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Diversity and trophic structure of bird's communities from a Restinga forest in Brazil

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ABSTRACT

The forests along Brazil's Atlantic coast have undergone extensive transformation from clearing for pastures, eucalyptus forests, agricultural crops, and urban expansion. In this study we described the avian community in a coastal Restinga Forest near the city of Ubatuba, in the São Paulo State, Brazil. The method used to sample the avifauna specimens was the technique of observations per point-counts, and random observations were also carried. The bird's observations were realized in 84 days during all four seasons out between the years 2005 and 2007 and were registered 142 bird species distributed among 18 orders and 41 families and categorized in 17 trophic guilds. The omnivores and insectivores birds composed most of the community, occupying the edge and different strata of the forest such as canopy and understory. The great abundance of omnivores birds may be directly related to the abundant fruit resources, and also with the great abundance of understory insectivores are indication of the good environmental quality of the studied area.

Keywords: Atlantic forest, avifauna, bird, Brazil, ecology, Restinga, trophic guild

1. INTRODUCTION

The Atlantic Forest is one of the most important biodiversity hotspots; originally covering over 1.3 million km², distributed along the Brazilian coastal, and is the most threatened

Brazilian biome. This important biome harbors a high diversity of bird species, with several endemic and threatened species [1].

The Brazilian Atlantic Forest *sensu lato* is classified as an area that comprises three types of forests: Ombrophylous Dense forests, Semideciduous and Deciduous Stationary forests from the South and Southern regions, and Ombrophylous Mist forest, also known as *Araucaria* forest from Southern Brazil [2, 3].

Other ecosystems present in the Atlantic Forest are the mangrove and the restinga. Restinga is a coastal ecosystem which form on sandy, acidic, and nutrient-poor soils, and is characterized by medium sized trees and shrubs adapted to the dry and nutrient-poor conditions found there [4, 5].

Restingas occur along approximately 70% of the Brazilian coastline [6], which exceeds 8,000 km in length [7]. However, distribution of restinga areas is not continuous, and consist of three well-defined forest enclaves distributed from northeastern to southeastern Brazil [8]. Restinga forests vary from shrub vegetation to 15 meters tall forests, which are distributed over soil mosaics and gradients from the coastal zone inland [9, 10].

The arboreal restinga occurs between the “*nhundú*” and the Atlantic coastal forest, and it can reach the Atlantic Slope in places where the coastal plain is overly narrow, as it happens in Ubatuba, in the State of São Paulo. This kind of Restinga is formed from soggy soils, with sparse trees varying in average height between 10 and 15 meters. The thick understory is overgrown by bushes and trees covered with various epiphytes [11, 12].

During the last 500 years, the Atlantic Forest has been exploited and destroyed. Its forests were suppressed and replaced by areas of pastures, eucalyptus forests and agricultural crops. The forests were also replaced by cities, being the homeland of about 125 million Brazilians, since all state capitals from the S, SE, and NE region, including Porto Alegre, São Paulo, Rio de Janeiro, Salvador, and Recife, are within the Atlantic Forest domain. Therefore, there is only 7.6% of the original Atlantic Forest left, and less than 50% of the remnants are protected in conservation Units, according to INPE, the National Institute for Space Research, a research unit of the Brazilian Ministry of Science, Technology and Innovation [13].

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 [14]. This avifauna is a highly endangered community: 68 % of the species are rare and there are 23 endemic genera [15].

The biological diversity of tropical forests is seriously threatened by rapid and continuous deforestation. Expanding human populations and attendant land-use changes are the primary factors driving changes in biological diversity [16, 17]. The future scenario of species extinctions appears to hold dramatic changes for the bird communities in the smaller remnants [18]. Due to the paucity of information regarding avian abundance estimates in Restinga, the main objective of our study was to characterize the groups of birds that occurs in this important ecosystem [53-55].

2. MATERIALS AND METHODS

The studies were carried out in remnant of Restinga in the Brazilian Atlantic Forest, situated in the Felix beach, municipality of Ubatuba, in the São Paulo State, Southeastern Brazil. It lies in latitude 23°23'S and longitude 44°58'W (Figure 1), between 8 and 15 meters of altitude.

The climate of the region is the Cfa type according to Köppen's classification, humid subtropical climate with hot and humid summers, and cold to mild winters. The annual average rainfall is over 2,200 mm, concentrated in the spring and summer. The annual medium temperature is 21.9 °C (71.42 °F).

Vegetation structure is dominated by arboreal Restinga, a transition between coastal scrub and coastal forest. The overstory is characterized by crowns of large-sized trees varying in average height between 8 and 12 meters, mean trunk diameter is 12 centimeters. Important species recorded included: *Alchornea triplinervia*, *Cytherexylum myrianthum*, *Inga laurina*, *Ocotea pulchella*, *Ficus organensis*, *Cabralea canjerana*, *Calophyllum brasiliensis*, *Hirtella hebeclada*, *Rollinia silvatica*, *Campomanesia xanthocarpa*, *Casearia sylvestris*, *Guatteria australis*, *Guapira opposita*, *Rapanea ferruginea*, *Cupania vernalis*, *Zanthoxylum rhoifolium*, *Tibouchina mutabilis*, *Nectandra rigida*, *Cecropia pachystachya*, *Tapirira guianensis*, and small patches of Jussara palm (*Euterpe edulis*). Most of these trees produced fruit used by local wildlife [19-23].

