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Bird-termite interactions in Brazil: A review with perspectives for future studies

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Abstract: We present a review on the principal interactions between birds and termites in Brazil. We found 218 bird species feeding on termites or using termitaria for nesting or perching. Termites were mentioned as food source for 179 bird species. Alates were the most consumed caste. Termitaria were mentioned as nest site for 45 bird species. Some bird species also perch on the top of termite mounds to search for their prey or to conduct territorial and/or courtship displays. Considering all interactions between both animal groups, little is known about the identification of termite genera or species. Therefore, we suggest more detailed studies to be conducted on the natural history and ecology of interactions between birds and termites in Brazil.

Keywords: birds, Brazil, feeding, nesting, termites.

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Resumo: Apresentamos aqui uma revisão sobre as principais interações entre aves e cupins no Brasil. Foram registradas 218 espécies de aves alimentando-se de cupins ou usando cupinzeiros para nidificar ou se empoleirar. Os cupins foram citados como recurso alimentar para 179 espécies de aves, sendo as formas aladas as mais consumidas. Os cupinzeiros foram citados como sítio de nidificação para 45 espécies de aves. Algumas espécies de aves também se empoleiram no alto de termiteiros para localizar suas presas ou para realizar exibições territoriais e/ou de corte. Considerando-se todas as interações entre ambos os grupos de animais, pouco ainda se conhece sobre a identificação dos gêneros e espécies de térmitas envolvidos. Assim, sugerimos a realização de estudos mais detalhados sobre história natural e ecologia das interações entre aves e cupins no Brasil.

Palavras-chave: aves, Brasil, alimentação, nidificação, cupins.

Introduction

Termites (Insecta: Isoptera) have been reported as an important food resource for birds around the world (Eisenmann 1961, De Bont 1964, Thiollay 1970, Dial & Vaughan 1987, Paiva 1998, Kok et al. 2000, Kopij 2000, Mallet-Rodrigues 2001, Gussoni & Campos 2003, Olson & Alvarenga 2006, Faria 2007, Sazima 2008). Termitaria (termite nests) also represent nest sites for several bird species (Hardy 1963, Sazima 1989, Dubs 1992, Naka 1997, Sick 1997, Brightsmith 2000).

Brazil holds one of the richest world avifaunas, with c. 1,800 bird species (Sick 1997, CBRO 2014). Nevertheless, little is known about various aspects of natural history of these species. Examples are the interactions between birds and termites. The 19th century German naturalist, Prince Maximilian of Wied-Neuwied explored the Campos Geraes, between the states of Minas Gerais and Bahia, and appears to have been the first to report such observations (Wied-Neuwied 1821).

Later, the German ornithologist Helmut Sick, who visited and stayed in Brazil since 1939 and is one of the leading exponents of Brazilian ornithology of the 20th century, also studied termites when he was a prisoner on Ilha Grande, during the World War II (Gonzaga 1991, Sick 1997). He also remarked the importance of termites either as food as providing shelter for birds and other animals, especially in his study of the Cerrado fauna (Sick 1965) and in his classic book on Brazilian ornithology (Sick 1997).

The naturalist Balthasar Dubs was also devoted to the study of birds in the vegetations of the central-western regions of Brazil. His book on the birds of the Pantanal and adjacent areas (Dubs 1992) presents a discussion on the role of termite mounds in forming the landscape of patches of cerradão or forest in the Pantanal region (the mounds are called “murundus” – for a review of the theories on their role in the landscape formation, see Oliveira-Filho 1992a, b), including photographs of this habitat type.

Recently, some authors reported termites as a food resource for birds in Brazil (Paiva 1998, Mallet-Rodrigues 2001, Gussoni & Campos 2003, Olson & Alvarenga 2006, Faria 2007, Sazima 2008). Nevertheless, studies and information on the interaction between birds and termites in this country are very scarce and fragmentary. The aim of this paper is to present a review on the importance of termites for Brazilian birds and to suggest perspectives for future research.

Materials and methods

The present review attempted to cover all published information on interactions between birds and termites in Brazil, which includes articles, book chapters, books and photographs available online (www.wikiaves.com.br) until January 2014 (see Table 1). On the Wiki Aves database we searched for photos using the keywords for “foraging”, “feeding” and “nest” or “nesting”. The principal interactions we found were those related to birds using termites as food resources and termitaria as nest sites or perches. We also included unpublished observations made by several colleagues, as well as some of our personal field observations. Wherever possible, for each record, we considered the lowest taxonomic level of identification of the termites, the castes involved (alates, soldiers and workers - in the case of food resource) and the type of termite nest, according to the building site: epigeal or mound; arboreal (supported on a tree or similar); rupicolous (upon a rock). Taxonomy of bird species follows the Comitê Brasileiro de Registros Ornitológicos (CBRO 2014).

Results and Discussion

1. General inventory of bird-termite interactions in Brazil

We found a total of 218 bird species that use the termites in a direct way (food resource) or indirectly (such as the use of termitaria as nesting or perching sites) (Table 1). This number represents approximately only c. 12% of Brazilian the avifauna (Sick 1997, CBRO 2014). Below, we present and discuss each of these types of interactions.

2. Termites as food resource for Brazilian birds

Termites have been reported as food resource for 179 species of birds in Brazil, of 51 families (Table 1). The families with the largest number of bird species feeding on termites are: Thraupidae (29 species), Tyrannidae (25), Picidae (11) and Thamnophilidae (10) (Figure 1).

Little is known about the taxonomic groups of termites consumed by birds. Among the 277 records, in 189 (68.2%) termites were identified at order level; in 50 (18.1%), at the family level; in 33 (11.9%), at the genus level and only in 5 (1.8%), at specific level (Figure 2).

Considering the different castes consumed by birds, among the 290 records, 189 (65.2%) report alates, 17 (5.9%) are related to soldiers and 15 (5.2%) mention workers. In 69 records (23.7%), castes were not mentioned (Figure 3).

Thus, alates seem to represent the main caste consumed by birds. But the problem is that swarms are unpredictable events in space and time, so that winged termites represent a resource that should be exploited in an opportunistic manner. Predation of alates by birds has been studied in more details in Africa (e.g., De Bont 1964, Thiollay 1970, Dial & Vaughan 1987, Kok et al. 2000, Kopij 2000). Unfortunately, little has

been studied about this interaction in Brazil. For example, opportunistic information was reported by Cunha (1961), who observed a domestic hen, swallows and tyrant-flycatchers feeding on winged termites. In September 1989, Paiva (1998) observed 12 species of birds preying alates in an urban park in Piracicaba/SP.

Gussoni & Campos (2003) reported 26 species of birds feeding on alates in Arujá/SP, in January 2002.

In the montane forests of the Serra da Mantiqueira, in April 2001, Olson & Alvarenga (2006) observed 23 species of birds feeding on winged termites. In this event, they recorded many specimens of the Buff-throated Warbling-Finch (*Poospiza lateralis*), a species endemic to the high mountains of south-eastern Brazil (Assis et al. 2007). Further, three Black-capped Piprites (*Piprites pileata*), a threatened species (BirdLife International 2000, Machado et al. 2005), were also feeding on alates. The authors observed that several species that commonly forage on the ground or among bushes were catching those termites in the air during this event.

In the same mountain range, in December 2002, C. R. M. Abreu and M. Maldonado-Coelho (*pers. comm.*) observed alates swarming after rain, in a transitional area of montane forest and high-altitude grassland (*campo de altitude*), in Matutu Valley (elevation: 1,990 m), Aiuruoca/MG. Six bird species were consuming these insects: the Highland Elaenia (*Elaenia obscura*), the Blue-billed Black-Tyrant (*Knipolegus cyanirostris*), the Blue-and-white Swallow (*Pygochelidon cyanoleuca*), the Diademed Tanager (*Stephanophorus diadematus*), the Rufous-collared Sparrow (*Zonotrichia capensis*) and the Bay-chested Warbling-Finch (*Poospiza thoracica*). *Pygochelidon cyanoleuca* captured termites in flight, while *K. cyanirostris*, *Z. capensis* and *P. thoracica* caught insects among leaves (in the forest edge) and in the bushes (in the grassland). *Elaenia obscura* and *S. diadematus* captured termites both in flight, as well as among the foliage.

