frequency were Hirtella

hebeclada, Machaerium villosum, Guarea guidonia, Casearia gossypiosperma, Machaerium aculeatum, Pera glabrata, Lonchocarpus guilleminianus, Rollinia sylvatica, Colubrina glandulosa, Ocotea puberulla, and Nectandra megapotamica. Trees sheltered many epiphytes, including bromeliads, orchids, aroids, cacti, mosses, lichens, and vines. The understorey is characterized by the dominance of shrubs between 0.40 and 2.00 meters tall and the outstanding species in this stratum are of the families Melastomataceae, Rubiaceae, Fabaceae, Euphorbiaceae, and Myrtaceae.

2. 2. Bird surveys

The method used to sample the avifauna specimens was the technique of observations per point-counts [16]. The location of the points used for this census was randomly chosen and was representative of the whole area: for each sample, the point was sorted independently among previously determined points covering the whole area. The points were marked at least 200 meters apart to avoid over-representation of species with long-range voices [17].

The observations were realized in the first hours after dawn and during the twilight. The samplings were accomplished in 36 days during all four seasons the years 2006 to 2010 (in a total of 180 hours distributed in 540 samples). The duration of each point census is 20 minutes [18]. The birds' identification was visual and mainly through bird vocalization. The birds that overflew the areas without perching on the tree were not analyzed, because their dependence on the places was unlikely. Therefore, did not record raptors, hirundines, or vultures flying overhead, nor those species associated with the nearby aquatic habitats.

To determine if the samples were enough were plotted the accumulated number of species against the total number of hours of observation. Since the curves reached a plateau, it was possible to conclude that the samples were enough for the registration of most species existent at each site.

The forests were divided into strata: the understory (ground to 2.0 m), under canopy (from 4.0 m to below the canopy), and canopy (the top layer of vegetation and any emergent crowns). The bird species were recorded and the stratum position, and based on specific literature [19-21], these species were later categorized as inhabiting one of the three strata.

This study was limited to tracing the similar relationships of feeding habitats and preferred foraging strata in the vegetation for the different trophic guilds. These birds species are classified according to principal food items consumed [22]. The guilds obtained for birds were grouped into six broader groups based on diet, as follows:

Carnivores: birds of prey, such as hawks and owls, that feed on a wide variety of vertebrates (birds, mammals, reptiles) that they capture in the dark understory, and species active mainly at night as owls that hunt several species of vertebrates. Frugivores: birds foraging on fruits mainly in the upper parts of trees, such as parrots, macaws, and parakeets; and forest birds, from medium to large sizes that forage on the ground and in the lower parts of trees or shrubs, such as cracids. Granivores: these birds usually glean seeds on the ground and shrubs and rarely forage in trees. In the first category, the seed dispersers, such as pigeons and doves, and in the second category, the seed predators, have large bills specially adapted to open the hard seeds of graminoids.

Insectivores: birds feeding on insects and caterpillars mostly under the canopies of trees; also includes woodpecker species that feed on caterpillars and insects caught on the internal side of tree bark, thanks to their capacity for perforating hard tree timber, and the woodcreepers, that have feet are syndactyl, used to explore vertical perches, and their tails are provided with

stiff ”thorns” formed by elongation of their rectrices rachis, which are used to support their body’s weight on tree trunks when climbing, in the same manner as the woodpeckers, however, unlike them, woodcreepers possess a delicate bill, which does not serve to excavate wood, but only to capture arthropods in the bark cavities; and are also part of this group the understory insectivores, that feed on insects caught on the foliage, foraging from the lower to middle parts of trees, and some known for following army ants and feeding off insects flushed out by the vast ant legion in the understory.

Nectarivores: species whose main food item is nectar from flowers, and they complement their diet by capturing small insects and spiders, such as hummingbirds. Omnivores: this group included species that cannot be differentiated by any type of food because they feed on a wide variety of foods (insects, vertebrates, seeds, fruits, parts of plants), yet they can be distinguished by their foraging habits such as canopy omnivores, whose food is obtained from the canopy of trees, like toucans and some flycatchers; under canopy omnivores, like the thrushes, and the tanagers; and the understory omnivores, like tinamous, terrestrial birds which have gallinaceous features, live in the countryside or semi-open areas, but the majority of them have forest habits, roaming timidly throughout the understory of forests.