Understorey vegetation is characterized by shrubs (0.80 to 5 meters tall) and dominated by *Eugenia uniflora*, *Trema micrantha*, and *Schinus terebinthifolius*. Saplings of trees in the families Melastomataceae, Euphorbiaceae, Rubiaceae, Fabaceae, and Myrtaceae are common. Trees shelter a high number of epiphytes including bromeliads (*Quesnelia arvensis*), orchids (*Epidendrum* spp), aroids (*Monstera adansonii*), cacti (*Rhipsalis* spp), mosses, lichens and vines. The vegetal community is part of a forest subjected to human interference [24]. It forms in some places riparian forests of streams and swamps. Marsh vegetation appear on poorly drained soils and is dominated by aquatic macrophytes like *Hedychium coronarium* and *Typha domingensis*. These areas periodically flooded, providing habitat for a large variety of wading birds [25, 26].

The method used to sample the avifauna specimens was the technique of observations per point-counts [27]. 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 [28]. Random observations were also carried and consist of non-systematic observations, with the aim of increasing the number of species recorded.

The bird's observations were realized mainly in the first hours after the dawn and during the twilight. The observations were carried in 84 days during all four seasons out between the years 2005 and 2007. Bird species were identified by vocal recognition and by observations with binoculars. The birds that overflying the areas without to perch on a tree were not analyzed, because their dependence on the places was unlikely.

Species were identified based on the specialized literature. To the scientific nomenclature and taxonomic order was used the new systematic list of CBRO [29]. The vocalizations recorded in the field were compared with the sound files available on specialized site (<http://www.wikiaves.com.br>). This study was limited to trace the similar relationships of feeding habitats and preferred foraging strata in the vegetation for the trophic guilds in different environments: open areas, forest canopy, forest edge, riparian woodland, forest understory, swamps, and pond margins.

These birds species are classified according to principal food items consumed: insectivores (arthropods), frugivores (fruits), omnivores (arthropods, fruits, and small vertebrates), granivores (seeds), nectarivores (nectar), carnivores (vertebrates captured alive), and detritivores (dead vertebrates) [30].



Figure 1. Localization of the studied area, situated in the Felix beach, municipality of Ubatuba, São Paulo State, Brazil.

3. RESULTS AND DISCUSSION

A total of 142 bird species were recorded in our study (Table 1). Bird species detected were distributed among 18 orders and 41 families and categorized into seven alimentary diet and 17 trophic guilds (Figure 2). The most representative order was Passeriformes with 86 species which accounted for 60.5% of all species recorded.

Omnivores included 62 species occupying the edge and different strata of the forest such as canopy and understory. 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 [31].

Insectivores were represented by 43 species also as large distribution on the edge and inside the forest. Among the 13 species of hummingbirds observed visiting flowers, *Phaethornis eurynome*, *Phaethornis pretrei* and *Amazilia fimbriata* were most common. The avian community in our study was similar to other Atlantic Forest and specifically in restinga areas studied [32-37] with a predominance of omnivores and insectivores species.

The most abundant species were *Tangara seledon*, *Tangara cyanocephala*, *Tangara palmarum*, *Ramphocelus bresilius*, and *Tangara sayaca*, all omnivorous species. *Tangara seledon* is an abundant species found along Atlantic Rainforest slopes. It lives in large monospecific groups in association with other species in the genus *Tangara*, especially *T. cyanocephala*, and other tanager species in the genera *Tachyphonus*, *Dacnis* and *Euphonia*.

Among the least abundant species in the study area were small frugivores. Despite the reduced abundance of frugivores such as *Penelope obscura*, and understory species such as *Formicarius colma*, *Attila rufus* and some antshrike species (family *Thamnophilidae* like *Dysithamnus stictothorax* and *Myrmoderus squamosus*) the study area represented relatively well conserved, albeit secondary forest. Other signs of adequate habitat conditions included the occurrence of mixed-species flocks [38] and army-ant swarm following birds (e.g., *Pyriglena*

leucoptera). However, many of the species registered in our study were edge species (e.g., *Pitangus sulphuratus*, *Tyrannus melancholicus*, *Tangara sayaca*, *Zonotrichia capensis*, *Sporophila caerulea*, and *Turdus rufiventris*).

Table 1. List of the bird species registered in this study and presented in the taxonomic order by Brazilian Ornithological Records Committee [22] with English names, Trophic Guilds (TG): carnivores (C), detritivores (D), frugivores (F), granivores (G), insectivores (I), nectarivores (N), omnivores (O); Environments (En): forest canopy (C), forest edge (E), open areas (O), riparian woodland (R), swamps and pond margins (S), forest understory (U).