Also in the Serra da Mantiqueira, a termite swarm was observed after a light rain in the late afternoon of 27 March 2007, in a transition area between a montane forest and the *campo de altitude* at Pedra de São Domingos (elevation: c. 1,970 m), in Gonçalves/MG (MFV *pers. obs.*). Only one specimen of *Z. capensis* and two individuals of *P. lateralis* were observed feeding on the winged termites among the foliage.

In November 2001, MFV and S. D'Angelo-Neto observed a swarm in Lavras/MG. Alates were flying in the edge of a secondary forest and adjacent open areas (pastures), being captured by the domestic Helmeted Guineafowl (*Numida meleagris*, n = 2), and the following native species: Green-barred Woodpecker (*Colaptes melanochloros*, n = 1), Rufous Hornero (*Furnarius rufus*, n = 2), Masked Water-Tyrant (*Fluvicola nengeta*, n = 2), Social Flycatcher (*Myiozetetes similis*, n = 1), Boat-billed Flycatcher (*Megarynchus pitangua*, n = 1), Streaked Flycatcher (*Myiodynastes maculatus*, n = 1), Variegated Flycatcher (*Empidonomus varius*, n = 1), Crested Becard (*Pachyrhamphus validus*, n = 1), Hooded Tanager (*Nemosia pileata*, n = 2), Pileated Finch (*Lanio pileatus*, n = 1), Sayaca Tanager (*Tangara sayaca*, n = 3), Swallow Tanager (*Tersina viridis*, n = 2), Rufous-collared Sparrow (n = 1), Saffron Finch (*Sicalis flaveola*, n = 2), Crested Oropendola (*Psarocolius decumanus*, n = 1) and Shiny Cowbird (*Molothrus bonariensis*, n = 1). Except *F. nengeta*, *Z. capensis* and *L. pileatus*, which caught the alates when they landed on the ground, all other species caught insects in the air. The Helmeted

Table 1. Bird species and their interactions with termites in Brazil.

| Interaction Type | | | Feeding on termites | | | Nesting on termitaria | | Source |
|----------------------------------|---------|---------|---------------------|-------------------------------|-----------------|-----------------------|-----------------|--------------------------|
| Family / Species | Feeding | Nesting | Perching | Taxon | Caste | Taxon | Termitaria type | |
| Tinamidae | | | | | | | | |
| <i>Crypturellus soui</i> | X | | | Termitidae | soldier | - | - | Schubart et al. (1965) |
| <i>Crypturellus parvirostris</i> | X | | | Isoptera | worker | - | - | Moojen et al. (1941) |
| | | | | Isoptera | not mentioned | - | - | Hempel (1949) |
| <i>Rhynchotus rufescens</i> | X | | | Termitidae | not mentioned | - | - | Schubart et al. (1965) |
| | | | | <i>Syntermes silvestrii</i> | not mentioned | - | - | Hempel (1949) |
| | | | | <i>Syntermes parallelus</i> | not mentioned | - | - | Hempel (1949) |
| | | | | Isoptera | not mentioned | - | - | Hempel (1949) |
| <i>Nothura minor</i> | X | | | Termitidae | worker, soldier | - | - | Schubart et al. (1965) |
| <i>Nothura maculosa</i> | X | | | <i>Syntermes</i> sp. | not mentioned | - | - | Penha (1995) |
| | | | | Isoptera | not mentioned | - | - | Sick (1997) |
| <i>Taoniscus nanus</i> | X | | | Isoptera | not mentioned | - | - | Hempel (1949) |
| | | | | <i>Procornitermes araujoi</i> | not mentioned | - | - | Hempel (1949) |
| | | | | Isoptera | not mentioned | - | - | Belton (1994) |
| | | | | | not mentioned | - | - | Teixeira & Negret (1984) |
| | | | | | not mentioned | - | - | Sick (1997) |
| Cracidae | | | | | | | | |
| <i>Crax blumenbachii</i> | X | | | Isoptera | not mentioned | - | - | Sick (1997) |
| Odontophoridae | | | | | | | | |
| <i>Odontophorus gujanensis</i> | X | | | Termitidae | not mentioned | - | - | Schubart et al. (1965) |
| Numididae | | | | | | | | |
| <i>Numida meleagris</i> | X | | | Isoptera | alate | - | - | pers. obs. |
| Phasianidae | | | | | | | | |
| <i>Gallus gallus</i> | X | | | Isoptera | alate | - | - | Cunha (1961) |
| Accipitridae | | | | | | | | |
| <i>Elanoides forficatus</i> | X | | X | Isoptera | alate | - | - | Sick (1997) |
| <i>Ictinia plumbea</i> | X | | | Isoptera | not mentioned | - | - | Hempel (1949) |
| | | | | Termitidae | alate, soldier | - | - | Schubart et al. (1965) |
| | | | | Isoptera | alate | - | - | Sick (1997) |
| <i>Rupornis magnirostris</i> | X | | | Termitidae | not mentioned | - | - | Schubart et al. (1965) |
| <i>Leucopternis</i> sp. | X | | | Termitidae | alate | - | - | Schubart et al. (1965) |
| Psophiidae | | | | | | | | |
| <i>Psophia crepitans</i> | X | | | Termitidae | worker | - | - | Schubart et al. (1965) |
| <i>Psophia viridis</i> | X | | | Termitidae | not mentioned | - | - | Schubart et al. (1965) |
| Rallidae | | | | | | | | |
| <i>Neocrex erythrops</i> | X | | | Termitidae | not mentioned | - | - | Schubart et al. (1965) |
| Charadriidae | | | | | | | | |
| <i>Vanellus chilensis</i> | X | | | Termitidae | worker | - | - | Schubart et al. (1965) |
| <i>Pluvialis dominica</i> | X | | | Termitidae | soldier | - | - | Schubart et al. (1965) |

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Table 1. Continued.

| Interaction Type | | | | Feeding on termites | | | Nesting on termitaria | | | Source |
|-------------------------------------|---------|---------|----------|-------------------------|---------------|--------------------------------------|-----------------------|------------------------------|--|--------|
| Family / Species | Feeding | Nesting | Perching | Taxon | Caste | Taxon | Termitaria type | | | |
| Scolopacidae | | | | | | | | | | |
| <i>Actitis macularius</i> | X | | | Isoptera | alate | - | - | Sick (1997) | | |
| <i>Tringa melanoleuca</i> | X | | | Termitidae | not mentioned | - | - | Schubart et al. (1965) | | |
| <i>Tringa flavipes</i> | X | | | Termitidae | not mentioned | - | - | Schubart et al. (1965) | | |
| Laridae | | | | | | | | | | |
| <i>Chroicocephalus maculipennis</i> | X | | | Isoptera | alate | - | - | Belton (1994) | | |
| Sternidae | | | | | | | | | | |
| <i>Phaetusa simplex</i> | X | | | Isoptera | alate | - | - | Belton (1994) | | |
| <i>Sterna hirundinacea</i> | X | | | Isoptera | alate | - | - | Sick (1997) | | |
| <i>Sterna</i> | X | | | Isoptera | alate | - | - | Sick (1997) | | |
| Cuculidae | | | | | | | | | | |
| <i>Guira guira</i> | X | | | Isoptera | alate | - | - | Belton (1994) | | |
| Strigidae | | | | | | | | | | |
| <i>Megascops choliba</i> | | X | | - | - | <i>Constrictotermes cyphergaster</i> | arboreal | Negret & Teixeira (1983) | | |
| <i>Glaucidium brasilianum</i> | X | X | | - | - | Isoptera | arboreal | Sick (1997) | | |
| <i>Athene cunicularia</i> | X | X | X | <i>Nasutitermes</i> sp. | soldier | - | - | Schubart et al. (1965) | | |
| | X | X | | - | - | Isoptera | epigean | Sick (1997) | | |
| | | | | Isoptera | alate | - | - | Martins & Egler (1990) | | |
| | | | | - | - | Isoptera | epigean | Burmeister apud Euler (1900) | | |
| | | | | - | - | Isoptera | epigean | Wied-Neuwied (1821) | | |
| | | | | - | - | Isoptera | epigean | Cunha (1961) | | |
| | | | | - | - | Isoptera | epigean | Negret & Teixeira (1983) | | |
| | | | | - | - | Isoptera | epigean | Sick (1997) | | |
| | | | | - | - | Isoptera | epigean | pers. obs. | | |
| Nyctibiidae | | | | | | | | | | |
| <i>Nyctibius aethereus</i> | X | | | Isoptera | not mentioned | - | - | Moojen et al. (1941) | | |
| <i>Nyctibius griseus</i> | X | | | Isoptera | alate | - | - | Sick (1997) | | |
| Caprimulgidae | | | | | | | | | | |
| <i>Hydropsalis albicollis</i> | X | | | Termitidae | not mentioned | - | - | Schubart et al. (1965) | | |
| <i>Hydropsalis parvula</i> | X | | | Termitidae | not mentioned | - | - | Schubart et al. (1965) | | |
| <i>Hydropsalis candicans</i> | | | X | - | - | - | - | Rodrigues et al. (1999) | | |
| <i>Hydropsalis longirostris</i> | X | | | Isoptera | alate | - | - | Sick (1997) | | |
| | | | | Isoptera | alate | - | - | Vasconcelos et al. (1999) | | |
| <i>Hydropsalis torquata</i> | X | | | Termitidae | not mentioned | - | - | Schubart et al. (1965) | | |
| <i>Hydropsalis forcipata</i> | X | | | Isoptera | not mentioned | - | - | Moojen et al. (1941) | | |
| <i>Chordeiles rupestris</i> | X | | | Isoptera | alate | - | - | Sick (1997) | | |