3. RESULTS AND DISCUSSION

Considering the different natural environments studied, it was possible to register a total of 120 species of birds in forest habitats, distributed in 28 families and 13 orders (Table 1). Equitability was high, an average of 0.90, suggesting the number of species registered in n the study sites represented the maximum capacity the areas can shelter.

A total of 29 bird species was recorded in the forest fragments in the initial stage of ecological succession, and this site was characterized by low diversity. Bird richness and abundance did not differ between the remnants. The Shannon-Weaver diversity index H’ presented a value of 3.06. In this anthropic environment, under canopy omnivores with ten species were the most representative guild. Most of these species are also common on the edges of forest fragments in Atlantic Forest [23-26]. Understory species had little importance, because the understory is inexpressive, and this shows that habitat degradation within fragments may be an important determinant of the ability of individual species to persist in them, and it is clearly important to separate the effects of habitat alteration essentially from those of patch size and isolation [27]. Small fragments are under an intense influence of edge effects that change microclimate conditions and affect the plant community, especially in the early stages of regeneration [28]. Among the species registered, only five are understory insectivores. It is a group very affected by forest fragmentation. The decline in abundance of species less suited to anthropogenic disturbance, like frugivores and insectivores understory birds is a hallmark in fragmented areas [29, 30]. Forest understory birds depend on forest structures. Fragmentation and the consequent increase in edge areas do influence the movement behavior of sensitive forest understory birds [31].

In the forest fragments in the medium stage of ecological succession were registered a total of 75 species of birds and the Shannon-Weaver diversity index H’ presented a value of 3.88. Bird richness and abundance did not differ between the remnants of this stage of succession. According to results, under canopy omnivores and understory insectivores, were the most representative guilds respectively with 28 and 14 species. The great abundance of

omnivores birds may be directly related to the abundant fruit resources. These results suggest the sensitivities of bird species to vegetation are associated with their dependence on a fruit diet [32].

In the forest fragment in the advanced stage of ecological succession was registered a total of 107 species of birds and the Shannon-Weaver diversity index H' presented a high value of 4.21, suggesting high equitability. This fact was already expected since it is common in mature forests with great vertical heterogeneity [33, 34]. According to the results, is observed that the number of species of birds registered on this site in comparison with species registered in the forest fragments in the medium stage of ecological succession, there was an increase of more than 100% in the number of canopy species and about 50% in the number of under canopy and understory species. The increase in the number of forest species of birds, from forest fragments in initial stages to the forest fragments in more advanced stages is the result of the better vegetation structure in the more advanced stages. This fact is because the forest fragments in more advanced stages are the most important centers of colonization of forest species [35].

Omnivores and insectivores birds represented the most species-rich trophic guilds (Table 2). The insectivores had several species and their abundances decreased from the understory to the canopy. The highest diversity of frugivores and omnivores birds was related to higher vertical strata, in the canopy and under canopy, in the more advanced stages of ecological succession. Carnivores and insectivores birds did not show any pattern of diversity along the vertical gradient. Further, insectivores preferred strata with thick vegetation, present in the forest fragment in an advanced stage of ecological succession. Among the 12 species of hummingbirds observed visiting the flowers, two of these species were registered in the forest fragments in the initial stages, however, five species of hummingbirds were only observed in the forest fragments in a more advanced stage of ecological succession. This fact also happened for the guilds understory insectivores, understory frugivores, under canopy omnivores, under canopy insectivores, and also the canopy guilds. The significant presence of these guilds is a reason for the vertical structure of these forest fragments in medium and advanced stages of ecological succession, with three strata of the vegetation: herbaceous stratum, understorey, and canopy stratum [36, 37].