ORDER Family Taxon names	English names	TG	En
ANSERIFORMES (Linnaeus, 1758)			
Anatidae (Leach, 1820)			
<i>Amazonetta brasiliensis</i> (Gmelin, 1789)	Brazilian Teal	O	S
GALLIFORMES (Linnaeus, 1758)			
Cracidae (Rafinesque, 1815)			
<i>Penelope obscura</i> (Temminck, 1815)	Dusky-legged Guan	F	U
PELECANIFORMES (Sharpe, 1891)			
Ardeidae (Leach, 1820)			
<i>Tigrisoma lineatum</i> (Boddaert, 1783)	Rufescent Tiger-Heron	C	R
<i>Butorides striata</i> (Linnaeus, 1758)	Striated Heron	C	R
<i>Ardea alba</i> (Linnaeus, 1758)	Great Egret	C	R
<i>Egretta thula</i> (Molina, 1782)	Snowy Egret	C	R
CATHARTIFORMES (Seebohm, 1890)			
Cathartidae (Lafresnaye, 1839)			
<i>Coragyps atratus</i> (Bechstein, 1793)	Black Vulture	D	O
ACCIPITRIFORMES (Bonaparte, 1831)			

Accipitridae (Vigors, 1824)			
<i>Leptodon cayanensis</i> (Latham, 1790)	Gray-headed Kite	C	E
<i>Elanus leucurus</i> (Vieillot, 1818)	White-tailed Kite	C	E
<i>Urubitinga urubitinga</i> (Gmelin, 1788)	Great Black Hawk	C	E
<i>Rupornis magnirostris</i> (Gmelin, 1788)	Roadside Hawk	C	E
<i>Geranoaetus albicaudatus</i> (Vieillot, 1816)	White-tailed Hawk	C	E
<i>Pseudastur polionotus</i> (Kaup, 1847)	Mantled Hawk	C	E
<i>Buteo brachyurus</i> (Vieillot, 1816)	Short-tailed Hawk	C	E
GRUIFORMES (Bonaparte, 1854)			
Rallidae (Rafinesque, 1815)			
<i>Laterallus viridis</i> (Statius Muller, 1776)	Russet-crowned Crane	O	S
<i>Aramides cajaneus</i> (Statius Müller, 1776)	Gray-necked Wood-Rail	O	S
<i>Aramides saracura</i> (Spix, 1825)	Slaty-breasted Wood-Rail	O	S
<i>Pardirallus nigricans</i> (Vieillot, 1819)	Blackish Rail	O	S
CHARADRIIFORMES (Huxley, 1867)			
Laridae (Rafinesque, 1815)			
<i>Larus dominicanus</i> (Lichtenstein, 1823)	Kelp Gull	C	O
COLUMBIFORMES (Latham, 1790)			
Columbidae (Leach, 1820)			
<i>Columbina talpacoti</i> (Temminck, 1811)	Ruddy Ground-Dove	G	O
<i>Claravis pretiosa</i> (Ferrari-Perez, 1886)	Blue Ground-Dove	O	O

<i>Patagioenas picazuro</i> (Temminck, 1813)	Picazuro Pigeon	O	E
<i>Leptotila verreauxi</i> (Bonaparte, 1855)	White-tipped Dove	O	E
CUCULIFORMES (Wagler, 1830)			
Cuculidae (Leach, 1820)			
<i>Piaya cayana</i> (Linnaeus, 1766)	Squirrel Cuckoo	I	C
STRIGIFORMES (Wagler, 1830)			
Tytonidae (Mathews, 1912)			
<i>Tyto furcata</i> (Temminck, 1827)	American Barn Owl	C	E
Strigidae (Leach, 1820)			
<i>Athene cunicularia</i> (Molina, 1782)	Burrowing Owl	I	E
NYCTIBIIFORMES (Yuri et al., 2013)			
Nyctibiidae (Chenu & Des Murs, 1851)			
<i>Nyctibius griseus</i> (Gmelin, 1789)	Common Potoo	I	U
CAPRIMULGIFORMES (Ridgway, 1881)			
Caprimulgidae (Vigors, 1825)			
<i>Nyctidromus albicollis</i> (Gmelin, 1789)	Common Pauraque	I	O
APODIFORMES (Peters, 1940)			
Trochilidae (Vigors, 1825)			
<i>Ramphodon naevius</i> (Dumont, 1818)	Saw-billed Hermit	N	E
<i>Glaucis hirsutus</i> (Gmelin, 1788)	Rufous-breasted Hermit	N	E
<i>Phaethornis squalidus</i> (Temminck, 1822)	Dusky-throated Hermit	N	E
<i>Phaethornis ruber</i> (Linnaeus, 1758)	Reddish Hermit	N	E
<i>Phaethornis pretrei</i> (Lesson & Delattre, 1839)	Planalto Hermit	N	E