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Table 1. Continued.

| Family / Species | Interaction Type | | Feeding on termites | | | Nesting on termitaria | | Source |
|-------------------------------|------------------|---------|---------------------|------------|---------------|-----------------------|-----------------|--------------------------|
| | Feeding | Nesting | Perching | Taxon | Caste | Taxon | Termitaria type | |
| <i>Chordeiles acutipennis</i> | X | | | Termitidae | alate | - | - | Schubart et al. (1965) |
| Apodidae | | | | | | | | |
| <i>Streptoprocne zonaris</i> | X | | | Isoptera | alate | - | - | Olson & Alvarenga (2006) |
| <i>Tachornis squamata</i> | X | | | Termitidae | not mentioned | - | - | Schubart et al. (1965) |
| | | | | Isoptera | not mentioned | - | - | Sick (1997) |
| <i>Panyptila cayennensis</i> | X | | | Termitidae | not mentioned | - | - | Schubart et al. (1965) |
| <i>Cypseloides</i> sp. | X | | | Isoptera | not mentioned | - | - | Sick (1997) |
| | | | | Isoptera | alate | - | - | Sick (1997) |
| Trochilidae | | | | | | | | |
| <i>Eupetomena macroura</i> | X | | | Isoptera | alate | - | - | Gussoni & Campos (2003) |
| | | | | Isoptera | alate | - | - | Sazima (2008) |
| Trogonidae | | | | | | | | |
| <i>Trogon viridis</i> | | X | | - | - | Isoptera | arboreal | von Ihering (1914) |
| | | | | - | - | Isoptera | arboreal | Dubs (1992) |
| | | | | - | - | Isoptera | arboreal | Sick (1997) |
| | | | | - | - | Isoptera | arboreal | Ribas (2010) |
| | | | | - | - | Isoptera | arboreal | Euler (1900) |
| | | X | | - | - | Isoptera | arboreal | Dubs (1992) |
| | | | | - | - | Isoptera | arboreal | Sick (1997) |
| | | | | - | - | Isoptera | arboreal | Silva (2004) |
| | | | | - | - | Isoptera | arboreal | Alexandrino (2009) |
| | | | | - | - | Isoptera | arboreal | Menq (2009) |
| | X | | | - | - | Isoptera | arboreal | Santos (2009) |
| <i>Trogon surrucura</i> | | | | - | - | Isoptera | arboreal | Boso (2010) |
| | | | | - | - | Isoptera | arboreal | Bucci (2010) |
| | | | | - | - | Isoptera | arboreal | Konze (2010) |
| | | | | - | - | Isoptera | arboreal | Licco (2010) |
| | | | | - | - | Isoptera | arboreal | Oliveira (2010b) |
| | | | | - | - | Isoptera | arboreal | Pereira (2010a) |
| | | | | - | - | Isoptera | arboreal | Pereira (2010b) |
| | | | | - | - | Isoptera | arboreal | Sanson (2010) |
| | | | | - | - | Isoptera | arboreal | Si (2010) |
| | | | | - | - | Isoptera | arboreal | Zimer (2010) |
| | | | | - | - | Isoptera | arboreal | Amaral (2011) |
| | | | | - | - | Isoptera | arboreal | Biazotto (2011) |
| | | | | - | - | Isoptera | arboreal | Hansch (2011) |
| | | | | - | - | Isoptera | arboreal | Luccia (2011) |
| | | | | - | - | Isoptera | arboreal | Motta (2011) |
| | | | | - | - | Isoptera | arboreal | Riedtmann (2011) |

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Table 1. Continued.

| Interaction Type | | | Feeding on termites | | | Nesting on termitaria | | | Source |
|----------------------------------|---------|---------|---------------------|-------------------------|---------------|------------------------|-------------------------|-----------------------------|------------|
| Family / Species | Feeding | Nesting | Perching | Taxon | Caste | Taxon | Termitaria type | | |
| <i>Trogon violaceus</i> | X | | | Isoptera | alate | - | arboreal | Salazar (2012) | |
| <i>Trogon curucui</i> | | X | | Termitidae | not mentioned | - | <i>Nasutitermes</i> sp. | arboreal | pers. obs. |
| <i>Trogon rufus</i> | | X | | - | - | - | - | Olson & Alvarenga (2006) | |
| <i>Trogon collaris</i> | | X | | - | - | Isoptera | arboreal | Schubart et al. (1965) | |
| Alcedinidae | | X | | - | - | Isoptera | arboreal | Soares (2010) | |
| <i>Chloroceryle americana</i> | | X | | - | - | Isoptera | arboreal | Silveira (2010) | |
| Galbulidae | | | | - | - | Isoptera | arboreal | Adeodato (2012) | |
| <i>Jacamaralecyon tridactyla</i> | X | | | Isoptera | not mentioned | - | arboreal | Sick (1997) | |
| <i>Galbula ruficauda</i> | | X | | - | - | Isoptera | arboreal | Sick (1997) | |
| Bucconidae | | | | - | - | Isoptera | epigeal | Sick (1997) | |
| <i>Notharchus macrorhynchos</i> | | X | | - | - | Isoptera | arboreal | Melo-Júnior (2001) | |
| <i>Notharchus tectus</i> | | X | | - | - | Isoptera | arboreal | Sick (1997) | |
| <i>Bucco tamatia</i> | | X | | - | - | Isoptera | arboreal | Castro (2012) | |
| <i>Monasa nigrifrons</i> | X | | | Termitidae | not mentioned | - | arboreal | Mazzoni et al. (2013) | |
| <i>Chelidoptera tenebrosa</i> | X | | | Isoptera | not mentioned | - | arboreal | Czaban (2003) | |
| Ramphastidae | | | | - | - | - | arboreal | Schubart et al. (1965) | |
| <i>Ramphastos toco</i> | | X | | - | - | Isoptera | arboreal | Sick (1997) | |
| | | | | - | - | <i>Cornitermes</i> sp. | epigeal | Buzzetti & Silva (2005) | |
| <i>Ramphastos vitellinus</i> | | | X | - | - | Isoptera | not mentioned | Rodrigues & Costa (2006) | |
| <i>Pteroglossus castanotis</i> | X | X | | Isoptera | alate | - | arboreal | Sick (1997) | |
| | | | | - | - | <i>Cornitermes</i> sp. | epigeal | Sick (1997) | |
| | | | | - | - | - | - | Silva e Silva (pers. comm.) | |
| Picidae | | | | - | - | - | - | | |
| <i>Veniliornis passerinus</i> | X | | | <i>Heterotermes</i> sp. | soldier | - | - | Schubart et al. (1965) | |
| | | | | Termitidae | not mentioned | - | - | Schubart et al. (1965) | |
| <i>Veniliornis mixtus</i> | X | | | Isoptera | not mentioned | - | - | Vasconcelos et al. (2006) | |
| <i>Piculus chrysocloros</i> | | X | | - | - | Isoptera | arboreal | Dubs (1992) | |
| <i>Colaptes melanochloros</i> | X | | | Isoptera | alate | - | - | Sazima (2008) | |
| | | | | Isoptera | alate | - | - | pers. obs. | |

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Table 1. Continued.