The species diversity is related not only to the structure of the forest but also to the size of the forest fragment and degree of isolation. The communities of understorey birds are very dependent on forest environments and rarely move between fragmented areas [27]. Many understory species are dispersal limited and are incapable of crossing open areas, rivers, even small gaps in forest cover [38-40]. Understory insectivores prefer environments with vine tangles and bamboos, and it forages moving actively through the forest understory [41] and along edges in fragmented landscapes [42]. The antbirds' territories, like Thamnophilus caerulescens and Dysithamnus mentalis, may be restricted to less than two hectares [43], and the spatial distribution of these insectivores birds may have related to the availability of arthropods [44, 45]. Foliage density is one of the main factors associated with the distribution of birds along the vertical forest gradient [46, 47], and is probably linked to food resource availability, but vegetation density may not apply to all particular food resources [48].

The forest canopy has a complex structure. The upper tree canopy produces extremely diverse communities, such as vascular epiphytes and arthropods, that contribute to the diversity of birds because they add to the total amounts of resources, provide opportunities for resource specialization, and temporally spread available resources in the canopy throughout the year [49, 50]. Furthermore, canopy birds seem to be more easily adaptable to conditions in secondary

habitats than understory species, since many canopy species can move across open areas, and so for these species, landscapes may remain functionally connected even if fragmented [51-55].

Table 1. List of the bird species in different natural environments grouped into trophic guilds.

GUILDS/Family/Taxon names	English name	Environments		
		Initial stage	Medium stage	Advanced stage
CANOPY CARNIVORES				
Accipitridae				
Harpagus diodon (Temminck, 1823)	Rufous-thighed Kite			X
Accipiter striatus (Vieillot, 1808)	Sharp-shinned Hawk		X	X
Buteo brachyurus (Vieillot, 1816)	Short-tailed Hawk	X	X	X
Tytonidae				
Tyto furcata (Temminck, 1827)	American Barn Owl			X
Strigidae				
Megascops choliba (Vieillot, 1817)	Tropical Screech-Owl			X
Asio clamator (Vieillot, 1808)	Striped Owl			X
CANOPY FRUGIVORES				
Cracidae				
Penelope obscura (Temminck, 1815)	Dusky-legged Guan		X	X
Psittacidae				
Brotogeris tirica (Gmelin, 1788)	Plain Parakeet		X	X
Brotogeris chiriri (Vieillot, 1818)	Yellow-chevroned Parakeet		X	X
Pionopsitta pileata (Scopoli, 1769)	Pileated Parrot			X
Pionus maximiliani (Kuhl, 1820)	Scaly-headed Parrot			X
Amazona aestiva (Linnaeus, 1758)	Turquoise-fronted Parrot			X

Forpus xanthopterygius (Spix, 1824)	Blue-winged Parrotlet	X	X	X
Pyrrhura frontalis (Vieillot, 1817)	Maroon-bellied Parakeet			X
Diopsittaca nobilis (Linnaeus, 1758)	Red-shouldered Macaw			X
Psittacara leucophthalmus (Statius Muller, 1776)	White-eyed Parakeet	X	X	X
CANOPY OMNIVORES				
Ramphastidae				
Ramphastos toco (Statius Muller, 1776)	Toco Toucan		X	X
Ramphastos vitellinus (Lichtenstein, 1823)	Channel-billed Toucan			X
Ramphastos dicolorus (Linnaeus, 1766)	Red-breasted Toucan			X
Tityridae				
Pachyramphus polychopterus (Vieillot, 1818)	White-winged Becard			X
Tyrannidae				
Pitangus sulphuratus (Linnaeus, 1766)	Great Kiskadee	X	X	X
Megarynchus pitangua (Linnaeus, 1766)	Boat-billed Flycatcher		X	X
UNDER CANOPY INSECTIVORES				
Cuculidae				
Tapera naevia (Linnaeus, 1766)	Striped Cuckoo			X
Piaya cayana (Linnaeus, 1766)	Squirrel Cuckoo		X	X
Bucconidae				
Malacoptila striata (Spix, 1824)	White-chested Puffbird			X
Tyrannidae				
Serpophaga subcristata (Vieillot, 1817)	White-crested Tyrannulet		X	X
Satrapa icterophrys (Vieillot, 1818)	Yellow-browed Tyrant			X
Picidae				
Picumnus cirratus(Temminck, 1825)	White-barred Piculet	X	X	X