<i>Phaethornis eurynome</i> (Lesson, 1832)	Scale-throated Hermit	N	E
<i>Eupetomena macroura</i> (Gmelin, 1788)	Swallow-tailed Hummingbird	N	E
<i>Aphantochroa cirrochloris</i> (Vieillot, 1818)	White-throated Hummingbird	N	E
<i>Florisuga fusca</i> (Vieillot, 1817)	Black Jacobin	N	E
<i>Chlorostilbon lucidus</i> (Shaw, 1812)	Glittering-bellied Emerald	N	E
<i>Thalurania glaucopis</i> (Gmelin, 1788)	Violet-capped Woodnymph	N	E
<i>Amazilia versicolor</i> (Vieillot, 1818)	Versicolored Emerald	N	E
<i>Amazilia fimbriata</i> (Gmelin, 1788)	Glittering-throated Emerald	N	E
CORACIIFORMES (Forbes, 1844)			
Alcedinidae (Rafinesque, 1815)			
<i>Chloroceryle americana</i> (Gmelin, 1788)	Green Kingfisher	C	R
PICIFORMES (Meyer & Wolf, 1810)			
Ramphastidae (Vigors, 1825)			
<i>Ramphastos vitellinus</i> (Lichtenstein, 1823)	Channel-billed Toucan	O	C
<i>Ramphastos dicolorus</i> (Linnaeus, 1766)	Red-breasted Toucan	O	C
Picidae (Leach, 1820)			
<i>Picumnus cirratus</i> (Temminck, 1825)	White-barred Piculet	I	E
<i>Melanerpes flavifrons</i> (Vieillot, 1818)	Yellow-fronted Woodpecker	O	E
<i>Celeus flavescens</i> (Gmelin, 1788)	Blond-crested Woodpecker	I	E
<i>Dryocopus lineatus</i> (Linnaeus, 1766)	Lineated Woodpecker	I	E
<i>Campephilus robustus</i> (Lichtenstein, 1818)	Robust Woodpecker	I	E

FALCONIFORMES (Bonaparte, 1831)			
Falconidae (Leach, 1820)			
<i>Caracara plancus</i> (Miller, 1777)	Southern Caracara	O	E
<i>Milvago chimachima</i> (Vieillot, 1816)	Yellow-headed Caracara	C	E
PSITTACIFORMES (Wagler, 1830)			
Psittacidae (Rafinesque, 1815)			
<i>Pyrrhura frontalis</i> (Vieillot, 1817)	Maroon-bellied Parakeet	F	C
<i>Forpus xanthopterygius</i> (Spix, 1824)	Blue-winged Parrotlet	F	C
<i>Brotogeris tirica</i> (Gmelin, 1788)	Plain Parakeet	F	C
<i>Pionus maximiliani</i> (Kuhl, 1820)	Scaly-headed Parrot	F	C
PASSERIFORMES (Linnaeus, 1758)			
Thamnophilidae (Swainson, 1824)			
<i>Myrmotherula unicolor</i> (Menetries, 1835)	Unicolored Antwren	I	U
<i>Dysithamnus stictothorax</i> (Temminck, 1823)	Spot-breasted Antvireo	I	U
<i>Dysithamnus mentalis</i> (Temminck, 1823)	Plain Antvireo	I	U
<i>Thamnophilus ruficapillus</i> (Vieillot, 1816)	Rufous-capped Antshrike	I	U
<i>Thamnophilus caerulescens</i> (Vieillot, 1816)	Variable Antshrike	I	U
<i>Mackenziaena severa</i> (Lichtenstein, 1823)	Tufted Antshrike	I	U
<i>Myrmoderus squamosus</i> (Pelzeln, 1868)	Squamate Antbird	I	U
<i>Pyriglena leucoptera</i> (Vieillot, 1818)	White-shouldered Fire-eye	I	U

<i>Drymophila malura</i> (Temminck, 1825)	Dusky-tailed Antbird	I	U
<i>Drymophila squamata</i> (Lichtenstein, 1823)	Scaled Antbird	I	U
Conopophagidae (Sclater & Salvin, 1873)			
<i>Conopophaga melanops</i> (Vieillot, 1818)	Black-cheeked Gnateater	I	U
Formicariidae (Gray, 1840)			
<i>Formicarius colma</i> (Boddaert, 1783)	Rufous-capped Anthrush	I	U
Dendrocolaptidae (Gray, 1840)			
<i>Dendrocincla turdina</i> (Lichtenstein, 1820)	Plain-winged Woodcreeper	I	U
<i>Sittasomus griseicapillus</i> (Vieillot, 1818)	Olivaceous Woodcreeper	I	U
<i>Xiphorhynchus fuscus</i> (Vieillot, 1818)	Lesser Woodcreeper	I	U
Xenopidae (Bonaparte, 1854)			
<i>Xenops rutilans</i> (Temminck, 1821)	Streaked Xenops	I	U
Furnariidae (Gray, 1840)			
<i>Philydor atricapillus</i> (Wied, 1821)	Black-capped Foliage-gleaner	I	E
<i>Certhiaxis cinnamomeus</i> (Gmelin, 1788)	Yellow-chinned Spinetail	I	S
Pipridae (Rafinesque, 1815)			
<i>Manacus manacus</i> (Linnaeus, 1766)	White-bearded Manakin	O	U
<i>Chiroxiphia caudata</i> (Shaw & Nodder, 1793)	Swallow-tailed Manakin	O	U
Onychorhynchidae (Tello et al., 2009)			
<i>Myiobius barbatus</i> (Gmelin, 1789)	Whiskered Flycatcher	I	U