| Interaction Type | | Feeding on termites | | | Nesting on termitaria | | | Source |
|----------------------------|---------|---------------------|----------|---|---|---|-----------------|--------------------------|
| Family / Species | Feeding | Nesting | Perching | Taxon | Caste | Taxon | Termitaria type | |
| <i>Colaptes campestris</i> | X | X | X | Isoptera | not mentioned | - | - | Wied (1821) |
| | | | | | | | | -Neuwied |
| | | | | | | | | von Ihering (1900) |
| | | | | | | | | Negret & Teixeira (1983) |
| | | | | | | | | Negret & Teixeira (1983) |
| | | | | | | | | Negret & Teixeira (1983) |
| | | | | | | | | |
| | | | | | | | | Redford (1984) |
| | | | | | | | | |
| | | | | | | | | Dubs (1992) |
| | | | | | | | | Sick (1997) |
| | | | | | | | | |
| | | | | | | | | Sick (1997) |
| | | | | | | | | |
| | | | | | | | | Castro (2000) |
| <i>Celeus elegans</i> | | | | | | | | Amaral (2003) |
| | | | | | | | | Silva e Silva (2004) |
| | | | | | | | | Rodrigues & Costa (2006) |
| | | | | | | | | Santos (2007) |
| | | | | | | | | Avelino (2009) |
| | | | | | | | | Bete (2009) |
| | | | | | | | | Bucci (2009) |
| | | | | | | | | Rodrigues (2009) |
| | | | | | | | | Cezar (2010) |
| | | | | | | | | Zachetti (2010) |
| | | | | | | | | Bessa (2011) |
| | | | | | | | | Filho (2011) |
| | | | | | | | | Vieira (2011) |
| | | | | | | | | Schubart et al. (1965) |
| | | X | | | Termitidae Isoptera <i>Nasutitermes</i> sp. | alate, worker not mentioned alate, worker, soldier | - - - | - - - |
| <i>Celeus lugubris</i> | X | X | | <i>Nasutitermes</i> sp. Termitidae | worker, soldier worker, soldier | - - | - - | Schubart et al. (1965) |
| | | | | | | | | Schubart et al. (1965) |
| | | | | | | | | Dubs (1992) |
| <i>Celeus flavescens</i> | X | | | Termitidae <i>Nasutitermes</i> sp. Isoptera | worker, soldier worker, soldier not mentioned | - - - | - - - | Schubart et al. (1965) |
| | | | | | | | | Schubart et al. (1965) |
| <i>Celeus torquatus</i> | X | | | <i>Nasutitermes</i> sp. | worker, soldier | - | - | Sick (1997) |
| | | | | | | | | Schubart et al. (1965) |

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Table 1. Continued.

| Interaction Type | | | Feeding on termites | | | Nesting on termitaria | | Source |
|--------------------------------|---------|---------|---------------------|----------------------------|-----------------|--------------------------------------|-----------------|--------------------------|
| Family / Species | Feeding | Nesting | Perching | Taxon | Caste | Taxon | Termitaria type | |
| <i>Dryocopus lineatus</i> | X | | | Termitidae | worker, soldier | - | - | Schubart et al. (1965) |
| <i>Campephilus rubricollis</i> | X | | | <i>Nasutitermes</i> sp. | soldier | - | - | Schubart et al. (1965) |
| <i>Campephilus robustus</i> | X | | | Termitidae | not mentioned | - | - | Schubart et al. (1965) |
| <i>Picumnus</i> sp. | | X | | Isoptera | not mentioned | - | - | Moojen et al. (1941) |
| Cariamidae | | | | - | - | Isoptera | epigean | Sick (1997) |
| <i>Cariamia cristata</i> | | | X | - | - | - | - | Redford (1984) |
| Falconidae | | | | | | | | |
| <i>Daptrius ater</i> | X | | | Isoptera | alate | - | - | Sick (1997) |
| <i>Ibycter americanus</i> | X | | | Isoptera | alate | - | - | Sick (1997) |
| <i>Caracara planicus</i> | X | | X | <i>Coritermes cumulans</i> | not mentioned | - | - | Redford (1984) |
| <i>Milvago chimachima</i> | X | | | Isoptera | alate | - | - | Sick (1997) |
| <i>Falco sparverius</i> | X | X | | - | - | <i>Constrictotermes cyphergaster</i> | arboreal | Negret & Teixeira (1983) |
| | | | | - | - | <i>Coritermes cumulans</i> | epigean | Redford (1984) |
| | | | | - | - | Isoptera | epigean | Sick (1997) |
| <i>Falco femoralis</i> | X | | | Termitidae | alate | - | - | Schubart et al. (1965) |
| <i>Falco peregrinus</i> | X | | | Isoptera | alate | - | - | Sick (1997) |
| Psittacidae | | | | <i>Syntermes dirus</i> | alate | - | - | Sick (1997) |
| <i>Primolius maracana</i> | | X | | - | - | Isoptera | epigean | Cunha (2010b) |
| <i>Aratinga auricapillus</i> | | X | | - | - | <i>Coritermes</i> sp. | epigean | pers. obs. |
| <i>Eupsittula aurea</i> | X | X | | Isoptera | alate | - | - | Sazima (1989) |
| | | | | Isoptera | alate | - | - | Sick (1997) |
| | | | | Isoptera | not mentioned | - | - | Faria (2007) |
| | | | | - | - | <i>Constrictotermes cyphergaster</i> | arboreal | Negret & Teixeira (1983) |
| | | | | - | - | <i>Coritermes cumulans</i> | epigean | Redford (1984) |
| | | | | - | - | Isoptera | arboreal | Sazima (1989) |
| | | | | - | - | Isoptera | arboreal | Dubs (1992) |
| | | | | - | - | <i>Constrictotermes cyphergaster</i> | arboreal | Sick (1997) |
| | | | | - | - | Isoptera | not mentioned | Bianchi et al. (2000) |
| | | | | - | - | Isoptera | not mentioned | Silva e Silva (2004) |
| | | | | - | - | Isoptera | rupicolous | Rodrigues & Costa (2006) |
| | | | | - | - | Isoptera | arboreal | Stamato (2009) |
| | | | | - | - | Isoptera | epigean | Camargo (2010) |

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Table 1. Continued.

| Family / Species | Interaction Type | | Feeding on termites | | Nesting on termitaria | | Source |
|---------------------------------|------------------|---------|---------------------|---------------------|-----------------------|--------------------------------------|-----------------------------|
| | Feeding | Nesting | Perching | Taxon | Caste | Taxon | |
| <i>Eupsittula pertinax</i> | | X | | - | - | Isoptera | Dalessandro (2010) |
| <i>Eupsittula cactorum</i> | | X | | - | - | Isoptera | Araujo (2011) |
| | | | | - | - | Isoptera | Costa (2011) |
| | | | | - | - | Isoptera | Oliveira (2011) |
| | | | | - | - | Isoptera | Olyntho (2011) |
| | | | | - | - | Isoptera | Sales (2011) |
| | | | | - | - | Isoptera | Ribeiro (2012) |
| | | | | - | - | <i>Conitermes</i> sp. | Silva e Silva (pers. comm.) |
| | | | | - | - | <i>Conitermes</i> sp. | pers. obs. |
| | | | | - | - | <i>Constrictotermes cyphergaster</i> | pers. obs. |
| | | | | - | - | Isoptera | Carvalho (2010) |
| | | | | - | - | <i>Nasutitermes</i> sp. | Naka (1997) |
| | | | | - | - | Isoptera | Netto (2010a) |
| | | | | - | - | Isoptera | Netto (2010b) |
| | | | | - | - | Isoptera | Netto (2010c) |
| | | | | - | - | Isoptera | Netto (2010d) |
| | | | | - | - | Isoptera | Teixeira (2010) |
| | | | | - | - | Isoptera | Couto (2010) |
| | | | | - | - | Isoptera | Sick (1997) |
| | | | | - | - | Isoptera | Costa (2008) |
| | | | | - | - | <i>Nasutitermes</i> sp. | Negret & Teixeira (1983) |
| | | | | - | - | Isoptera | Dubs (1992) |
| | | | | - | - | <i>Nasutitermes</i> sp. | Sick (1997) |
| | | | | - | - | Isoptera | Raso (2008) |
| | | | | - | - | Isoptera | Santos (2008) |
| | | | | - | - | Isoptera | Cunha (2010a) |
| | | | | - | - | Isoptera | Flores (2010) |
| | | | | - | - | Isoptera | Lima (2012) |
| | | | | - | - | Isoptera | Costa (2009) |
| | | | | - | - | Isoptera | Somntag (2011) |
| | | | | - | - | <i>Conitermes</i> sp. | Silva e Silva (2004) |
| | | | | - | - | <i>Conitermes</i> sp. | Silva e Silva (pers. comm.) |
| | | | | - | - | Isoptera | Bianchi et al. (2000) |
| | | | | - | - | <i>Conitermes</i> sp. | Buzzetti & Silva (2005) |
| Thamnophilidae | | | | | | | |
| <i>Myrmeciza atrothorax</i> | X | | | Termitidae | not mentioned | - | Schubart et al. (1965) |
| <i>Formicivora grisea</i> | X | | | Isoptera | alate | - | Sick (1997) |
| <i>Formicivora melanogaster</i> | X | | | <i>Eutermes</i> sp. | alate | - | Teixeira (1987) |