Campephilus robustus (Lichtenstein, 1818)	Robust Woodpecker		X	X
Dryocopus lineatus (Linnaeus, 1766)	Lineated Woodpecker			X
Dendrocolaptidae				
Sittasomus griseicapillus (Vieillot, 1818)	Olivaceous Woodcreeper		X	X
Lepidocolaptes angustirostris (Vieillot, 1818)	Narrow-billed Woodcreeper			X
UNDER CANOPY OMNIVORES				
Picidae				
Melanerpes flavifrons (Vieillot, 1818)	Yellow-fronted Woodpecker		X	X
Veniliornis spilogaster (Wagler, 1827)	White-spotted Woodpecker			X
Celeus flavescens (Gmelin, 1788)	Blond-crested Woodpecker		X	X
Tyrannidae				
Camptostoma obsoletum (Temminck, 1824)	Southern Beardless-Tyrannulet		X	X
Elaenia flavogaster (Thunberg, 1822)	Yellow-bellied Elaenia	X	X	X
Elaenia parvirostris (Pelzeln, 1868)	Small-billed Elaenia		X	
Elaenia mesoleuca (Deppe, 1830)	Olivaceous Elaenia			X
Myiarchus swainsoni (Cabanis & Heine, 1859)	Swainson's Flycatcher		X	X
Myiarchus ferox (Gmelin, 1789)	Short-crested Flycatcher		X	X
Myiodynastes maculatus (Statius Muller, 1776)	Streaked Flycatcher	X	X	X
Myiozetetes similis (Spix, 1825)	Social Flycatcher	X	X	X
Tyrannus melancholicus (Vieillot, 1819)	Tropical Kingbird	X	X	X
Tyrannus savana (Vieillot, 1808)	Fork-tailed Flycatcher		X	X
Empidonomus varius (Vieillot, 1818)	Variegated Flycatcher	X	X	X
Vireonidae				
Cyclarhis gujanensis (Gmelin, 1789)	Rufous-browed Peppershrike	X	X	X
Vireo olivaceus (Linnaeus, 1766)	Red-eyed Vireo		X	X

Vireo chivi (Vieillot, 1817)	Chivi Vireo			X
Turdidae				
Turdus leucomelas (Vieillot, 1818)	Pale-breasted Thrush		X	X
Turdus rufiventris (Vieillot, 1818)	Rufous-bellied Thrush	X	X	X
Turdus amaurochalinus (Cabanis, 1851)	Creamy-bellied Thrush		X	X
Fringillidae				
Euphonia chlorotica (Linnaeus, 1766)	Purple-throated Euphonia		X	X
Euphonia violacea (Linnaeus, 1758)	Violaceous Euphonia		X	X
Cardinalidae				
Piranga flava (Vieillot, 1822)	Hepatic Tanager		X	
Thraupidae				
Nemosia pileata (Boddaert, 1783)	Hooded Tanager		X	X
Tersina viridis (Illiger, 1811)	Swallow Tanager			X
Dacnis cayana (Linnaeus, 1766)	Blue Dacnis	X	X	X
Saltator similis (d'Orbigny & Lafresnaye, 1837)	Green-winged Saltator			X
Trichothraupis melanops (Vieillot, 1818)	Black-goggled Tanager		X	X
Tachyphonus coronatus (Vieillot, 1822)	Ruby-crowned Tanager		X	X
Thlypopsis sordida (d'Orbigny & Lafresnaye, 1837)	Orange-headed Tanager			X
Conirostrum speciosum (Temminck, 1824)	Chestnut-vented Conebill	X	X	X
Pipraeidea melanonota (Vieillot, 1819)	Fawn-breasted Tanager			X
Thraupis sayaca (Linnaeus, 1766)	Sayaca Tanager	X	X	X
Thraupis palmarum (Wied, 1821)	Palm Tanager		X	X
Stilpnia cayana (Linnaeus, 1766)	Burnished-buff Tanager		X	X
UNDERSTORY FRUGIVORES				
Tinamidae				
Crypturellus tataupa (Temminck, 1815)	Tataupa Tinamou			X