Rynchocyclidae (Berlepsch, 1907)			
<i>Leptopogon amaurocephalus</i> (Tschudi, 1846)	Sepia-capped Flycatcher	I	U
<i>Tolmomyias sulphurescens</i> (Spix, 1825)	Yellow-olive Flycatcher	I	U
<i>Todirostrum cinereum</i> (Linnaeus, 1766)	Common Tody-Flycatcher	I	E
Tyrannidae (Vigors, 1825)			
<i>Hemitriccus diops</i> (Temminck, 1822)	Drab-breasted Pygmy-Tyrant	I	U
<i>Camptostoma obsoletum</i> (Temminck, 1824)	Southern Beardless-Tyrannulet	O	E
<i>Elaenia flavogaster</i> (Thunberg, 1822)	Yellow-bellied Elaenia	O	E
<i>Elaenia parvirostris</i> (Pelzeln, 1868)	Small-billed Elaenia	O	E
<i>Serpophaga subcristata</i> (Vieillot, 1817)	White-crested Tyrannulet	I	U
<i>Attila rufus</i> (Vieillot, 1819)	Gray-hooded Attila	O	U
<i>Myiarchus ferox</i> (Gmelin, 1789)	Short-crested Flycatcher	O	E
<i>Pitangus sulphuratus</i> (Linnaeus, 1766)	Great Kiskadee	O	E
<i>Machetornis rixosa</i> (Vieillot, 1819)	Rusty-margined Flycatcher	O	E
<i>Myiodynastes maculatus</i> (Statius Muller, 1776)	Streaked Flycatcher	O	E
<i>Megarhynchus pitangua</i> (Linnaeus, 1766)	Boat-billed Flycatcher	O	E
<i>Myiozetetes similis</i> (Spix, 1825)	Social Flycatcher	O	E
<i>Tyrannus savana</i> (Vieillot, 1808)	Fork-tailed Flycatcher	O	E
<i>Tyrannus melancholicus</i> (Vieillot, 1819)	Tropical Kingbird	O	E
<i>Empidonomus varius</i> (Vieillot, 1818)	Variegated Flycatcher	O	E
<i>Colonia colonus</i> (Vieillot, 1818)	Long-tailed Tyrant	I	E

<i>Myiophobus fasciatus</i> (Statius Müller, 1776)	Bran-colored Flycatcher	O	E
<i>Pyrocephalus rubinus</i> (Boddaert, 1783)	Vermilion Flycatcher	I	E
<i>Fluvicola nengeta</i> (Linnaeus, 1766)	Masked Water-Tyrant	I	S
<i>Lathrotriccus euleri</i> (Cabanis, 1868)	Euler's Flycatcher	I	E
Vireonidae (Swainson, 1837)			
<i>Cyclarhis gujanensis</i> (Gmelin, 1789)	Rufous-browed Peppershrike	O	E
<i>Vireo chivi</i> (Vieillot, 1817)	Chivi Vireo	O	C
Hirundinidae (Rafinesque, 1815)			
<i>Pygochelidon cyanoleuca</i> (Vieillot, 1817)	Blue-and-white Swallow	I	O
<i>Progne chalybea</i> (Gmelin, 1789)	Gray-breasted Martin	I	O
Troglodytidae (Swainson, 1831)			
<i>Troglodytes musculus</i> (Vieillot, 1808)	Southern House Wren	I	E
Donacobiidae (Aleixo & Pacheco, 2006)			
<i>Donacobius atricapilla</i> (Linnaeus, 1766)	Black-capped Donacobius	I	S
Turdidae (Rafinesque, 1815)			
<i>Turdus flavipes</i> (Vieillot, 1818)	Yellow-legged Thrush	O	E
<i>Turdus rufiventris</i> (Vieillot, 1818)	Rufous-bellied Thrush	O	E
<i>Turdus amaurochalinus</i> (Cabanis, 1851)	Creamy-bellied Thrush	O	E
<i>Turdus albicollis</i> (Vieillot, 1818)	White-necked Thrush	O	E
Mimidae (Bonaparte, 1853)			
<i>Mimus saturninus</i> (Lichtenstein, 1823)	Chalk-browed Mockingbird	O	E
Passerellidae (Cabanis & Heine, 1850)			