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Table 1. Continued.

| Interaction Type | | | | Feeding on termites | | | Nesting on termitaria | | Source |
|--------------------------------------|---------|---------|----------|-------------------------|-----------------|----------|-----------------------|--------------------------|--------|
| Family / Species | Feeding | Nesting | Perching | Taxon | Caste | Taxon | Termitaria type | | |
| <i>Herpsilochmus sellowi</i> | X | | | <i>Eutermes</i> sp. | alate | - | - | Teixeira (1987) | |
| <i>Sakesphorus cristatus</i> | X | | | <i>Eutermes</i> sp. | alate | - | - | Teixeira (1987) | |
| <i>Thamnophilus pelzelni</i> | X | | | Isoptera | not mentioned | - | - | Lopes et al. (2005) | |
| <i>Thamnophilus ambiguus</i> | X | | | Isoptera | not mentioned | - | - | Lopes et al. (2005) | |
| <i>Taraba major</i> | X | | | Termitidae | worker | - | - | Schubart et al. (1965) | |
| <i>Rhopornis ardesiacus</i> | X | | | <i>Nasutitermes</i> sp. | not mentioned | - | - | Schubart et al. (1965) | |
| <i>Willisornis poecilnotus</i> | X | | | <i>Eutermes</i> sp. | alate | - | - | Teixeira (1987) | |
| Melanopareiidae | | | | Termitidae | not mentioned | - | - | Schubart et al. (1965) | |
| <i>Melanopareia torquata</i> | X | | | Termitidae | not mentioned | - | - | Schubart et al. (1965) | |
| Rhinocryptidae | | | | Termitidae | not mentioned | - | - | Schubart et al. (1965) | |
| <i>Scytalopus novacapitalis</i> | X | | | Termitidae | not mentioned | - | - | Schubart et al. (1965) | |
| Formicariidae | | | | Termitidae | not mentioned | - | - | Schubart et al. (1965) | |
| <i>Formicarius analis</i> | X | | | Termitidae | not mentioned | - | - | Schubart et al. (1965) | |
| Scleruridae | | | | Termitidae | alate | - | - | Schubart et al. (1965) | |
| <i>Sclerurus rufigularis</i> | X | X | | - | - | Isoptera | epigean | Silva e Silva (2005) | |
| <i>Geositta poecilopecta</i> | | | X | | | | | | |
| Dendrocolaptidae | | | | Termitidae | not mentioned | - | - | Schubart et al. (1965) | |
| <i>Sittasomus griseicapillus</i> | X | | | Isoptera | alate | - | - | Olson & Alvarenga (2006) | |
| <i>Xiphorhynchus obsoletus</i> | | X | | - | - | Isoptera | arboreal | Dubs (1992) | |
| <i>Lepidocolaptes angustirostris</i> | | X | | - | - | Isoptera | epigean | Marantz et al. (2003) | |
| Xenopidae | | | | Isoptera | alate | - | - | Olson & Alvarenga (2006) | |
| <i>Xenops rutilans</i> | X | | | | | | | | |
| Furnariidae | | | | Termitidae | soldier | - | - | Schubart et al. (1965) | |
| <i>Furnarius leucopus</i> | X | | | Termitidae | worker, soldier | - | - | Schubart et al. (1965) | |
| <i>Furnarius rufus</i> | X | | | Isoptera | alate | - | - | Sazima (2008) | |
| | | | | Isoptera | alate | - | - | pers. obs. | |
| | | | | <i>Rupititermes</i> sp. | alate | - | - | pers. obs. | |
| <i>Philydor erythrocerum</i> | X | | | Isoptera | not mentioned | - | - | Schubart et al. (1965) | |
| <i>Philydor atricapillus</i> | X | | | Isoptera | not mentioned | - | - | Mallet-Rodrigues (2001) | |
| <i>Philydor rufum</i> | X | | | Isoptera | alate | - | - | Olson & Alvarenga (2006) | |
| <i>Syndactyla dimidiata</i> | | X | | - | - | Isoptera | arboreal | Pacheco (1995a) | |
| | | | | - | - | Isoptera | arboreal | Pacheco (1995b) | |
| <i>Synallaxis spixi</i> | X | | | Isoptera | alate | - | - | Belton (1994) | |
| | | | | Isoptera | alate | - | - | Olson & Alvarenga (2006) | |
| <i>Synallaxis scutata</i> | X | | | Termitidae | not mentioned | - | - | Schubart et al. (1965) | |
| <i>Furnarius</i> sp. | X | | | Isoptera | alate | - | - | Sick (1997) | |

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Table 1. Continued.

| Family / Species | Interaction Type | | Feeding on termites | | | Nesting on termitaria | | Source |
|--------------------------------|------------------|---------|---------------------|------------------------|---------------|-----------------------|-----------------|---|
| | Feeding | Nesting | Perching | Taxon | Caste | Taxon | Termitaria type | |
| Onychorhynchidae | | | | | | | | |
| <i>Onychorhynchus</i> sp. | X | | | Isoptera | alate | - | - | Sick (1997) |
| Tityridae | | | | | | | | |
| <i>Pachyramphus validus</i> | X | | | Isoptera | alate | - | - | pers. obs. |
| Cotingidae | | | | | | | | |
| <i>Gymmoderus foetidus</i> | X | | | Isoptera | alate | Isoptera | arboreal | Sick (1997) |
| <i>Cotinga maculata</i> | | X | | - | - | - | - | Sick (1997) |
| Pipritidae | | | | | | | | |
| <i>Piprites pileata</i> | X | | | Isoptera | alate | - | - | Olson & Alvarenga (2006) |
| Rhynchocyclidae | | | | | | | | |
| <i>Mionectes rufiventris</i> | X | | | Isoptera | alate | - | - | Olson & Alvarenga (2006) |
| <i>Phylloscartes ventralis</i> | X | | | Isoptera | alate | - | - | Olson & Alvarenga (2006) |
| <i>Tolmomyias flaviventris</i> | X | | | Termitidae | not mentioned | - | - | Schubart et al. (1965) |
| Tyrannidae | | | | | | | | |
| <i>Camptostoma obsoletum</i> | X | | | Isoptera | alate | - | - | Gussoni & Campos (2003) |
| <i>Elaenia flavogaster</i> | X | | | Isoptera | alate | - | - | Paiva (1998) |
| | | | | Isoptera | alate | - | - | Gussoni & Campos (2003) |
| | | | | <i>Ruptitermes</i> sp. | alate | - | - | pers. obs. |
| | | | | <i>Ruptitermes</i> sp. | alate | - | - | pers. obs. |
| <i>Elaenia parvirostris</i> | X | | | Isoptera | alate | - | - | Belton (1994) |
| <i>Elaenia chiriquensis</i> | X | | | Isoptera | alate | - | - | pers. obs. |
| <i>Elaenia obscura</i> | X | | | Isoptera | alate | - | - | C. R. M. Abreu & M. M. Coelho (pers. comm.) |
| | | | | Isoptera | alate | - | - | Gussoni & Campos (2003) |
| <i>Elaenia</i> sp. | X | | | Isoptera | alate | - | - | pers. obs. |
| <i>Phaeomyias murina</i> | X | | | <i>Ruptitermes</i> sp. | alate | - | - | Gussoni & Campos (2003) |
| <i>Legatus leucophaius</i> | X | | | Isoptera | alate | - | - | Gussoni & Campos (2003) |
| | | | | <i>Ruptitermes</i> sp. | alate | - | - | pers. obs. |
| <i>Myiarchus swainsoni</i> | X | | | Isoptera | alate | - | - | Gussoni & Campos (2003) |
| <i>Myiarchus tyrannulus</i> | X | | | Isoptera | alate | - | - | Gussoni & Campos (2003) |
| <i>Pitangus sulphuratus</i> | X | | | Isoptera | alate | - | - | Gussoni & Campos (2003) |
| <i>Machetornis rixosa</i> | X | | | Isoptera | alate | - | - | Sazima (2008) |
| | | | | Isoptera | alate | - | - | Paiva (1998) |
| | | | | <i>Ruptitermes</i> sp. | alate | - | - | pers. obs. |
| <i>Myiodynastes maculatus</i> | X | | | Isoptera | alate | - | - | Gussoni & Campos (2003) |
| | | | | Isoptera | alate | - | - | pers. obs. |
| <i>Megarynchus pitangua</i> | X | | | Isoptera | alate | - | - | Gussoni & Campos (2003) |
| | | | | Isoptera | alate | - | - | pers. obs. |
| | | | | <i>Ruptitermes</i> sp. | alate | - | - | pers. obs. |
| <i>Myiozetetes similis</i> | X | | | Isoptera | alate | - | - | Gussoni & Campos (2003) |
| | | | | Isoptera | alate | - | - | pers. obs. |