Columbidae				
Patagioenas cayennensis (Bonnaterre, 1792)	Pale-vented Pigeon		X	X
Leptotila verreauxi (Bonaparte, 1855)	White-tipped Dove		X	X
Leptotila rufaxilla (Richard & Bernard, 1792)	Gray-fronted Dove		X	X
Rhynchocyclidae				
Mionectes rufiventris (Cabanis, 1846)	Gray-hooded Flycatcher		X	
Tyrannidae				
Lathrotriccus euleri (Cabanis, 1868)	Euler's Flycatcher	X	X	X
Turdidae				
Turdus flavipes (Vieillot, 1818)	Yellow-legged Thrush		X	X
Turdus albicollis (Vieillot, 1818)	White-necked Thrush			X
Thraupidae				
Thlypopsis sordida (d'Orbigny & Lafresnaye, 1837)	Orange-headed Tanager			X
UNDERSTORY GRANIVORES				
Columbidae				
Columbina talpacoti (Temminck, 1811)	Ruddy Ground-Dove	X	X	X
Columbina squammata (Lesson, 1831)	Scaled Dove	X	X	
Thraupidae				
Coryphospingus cucullatus (Statius Muller, 1776)	Red-crested Finch	X	X	
Sporophila caerulescens (Vieillot, 1823)	Double-collared Seedeater	X		
Sicalis flaveola (Linnaeus, 1766)	Saffron Finch	X		
UNDERSTORY INSECTIVORES				
Nyctibiidae				
Nyctibius griseus (Gmelin, 1789)	Common Potoo			X

Thamnophilidae				
Dysithamnus mentalis (Temminck, 1823)	Plain Antvireo		X	X
Thamnophilus ruficapillus (Vieillot, 1816)	Rufous-capped Antshrike	X	X	X
Thamnophilus caerulescens (Vieillot, 1816)	Variable Antshrike	X	X	X
Mackenziaena severa (Lichtenstein, 1823)	Tufted Antshrike			X
Pyriglena leuconota (Spix, 1824)	White-backed Fire-eye			X
Drymophila ferruginea (Temminck, 1822)	Ferruginous Antbird			X
Drymophila malura (Temminck, 1825)	Dusky-tailed Antbird	X	X	X
Conopophagidae				
Conopophaga lineata (Wied, 1831)	Rufous Gnateater		X	X
Furnariidae				
Lochmias nematura (Lichtenstein, 1823)	Sharp-tailed Streamcreeper			X
Syndactyla rufosuperciliata (Lafresnaye, 1832)	Buff-browed Foliage-gleaner			X
Certhiaxis cinnamomeus (Gmelin, 1788)	Yellow-chinned Spinetail			X
Synallaxis ruficapilla (Vieillot, 1819)	Rufous-capped Spinetail		X	X
Synallaxis spixi (Sclater,1856)	Spix's Spinetail	X	X	X
Rhynchocyclidae				
Tolmomyias sulphurescens (Spix, 1825)	Yellow-olive Flycatcher		X	X
Todirostrum cinereum (Linnaeus, 1766)	Common Tody-Flycatcher		X	X
Tyrannidae				
Phyllomyias fasciatus (Thunberg, 1822)	Planalto Tyrannulet		X	X
Myiophobus fasciatus (Statius Müller, 1776)	Bran-colored Flycatcher		X	
Troglodytidae				
Troglodytes musculus (Vieillot, 1808)	Southern House Wren	X	X	