<i>Zonotrichia capensis</i> (Statius Muller, 1776)	Rufous-collared Sparrow	O	O
Parulidae (Wetmore et al., 1947)			
<i>Setophaga pitayumi</i> (Vieillot, 1817)	Tropical Parula	O	E
<i>Geothlypis aequinoctialis</i> (Gmelin, 1789)	Masked Yellowthroat	I	E
<i>Myiothlypis rivularis</i> (Wied, 1821)	Neotropical River Warbler	I	U
Icteridae (Vigors, 1825)			
<i>Psarocolius decumanus</i> (Pallas, 1769)	Crested Oropendola	O	C
<i>Cacicus haemorrhous</i> (Linnaeus, 1766)	Red-rumped Cacique	O	C
<i>Molothrus bonariensis</i> (Gmelin, 1789)	Shiny Cowbird	O	O
Thraupidae (Cabanis, 1847)			
<i>Pipraeidea melanonota</i> (Vieillot, 1819)	Fawn-breasted Tanager	O	E
<i>Tangara seledon</i> (Statius Muller, 1776)	Green-headed Tanager	O	E
<i>Tangara cyanocephala</i> (Statius Muller, 1776)	Red-necked Tanager	O	E
<i>Tangara sayaca</i> (Linnaeus, 1766)	Sayaca Tanager	O	E
<i>Tangara palmarum</i> (Wied, 1821)	Palm Tanager	O	E
<i>Tangara ornata</i> (Sparman, 1789)	Golden-chevroned Tanager	O	E
<i>Tangara cayana</i> (Linnaeus, 1766)	Burnished-buff Tanager	O	E
<i>Conirostrum speciosum</i> (Temminck, 1824)	Chestnut-vented Conebill	I	E
<i>Sicalis flaveola</i> (Linnaeus, 1766)	Saffron Finch	G	O
<i>Chlorophanes spiza</i> (Linnaeus, 1758)	Green Honeycreeper	O	E
<i>Hemithraupis ruficapilla</i> (Vieillot, 1818)	Rufous-headed Tanager	O	E
<i>Volatinia jacarina</i> (Linnaeus, 1766)	Blue-black Grassquit	G	O

<i>Lanio cristatus</i> (Linnaeus, 1766)	Flame-crested Tanager	O	E
<i>Tachyphonus coronatus</i> (Vieillot, 1822)	Ruby-crowned Tanager	O	E
<i>Ramphocelus bresilius</i> (Linnaeus, 1766)	Brazilian Tanager	O	E
<i>Tersina viridis</i> (Illiger, 1811)	Swallow Tanager	O	E
<i>Dacnis nigripes</i> (Pelzeln, 1856)	Black-legged Dacnis	O	E
<i>Dacnis cayana</i> (Linnaeus, 1766)	Blue Dacnis	O	E
<i>Coereba flaveola</i> (Linnaeus, 1758)	Bananaquit	O	E
<i>Sporophila caerulescens</i> (Vieillot, 1823)	Double-collared Seedeater	G	O
<i>Saltator similis</i> (d'Orbigny & Lafresnaye, 1837)	Green-winged Saltator	O	E
Cardinalidae (Ridgway, 1901)			
<i>Habia rubica</i> (Vieillot, 1817)	Red-crowned Ant-Tanager	O	E
Fringillidae (Leach, 1820)			
<i>Euphonia violacea</i> (Linnaeus, 1758)	Violaceous Euphonia	O	E
<i>Euphonia pectoralis</i> (Latham, 1801)	Chestnut-bellied Euphonia	O	E

The main indication of the good environmental quality of the studied area was the record of 27 understory species. Among these species, 23 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 [39, 40]. In tropical forest areas, communities of understory birds are very dependent on forest environments and rarely move between forest patches in fragmented areas [41], and the composition and diversity of the understory bird should vary mostly in response to fluctuations in the supply of food [42]. Insectivores birds usually have greater spatial stability and are more site-attached than frugivores ones [43], but this does not mean that fluctuations do not occur, since forest insectivores birds may have spatial distribution related to the availability of arthropods [44, 45]. We recorded a number of wetland species (e.g., *Tigrisoma lineatum*, *Pardirallus nigricans*, and *Aramides saracura*) associated with swampy vegetation and flooded areas with cattails. We observed several mixed-species flocks composed of large numbers of insectivore and omnivore species such as *Tangara seledon*, *Tangara cyanocephala*, *Tangara sayaca*, *Ramphocelus bresilius*, *Attila rufus*, *Habia rubica*, *Sittasomus griseicapillus*, and *Lanio cristatus*. Frequency and structure of mixed-species flocks also suggests habitat

conditions at the study area were adequate for many common Atlantic Rainforest bird species [46]. Mixed-species groups of these understory birds congregate around ant swarms, where they forage on insects flushed by the ants. Obligate ant-followers have specialized behaviors to track ant swarms and may serve as information sources for facultative ant-followers [47]. Mixed-species flocks are common in many tropical forests and have been well described in the Neotropics. Mixed-species flocking birds may increase foraging efficiency [48, 49] and protection from predation [50].