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Table 1. Continued.

| Interaction Type | | | Feeding on termites | | | Nesting on termitaria | | | Source |
|--------------------------------|---------|---------|---------------------|------------------------|---------------|-----------------------------|-----------------|---|--------|
| Family / Species | Feeding | Nesting | Perching | Taxon | Caste | Taxon | Termitaria type | | |
| <i>Tyrannus melancholicus</i> | X | | | Isoptera | alate | - | - | Paiva (1998) | |
| | | | | Isoptera | alate | - | - | Gussoni & Campos (2003) | |
| | | | | Isoptera | alate | - | - | Sazima (2008) | |
| | | | | <i>Ruptitermes</i> sp. | alate | - | - | pers. obs. | |
| <i>Tyrannus savana</i> | X | | | Isoptera | alate | - | - | Cunha (1961) | |
| | | | | Termitidae | alate | - | - | Schubart et al. (1965) | |
| | | | | Isoptera | alate | - | - | Sick (1997) | |
| <i>Empidonomus varius</i> | X | | | Isoptera | alate | - | - | Gussoni & Campos (2003) | |
| | | | | Isoptera | alate | - | - | Gussoni & Campos (2003) | |
| | | | | Isoptera | alate | - | - | pers. obs. | |
| <i>Colonia colonus</i> | X | | | <i>Ruptitermes</i> sp. | alate | - | - | pers. obs. | |
| <i>Myiophobus fasciatus</i> | X | | | Isoptera | alate | - | - | Paiva (1998) | |
| | | | | Isoptera | alate | - | - | Gussoni & Campos (2003) | |
| <i>Fluvicola nengeta</i> | X | | | Isoptera | alate | - | - | pers. obs. | |
| | | | | <i>Ruptitermes</i> sp. | alate | - | - | pers. obs. | |
| <i>Lathrotriccus euleri</i> | X | | | Isoptera | alate | - | - | Gussoni & Campos (2003) | |
| <i>Knipolegus cyanirostris</i> | X | | | Isoptera | alate | - | - | C. R. M. Abreu & M. M. Coelho (pers. comm.) | |
| <i>Knipolegus lophotes</i> | X | | | Isoptera | alate | - | - | pers. obs. | |
| <i>Xolmis velatus</i> | | X | | - | - | Isoptera | epigean | Sick (1997) | |
| <i>Xolmis irupero</i> | | X | | - | - | <i>Cornitermes</i> sp. | epigean | Buzzetti & Silva (2005) | |
| <i>Xolmis</i> sp. | | X | | - | - | Isoptera | not mentioned | von Ihering (1914) | |
| | | | | - | - | <i>Cornitermes cumulans</i> | epigean | Redford (1984) | |
| <i>Muscipipra vetula</i> | X | | | Isoptera | alate | - | - | Olson & Alvarenga (2006) | |
| Vireonidae | | | | | | | | | |
| <i>Cyclarhis gujanensis</i> | X | | | Isoptera | alate | - | - | Olson & Alvarenga (2006) | |
| <i>Vireo olivaceus</i> | X | | | Termitidae | not mentioned | - | - | Schubart et al. (1965) | |
| | | | | Isoptera | alate | - | - | Gussoni & Campos (2003) | |
| <i>Hylophilus poicilotis</i> | X | | | Isoptera | alate | - | - | Olson & Alvarenga (2006) | |
| Corvidae | | | | | | | | | |
| <i>Cyanocorax cyanomelas</i> | X | | | Termitidae | not mentioned | - | - | Schubart et al. (1965) | |
| <i>Cyanocorax cyanopogon</i> | X | | | Isoptera | alate | - | - | Sick (1997) | |
| Hirundinidae | | | | | | | | | |
| <i>Pygochelidon cyanoleuca</i> | X | | | Isoptera | alate | - | - | Paiva (1998) | |
| | | | | Isoptera | alate | - | - | Gussoni & Campos (2003) | |
| | | | | Isoptera | alate | - | - | Olson & Alvarenga (2006) | |
| | | | | Isoptera | alate | - | - | Sazima (2008) | |

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Table 1. Continued.

| Family / Species | Interaction Type | | Feeding on termites | | | Nesting on termitaria | | Source |
|---|------------------|---------|---------------------|---------------------------|-----------------|-----------------------|-----------------|---|
| | Feeding | Nesting | Perching | Taxon | Caste | Taxon | Termitaria type | |
| <i>Progne tapera</i> | | | | Isoptera | alate | - | - | C. R. M. Abreu & M. M. Coelho (pers. comm.) |
| | | | | Isoptera | alate | - | - | pers. obs. |
| | | | | <i>Ruptitermes</i> sp. | alate | - | - | pers. obs. |
| | X | X | | Isoptera | alate | Isoptera | arboreal | Sick (1997) |
| <i>Progne chalybea</i> | | | | - | - | - | - | Sick (1997) |
| | | | | Isoptera | alate | - | - | Gussoni & Campos (2003) |
| | | X | | Isoptera | alate | - | - | Sazima (2008) |
| <i>Tachycineta leucorrhoa</i> | | | | - | - | - | - | Sick (1997) |
| | | | | - | - | Isoptera | arboreal | Oliveira (2010a) |
| | | X | | - | - | Isoptera | epigeal | Bessa (2008) |
| | | | | - | - | Isoptera | epigeal | Guedes (2009) |
| Troglodytidae | | | | - | - | Isoptera | epigeal | Couto (2011) |
| <i>Troglodytes musculus</i> | X | | | Isoptera | alate | - | - | Paiva (1998) |
| <i>Cyphorhinus arada</i> | | | | Isoptera | alate | - | - | Sazima (2008) |
| | X | | | Termitidae | not mentioned | - | - | Schubart et al. (1965) |
| <i>Turdus leucomelas</i> | X | | | Isoptera | not mentioned | - | - | Lopes et al. (2005) |
| <i>Turdus amaurochalinus</i> | | | | Isoptera | alate | - | - | Sazima (2008) |
| | | | | <i>Ruptitermes</i> sp. | alate | - | - | pers. obs. |
| | X | | | Isoptera | alate | - | - | Belton (1994) |
| | | | | Isoptera | not mentioned | - | - | Lopes et al. (2005) |
| <i>Turdus subalaris</i> | X | | | Isoptera | alate | - | - | Olson & Alvarenga (2006) |
| Mimidae | | | | - | - | - | - | - |
| <i>Mimus saturninus</i> | X | | | Isoptera | not mentioned | - | - | Moojen et al. (1941) |
| <i>Passerellidae</i> <i>Zonotrichia capensis</i> | | | | Termitidae | worker, soldier | - | - | Schubart et al. (1965) |
| | | | | Isoptera | alate | - | - | Schubart et al. (1965) |
| | | | | Isoptera | alate | - | - | Paiva (1998) |
| | | | | Isoptera | alate | - | - | Sazima (2008) |
| | | | | Isoptera | alate | - | - | Belton (1994) |
| | X | | | Isoptera | alate | - | - | Paiva (1998) |
| | | | | <i>Neocapritermes</i> sp. | alate | - | - | Vasconcelos (1999) |
| <i>Passerellidae</i> <i>Zonotrichia capensis</i> | | | | Isoptera | alate | - | - | Gussoni & Campos (2003) |
| | | | | Isoptera | alate | - | - | Olson & Alvarenga (2006) |
| | | | | Isoptera | alate | - | - | Sazima (2008) |
| | | | | Isoptera | alate | - | - | C. R. M. Abreu & M. M. Coelho (pers. comm.) |
| | | | | Isoptera | alate | - | - | Coelho (pers. comm.) |