Parulidae				
Geothlypis aequinoctialis (Gmelin, 1789)	Masked Yellowthroat			X
Setophaga pitiayumi (Vieillot, 1817)	Tropical Parula		X	X
Myiothlypis leucoblephara (Vieillot, 1817)	White-browed Warbler			X
Basileuterus culicivorus (Deppe, 1830)	Golden-crowned Warbler		X	
UNDERSTORY NECTARIVORES				
Trochilidae				
Florisuga fusca (Vieillot, 1817)	Black Jacobin			X
Phaethornis pretrei (Lesson & Delattre, 1839)	Planalto Hermit		X	X
Phaethornis eurynome (Lesson, 1832)	Scale-throated Hermit			X
Colibri serrirostris (Vieillot, 1816)	White-vented Violetear			X
Chlorostilbon lucidus (Shaw, 1812)	Glittering-bellied Emerald		X	
Thalurania glaucopis (Gmelin, 1788)	Violet-capped Woodnymph			X
Eupetomena macroura (Gmelin, 1788)	Swallow-tailed Hummingbird	X	X	X
Aphantochroa cirrochloris (Vieillot, 1818)	Sombre Hummingbird		X	
Leucochloris albicollis (Vieillot, 1818)	White-throated Hummingbird	X	X	X
Chrysuronia versicolor (Vieillot, 1818)	Versicolored Emerald		X	X
Chionomesa fimbriata (Gmelin, 1788)	Glittering-throated Emerald		X	X
Chionomesa lactea (Lesson, 1832)	Sapphire-spangled Emerald			X
Thraupidae				
Coereba flaveola (Linnaeus, 1758)	Bananaquit	X	X	X
UNDERSTORY OMNIVORES				
Tinamidae				
Crypturellus parvirostris (Wagler, 1827)	Small-billed Tinamou		X	X
Trogonidae				
Trogon surrucura (Vieillot, 1817)	Surucua Trogon			X