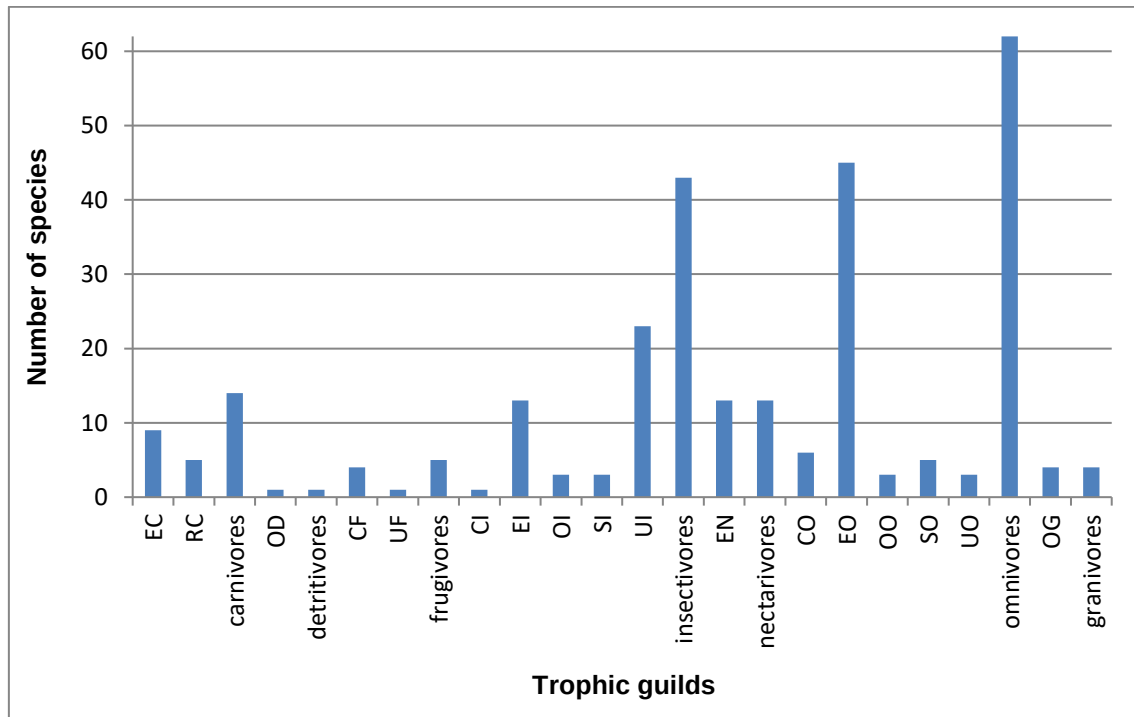


Figure 2. The number of bird species recorded in the area of study according to different trophic guilds. Edge carnivores (EC), riparian carnivores (RP), open-area detritivores (OD), canopy frugivores (CF), understory frugivores (UF), canopy insectivores (CI), edge insectivores (EI), open-area insectivores (OI), swamp insectivores (SI), understory insectivores (UI), edge nectarivores (EN), canopy omnivores (CO), edge omnivores (EO), open-area omnivores (OO), swamp omnivores (SO), understory omnivores (UO), open-area granivores (OG).

Some signs of good habitat conditions include the occurrence of mixed-species flocks [51] and army-ant swarm following birds, commons and confiding birds of primary and secondary forest that forage for small insects and other arthropods taken from twigs and foliage in the lower branches of trees. Among tropical forest birds, understory insectivores, such as some furnarids and formicarids, are particularly sensitive to habitat disturbance and fragmentation [52], and some of these important species were absent or rare in this study.

The guilds obtained for birds were grouped into seven broader groups based on diet, as follows: **Carnivores:** *Edge carnivores:* birds of prey, such as hawks and owls, that feed on a wide variety of vertebrates (birds, mammals, reptiles) that they capture on the ground, e.g., *Elanus leucurus* (White-tailed Kite), *Rupornis magnirostris* (Roadside Hawk), and *Buteo*

brachyurus (Short-tailed Hawk) and species active mainly at night as owls that hunt several species of vertebrates, e.g., *Tyto furcata* (American Barn Owl); *Riparian carnivores*: species that feed mainly on fish and a large number of aquatic invertebrates caught in rivers or lakes, e.g., *Butorides striata* (Striated Heron), *Ardea alba* (Great Egret), and *Chloroceryle americana* (Green Kingfisher).

Detritivores: *Open-area detritivores*: necrophagous birds, who eat animals that have been run over on roads or drowned in the rivers. In this study are represented by the *Coragyps atratus* (Black Vulture), the most common species of vulture in Brazil.

Frugivores: *Canopy frugivores*: birds foraging on fruits mainly in the upper parts of trees, such as parrots, macaws, and parakeets, e.g., *Pyrrhura frontalis* (Maroon-bellied Parakeet), *Forpus xanthopterygius* (Blue-winged Parrotlet), and *Pionus maximiliani* (Scaly-headed Parrot); *Understory frugivores*: the cracids, main representatives of that group, comprise essentially forest birds, from medium to large sizes that forage on the ground and in the lower parts of trees or shrubs, e.g., *Penelope obscura* (Dusky-legged Guan).

Granivores: *Open-area granivores*: these birds glean seeds principally on the ground and shrubs and rarely forage in trees. In the first category, the seed dispersers, such as pigeons and doves, e.g., *Columbina talpacoti* (Ruddy Ground-Dove), and in the second category, the seed predators, that have large bills, which are specially adapted to open the hard seeds of graminoids, e.g., *Sicalis flaveola* (Saffron Finch), *Volatinia jacarina* (Blue-black Grassquit), and *Sporophila caerulescens* (Double-collared Seedeater).