Continued on next page

Table 1. Continued.

| Family / Species | Interaction Type | | Feeding on termites | | | Nesting on termitaria | | Source |
|---------------------------------|------------------|---------|---------------------|------------------------|---------------|-----------------------|-----------------|--------------------------|
| | Feeding | Nesting | Perching | Taxon | Caste | Taxon | Termitaria type | |
| <i>Arremon taciturnus</i> | X | | | Isoptera | alate | - | - | pers. obs. |
| Parulidae | | | | Isoptera | alate | - | - | pers. obs. |
| <i>Setophaga pitiayumi</i> | | | | Termitidae | not mentioned | - | - | Schubart et al. (1965) |
| <i>Basileuterus culicivorus</i> | X | | | Isoptera | alate | - | - | Belton (1994) |
| <i>Myiothlypis flaveola</i> | X | | | Isoptera | alate | - | - | Olson & Alvarenga (2006) |
| Icteridae | | | | Isoptera | not mentioned | - | - | Lopes et al. (2005) |
| <i>Psarocolius decumanus</i> | X | | | Isoptera | alate | - | - | pers. obs. |
| <i>Cacicus chrysopterus</i> | X | | | Isoptera | alate | - | - | Olson & Alvarenga (2006) |
| <i>Icterus cayanensis</i> | X | | | Termitidae | not mentioned | - | - | Schubart et al. (1965) |
| <i>Gnorimopsar chopi</i> | | X | | - | - | Isoptera | epigeal | Sick (1997) |
| <i>Molothrus bonariensis</i> | X | | | Isoptera | alate | - | - | Belton (1994) |
| <i>Quiscalus lugubris</i> | X | | | Isoptera | alate | - | - | pers. obs. |
| <i>Psarocolius</i> sp. | X | | | Isoptera | alate | - | - | Sick (1997) |
| <i>Cacicus</i> sp. | X | | | Isoptera | alate | - | - | Sick (1997) |
| Thraupidae | | | | | | | | |
| <i>Coereba flaveola</i> | X | | | Isoptera | alate | - | - | Gussoni & Campos (2003) |
| | | | | Isoptera | alate | - | - | Sazima (2008) |
| | | | | <i>Ruptitermes</i> sp. | alate | - | - | pers. obs. |
| <i>Saltator similis</i> | X | | | Isoptera | alate | - | - | Paiva (1998) |
| <i>Orchesticus abeillei</i> | X | | | Isoptera | alate | - | - | Olson & Alvarenga (2006) |
| <i>Nemosia pileata</i> | X | | | Isoptera | alate | - | - | Sick (1997) |
| <i>Thlypopsis sordida</i> | X | | | Isoptera | alate | - | - | pers. obs. |
| | | | | Isoptera | alate | - | - | Paiva (1998) |
| <i>Pyrrihocomma ruficeps</i> | X | | | Isoptera | alate | - | - | Gussoni & Campos (2003) |
| <i>Tachyphonus coronatus</i> | X | | | Isoptera | alate | - | - | Olson & Alvarenga (2006) |
| | | | | Isoptera | not mentioned | - | - | Lopes et al. (2005) |
| <i>Ramphocelus carbo</i> | X | | | Isoptera | alate | - | - | Gussoni & Campos (2003) |
| <i>Lanio pileatus</i> | X | | | Isoptera | alate | - | - | Sazima (2008) |
| <i>Lanio melanops</i> | X | | | Isoptera | alate | - | - | pers. obs. |
| <i>Tangara sayaca</i> | X | | | Isoptera | alate | - | - | Sick (1997) |
| | | | | Isoptera | alate | - | - | Belton (1994) |
| | | | | Isoptera | alate | - | - | Sick (1997) |
| | | | | Isoptera | alate | - | - | Paiva (1998) |
| | | | | Isoptera | alate | - | - | Gussoni & Campos (2003) |
| | | | | Isoptera | alate | - | - | Sazima (2008) |
| | | | | Isoptera | alate | - | - | pers. obs. |

Continued on next page

Table 1. Continued.

| Interaction Type | | | Feeding on termites | | Nesting on termitaria | | Source |
|------------------------------------|---------|---------|---------------------|------------------------|-----------------------|-------|---|
| Family / Species | Feeding | Nesting | Perching | Taxon | Caste | Taxon | |
| <i>Tangara palmarum</i> | X | | | <i>Ruptitermes</i> sp. | alate | - | pers. obs. |
| <i>Tangara ornata</i> | X | | | <i>Ruptitermes</i> sp. | alate | - | pers. obs. |
| <i>Tangara cayana</i> | X | | | Isoptera | alate | - | Gussoni & Campos (2003) |
| | | | | Isoptera | alate | - | Olson & Alvarenga (2006) |
| | | | | Isoptera | alate | - | Sazima (2008) |
| | | | | Isoptera | alate | - | pers. obs. |
| | | | | <i>Ruptitermes</i> sp. | alate | - | pers. obs. |
| <i>Stephanophorus diadematus</i> | X | | | Isoptera | alate | - | Olson & Alvarenga (2006) |
| | | | | Isoptera | alate | - | C. R. M. Abreu & M. M. Coelho (pers. comm.) |
| <i>Neothraupis fasciata</i> | X | | | Isoptera | not mentioned | - | Alves (1991) |
| <i>Schistochlamys ruficapillus</i> | X | | | Isoptera | alate | - | pers. obs. |
| <i>Pipraeidea melanonota</i> | X | | | Isoptera | alate | - | Olson & Alvarenga (2006) |
| <i>Pipraeidea bonariensis</i> | X | | | Isoptera | alate | - | Belton (1994) |
| <i>Tersina viridis</i> | X | | | Isoptera | not mentioned | - | Sick (1997) |
| | | | | Isoptera | alate | - | pers. obs. |
| <i>Dacnis cayana</i> | X | | | <i>Ruptitermes</i> sp. | alate | - | pers. obs. |
| | | | | Isoptera | alate | - | Gussoni & Campos (2003) |
| <i>Cyanerpes cyaneus</i> | X | | | Isoptera | alate | - | pers. obs. |
| <i>Conirostrum speciosum</i> | X | | | <i>Ruptitermes</i> sp. | alate | - | pers. obs. |
| <i>Poospiza thoracica</i> | X | | | Isoptera | alate | - | Sick (1997) |
| | | | | Isoptera | alate | - | Gussoni & Campos (2003) |
| <i>Poospiza lateralis</i> | X | | | Isoptera | alate | - | C. R. M. Abreu & M. M. Coelho (pers. comm.) |
| <i>Sicalis flaveola</i> | X | | | Isoptera | alate | - | Olson & Alvarenga (2006) |
| <i>Embernagra longicauda</i> | X | | | Isoptera | alate | - | pers. obs. |
| <i>Volatinia jacarina</i> | X | | | Isoptera | not mentioned | - | pers. obs. |
| <i>Sporophila nigricollis</i> | X | | | Termitidae | not mentioned | - | Schubart et al. (1965) |
| Cardinalidae | | | | <i>Ruptitermes</i> sp. | alate | - | pers. obs. |
| <i>Piranga flava</i> | X | | | Termitidae | not mentioned | - | Schubart et al. (1965) |
| Passeridae | | | | | | | |
| <i>Passer domesticus</i> | X | | | Isoptera | alate | - | Sick (1997) |
| | | | | Isoptera | alate | - | Paiva (1998) |
| | | | | Isoptera | alate | - | Sazima (2008) |