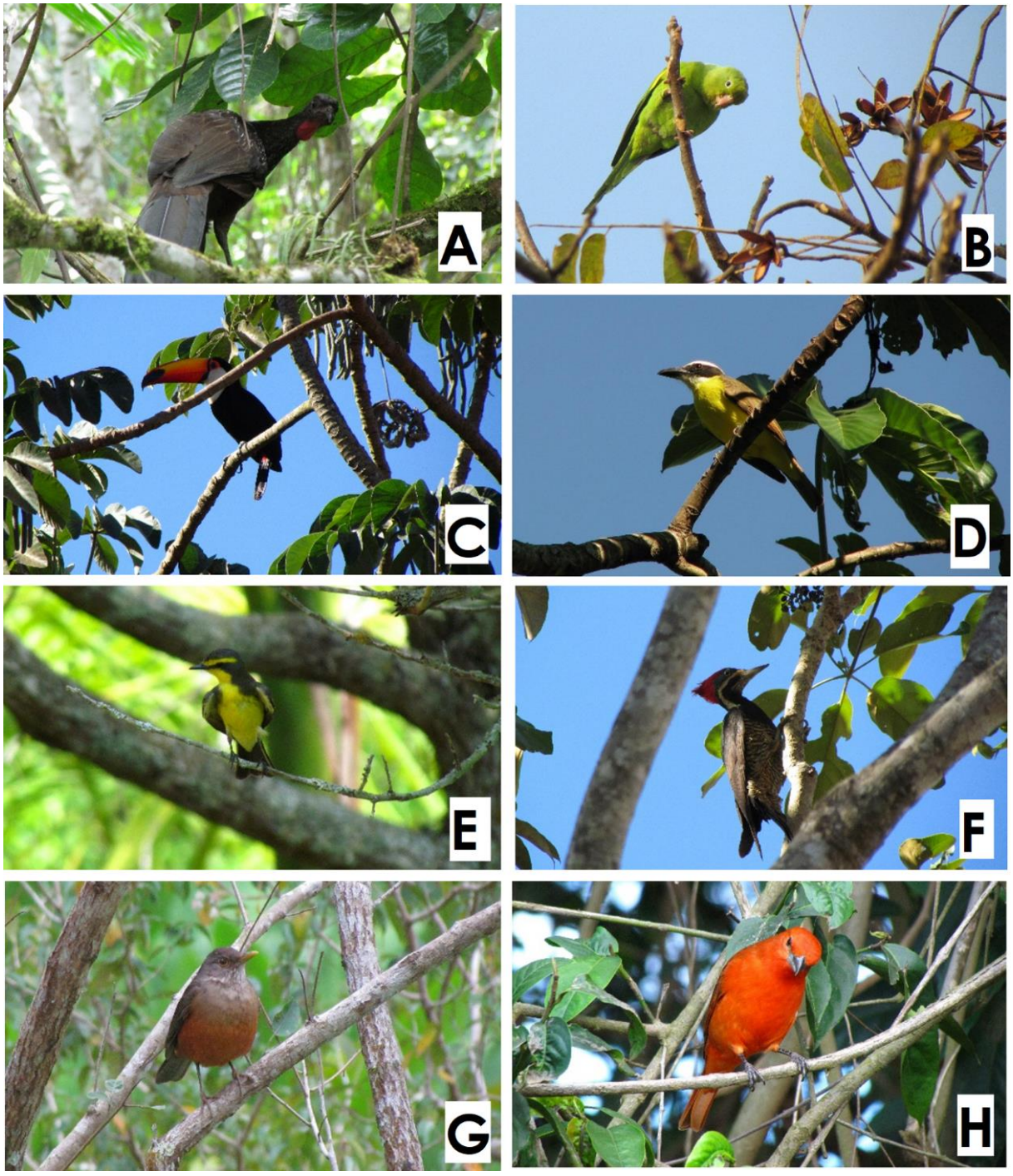

Figure 2. Examples of birds registered in this study: (A) canopy frugivore *Penelope obscura* (Dusky-legged Guan), (B) canopy frugivore *Brotogeris tirica* (Plain Parakeet), (C) canopy omnivore *Ramphastos toco* (Toco Toucan), (D) canopy omnivore *Pitangus sulphuratus* (Great Kiskadee), (E) under canopy insectivore *Satrapa icterophrys* (Yellow-browed Tyrant), (F) under canopy insectivore *Dryocopus lineatus* (Lineated Woodpecker ♀), (G) under canopy omnivore *Turdus rufiventris* (Rufous-bellied Thrush), (H) under canopy omnivore *Piranga flava* (Hepatic Tanager). Photos by Fabio Rossano Dario.