Insectivores: *Canopy insectivores*: birds feeding mainly on insects and caterpillars mostly under the canopies of trees, e.g., *Piaya cayana* (Squirrel Cuckoo); *Edge insectivores*: this group includes woodpecker species that feeds on caterpillars and insects caught on the internal side of tree bark, thanks to their capacity for perforating hard tree timber, e.g., *Celeus flavescens* (Blond-crested Woodpecker), and *Campephilus robustus* (Robust Woodpecker), also includes species that feed on insects caught on the foliage, foraging from the middle to high parts of trees, e.g., *Philydor atricapillus* (Black-capped Foliage-gleaner), *Todirostrum cinereum* (Common Tody-Flycatcher), *Colonia colonus* (Long-tailed Tyrant), and *Lathrotriccus euleri* (Euler's Flycatcher); *Open-area insectivores*: species feeding mainly on insects caught in the air above the tree canopy, such as swallows, which pursue winged insects flying in various flocks, e.g., *Pygochelidon cyanoleuca* (Blue-and-white Swallow), and species feeding on insects at night in mid-flight, e.g., *Nyctidromus albicollis* (Common Pauraque); *swamp insectivores*: includes species that feed primarily on insects caught on the ground, near streams and flooded areas, e.g., *Fluvicola nengeta* (Masked Water-Tyrant), and *Donacobius atricapilla* (Black-capped Donacobius); *Understory insectivores*: species that feed on insects caught on the foliage, foraging from the lower to middle parts of trees, e.g., *Dysithamnus mentalis* (Plain Antvireo), *Mackenziaena severa* (Tufted Antshrike), and *Thamnophilus ruficapillus* (Rufous-capped Antshrike), known for follow army ants and feeding off insects flushed out by the vast ant legion in the understory, and the woodcreepers, e.g., *Sittasomus griseicapillus* (Olivaceous Woodcreeper), and *Xiphorhynchus fuscus* (Lesser Woodcreeper), their feet are syndactyl, and are used to explore vertical perches, 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.



Figure 3. Examples of birds registered in this study: (A) edge carnivore *Rupornis magnirostris* (Roadside Hawk), (B) riparian carnivore *Butorides striata* (Striated Heron), (C) open-area detritivore *Coragyps atratus* (Black Vulture), (D) canopy frugivore *Forpus xanthopterygius* (Blue-winged Parrotlet) feeding on *Syagrus* palm fruits, (E) understory frugivore *Penelope obscura* (Dusky-legged Guan), (F) edge nectarivore *Thalurania glaucopis* (Violet-capped Woodnymph), (G) open-area granivore *Columbina talpacoti* (Ruddy Ground-Dove), and (H) canopy insectivore *Piaya cayana* (Squirrel Cuckoo). Photos by Fabio Rossano Dario.



Figure 4. Examples of birds registered in this study: (A) edge insectivore *Dryocopus lineatus* (Lineated Woodpecker ♂), (B) open-area insectivore *Progne chalybea* (Gray-breasted Martin), (C) swamp insectivore *Donacobius atricapilla* (Black-capped Donacobius), (D) understory insectivore *Leptopogon amaurocephalus* (Sepia-capped Flycatcher), (E) canopy omnivore *Ramphastos dicolorus* (Red-breasted Toucan), (F) edge omnivore *Tangara seledon* (Green-headed Tanager), (G) open-area omnivore *Zonotrichia capensis* (Rufous-collared Sparrow), and (H) swamp omnivore *Amazonetta brasiliensis* (Brazilian Teal ♂). Photos by Fabio Rossano Dario.

Nectarivores: *Edge nectarivores*: species whose main food item is nectar from flowers, and they complement their diet by capturing small insects and spiders, such as hummingbirds *Phaethornis pretrei* (Planalto Hermit), *Eupetomena macroura* (Swallow-tailed Hummingbird), and *Amazilia versicolor* (Versicolored Emerald).

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), but yet they can be distinguished by their foraging habits such as *Canopy omnivores*, whose food is obtained from the canopy of trees, e.g., *Ramphastos vitellinus* (Channel-billed Toucan); *Edge omnivores*: are more frequent at the edges of forests, e.g., the thrushes *Turdus rufiventris* and *Turdus amaurochalinus*, the flycatchers *Tyrannus melancholicus*, *Pitangus sulphuratus*, and *Megarhynchus pitangua*, the tanagers *Tangara seledon*, *Tangara cyanocephala*, *Tangara sayaca*, *Tachyphonus coronatus*, and *Dacnis cayana*; *Open-area omnivores*, e.g., *Zonotrichia capensis* (Rufous-collared Sparrow), and includes species that forage on several types of food, including carrion, mainly on the ground, e.g., *Caracara plancus* (Southern Caracara); *Swamp omnivores*: ducks and teals that live in aquatic environments at rivers edges, swamplands and wet grasslands, e.g., *Amazonetta brasiliensis* (Brazilian Teal), and rails like *Aramides cajaneus* (Gray-necked Wood-rail), and *Pardirallus nigricans* (Blackish Rail); *Understory omnivores*: the manakins inhabit different kinds of neotropical forest, live in the understory and middle growth, feed on fruits and insects and often perches on vertical perches close to the leaf litter, e.g., *Manacus manacus* (White-bearded Manakin), and *Chiroxiphia caudata* (Swallow-tailed Manakin).

4. CONCLUSION

The size of the area and the vegetation structure were reflected in the high diversity of bird species recorded. However, the connectivity with the Serra do Mar State Park has been influencing directly in the diversity of species of the avifauna registered. 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. The several mixed-species flocks observed, and the great abundance of understory insectivores are indication of the good environmental quality of the studied area.

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