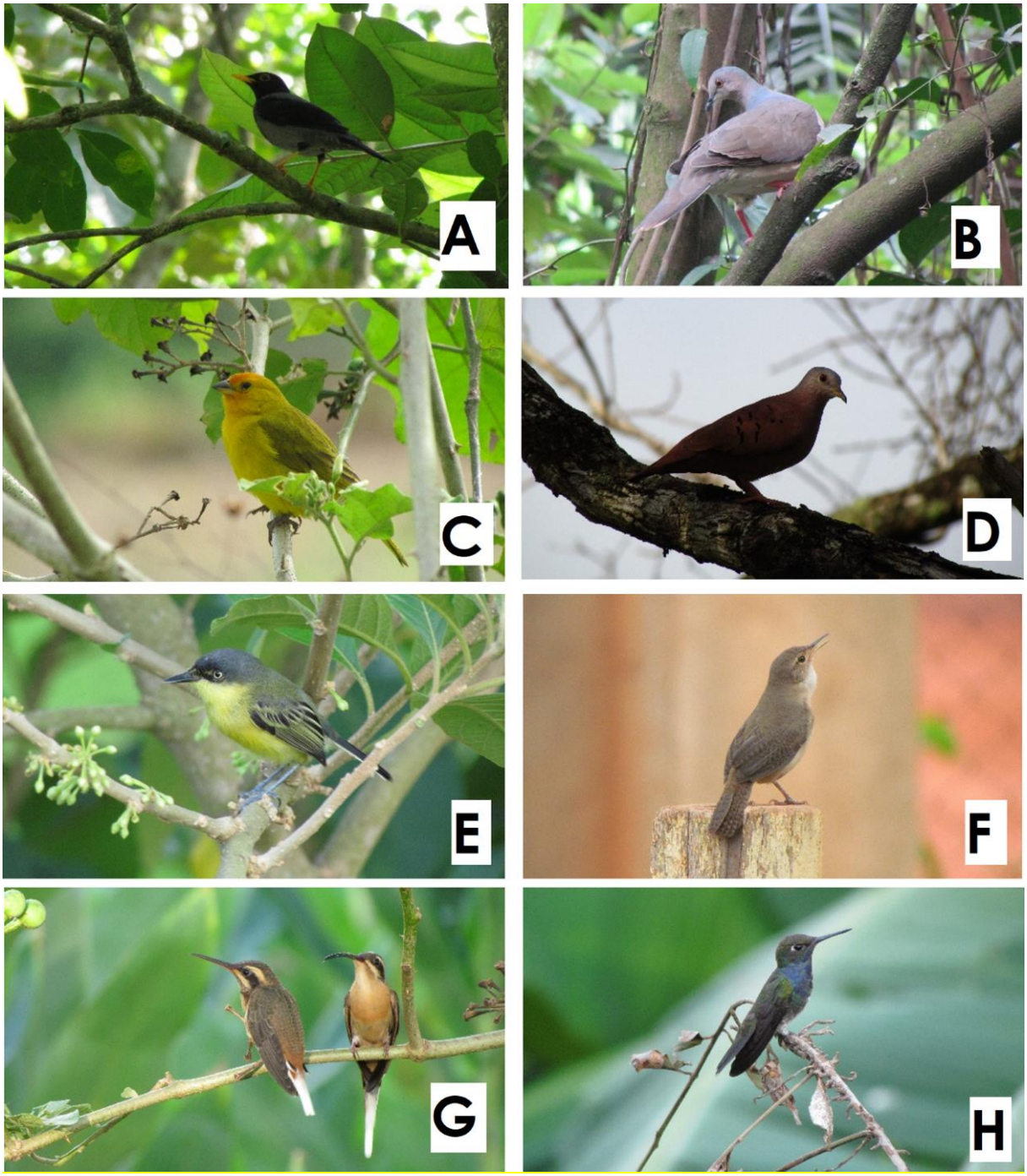

Figure 3. Examples of birds registered in this study: (A) understory frugivore *Turdus flavipes* (Yellow-legged Thrush ♂), (B) understory frugivore *Leptotila verreauxi* (White-tipped Dove), (C) understory granivore *Sicalis flaveola* (Saffron Finch ♂), (D) understory granivore *Columbina talpacoti* (Ruddy Ground-Dove), (E) understory insectivore *Todirostrum cinereum* (Common Tody-Flycatcher), (F) understory insectivore *Troglodytes musculus* (Southern House Wren), (G) understory nectarivore *Phaethornis pretrei* (Planalto Hermit), (H) understory nectarivore *Chionomesa lactea* (Sapphire-spangled Emerald). Photos by Fabio Rossano Dario.

Table 2. Number of bird species in different guilds and different natural environments.

Guilds	Number of species	Environments/Number of species		
		Initial stage	Medium stage	Advanced stage
Canopy carnivores	6	1	2	6
Canopy frugivores	10	2	5	10
Canopy omnivores	6	1	3	6
Total Canopy	22	4	10	22
Under canopy insectivores	10	1	5	10
Under canopy omnivores	36	10	28	33
Total Under Canopy	46	11	33	43
Understory frugivores	9	1	6	8
Understory granivores	5	5	3	1
Understory insectivores	23	5	14	20
Understory nectarivores	13	3	8	11
Understory omnivores	2	0	1	2
Total Understory	52	14	32	42
Total	120	29	75	107

4. CONCLUSION

The size of the forest areas and the vegetation structure reflected in the diversity of bird species, and in the number of trophic guilds. Forest understory birds depend on forest structures, and they are the most affected by forest fragmentation, with a decline in abundance of species less suited to anthropogenic disturbance, like frugivores and insectivores understory birds.

In the forest fragments in the advanced stage of ecological succession, there is great vertical heterogeneity, and the bird communities are better structured. This fact reinforces the claim that the forest fragments in more advanced stages are the most important centers of colonization of forest birds' species.

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