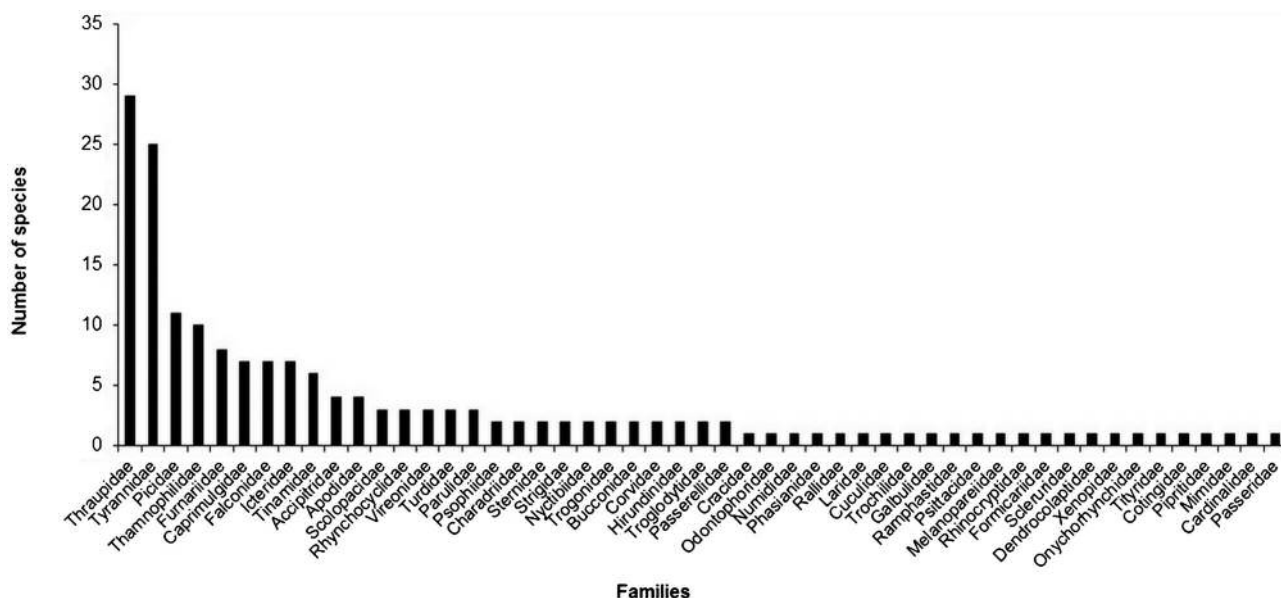


Figure 1. Number of bird species, per family, recorded feeding on termites in Brazil.

Guineafowl, despite being a terrestrial species, jumped and caught the termites in flight. Although it is a domestic and exotic species, it also feeds on termites in wildlife, as recorded by Thiollay (1970) in Africa.

In the course of another swarm, observed in December 2005 at a grassland savannah (*campo cerrado*), in the Serra do Mascate, Congonhas/MG, MFV (*pers. obs.*) recorded the following species of birds feeding on winged termites: Lesser Elaenia (*Elaenia chiriquensis*, $n = 1$), Crested Black-Tyrant (*Knipolegus lophotes*, $n = 1$), Blue-and-white Swallow ($n = 5$), Cinnamon Tanager (*Schistochlamys ruficapillus*, $n = 2$), Sayaca Tanager ($n = 2$), Burnished-buff Tanager (*Tangara cayana*, $n = 3$) and Blue Dacnis (*Dacnis cayana*, $n = 2$).

On 22 January 2008, at c. 17:30 h, MFV and L. N. Souza observed a swarm of *Ruptitermes* sp. at a light rain in Fazenda Bocaina (20° 00' 01"S, 43° 28' 17"W; elevation: c. 750 m), Santa Bárbara/MG. The alates were emerging from a hole in the soil of an orchard, protected by workers. Birds of the following species were observed catching these winged termites: Rufous Hornero ($n = 2$), Yellow-bellied Elaenia (*Elaenia*

flavogaster, $n = 1$), Masked Water-Tyrant ($n = 1$), Long-tailed Tyrant (*Colonia colonus*, $n = 1$), Cattle Tyrant (*Machetornis rixosa*, $n = 1$), Piratic Flycatcher (*Legatus leucophaius*, $n = 1$), Boat-billed Flycatcher ($n = 1$), Tropical Kingbird (*Tyrannus melancholicus*, $n = 1$), Blue-and-white Swallow ($n = 1$), Pale-breasted Thrush (*Turdus leucomelas*, $n = 1$), Bananaquit (*Coereba flaveola*, $n = 1$), Palm Tanager (*Tangara palmarum*, $n = 2$), Golden-chevrons Tanager (*Tangara ornata*, $n = 2$), Burnished-buff Tanager ($n = 2$) and Swallow Tanager ($n = 2$). Interestingly, several birds that usually do not perform aerial foraging tactics, such as: *E. flavogaster*, *T. leucomelas*, *T. ornata*, *T. palmarum*, *T. cayana* and *T. viridis*, caught insects in flight, landing later to consume them. In the case of *T. viridis*, the same specimen (a male) captured up to five alates in a single attempt. *Megarynchus pitangua* and *C. flaveola* captured winged termites that landed in trees and shrubs. One specimen of *T. cayana* combined both foraging techniques (in flight and perched in the shrubs). Birds that usually forage on the ground caught alates that were still on the ground, such as: *F. rufus*, *F. nengeta* and *M. rixosa*.

Around 17:00 h, on 28 January 2008, another swarm of *Ruptitermes* sp. was observed by MFV and L. N. Souza in a

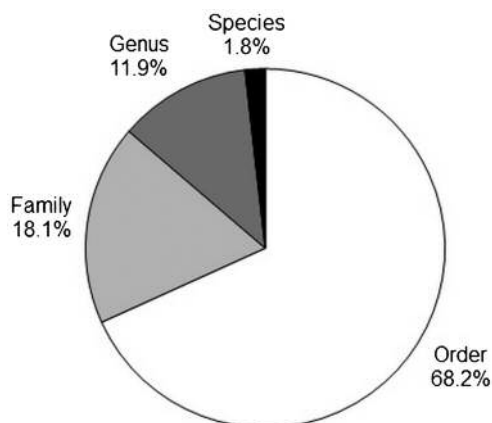


Figure 2. Percentages of identification, in different taxonomic levels, of the termites recorded as food resource for birds in Brazil.

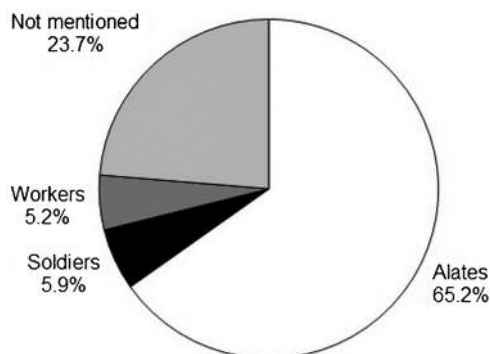


Figure 3. Percentage of termite castes recorded as food resource by birds in Brazil.

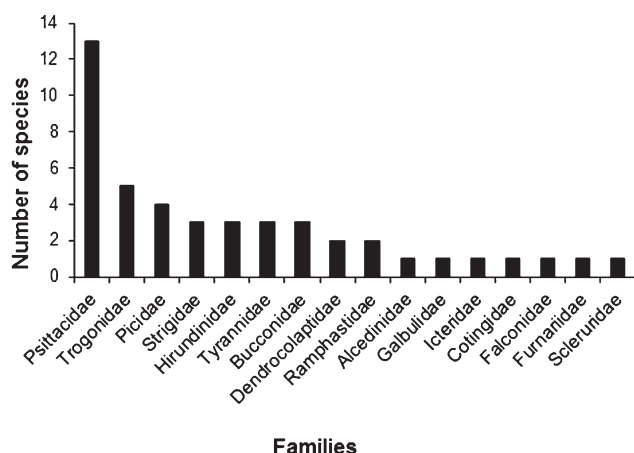


Figure 4. Number of bird species, per family, using termitaria as nesting sites in Brazil.

secondary forest edge at Córrego do Sítio (20° 00' 36" S, 43° 30' 45" W), also in Santa Bárbara/MG. The following species of birds captured insects in flight: Yellow-bellied Elaenia ($n = 1$), Mouse-colored Tyrannulet (*Phaeomyias murina*, $n = 1$), Blue Dacnis ($n = 2$; a couple) and Yellow-bellied Seedeater (*Sporophila nigricollis*, $n = 2$; a couple).

In a recent paper, Sazima (2008) also reported 16 bird species feeding on alates in Campinas/SP, in July 2007. He also noted the changing of regular foraging behavior of several species as pointed out by Olson & Alvarenga (2006).

The flight activity is unknown for most termites. Although not a rule, in southeastern Brazil swarmings generally occur from the end of the dry season to the beginning of the rainy season (between September and March), but in some parts of the Amazon region the effects of seasonality are less pronounced (Silvestri 1903, Costa-Lima 1938, Martius et al. 1996, Medeiros et al. 1999). It is noteworthy that most termite swarms seems to coincide with the breeding season of birds, i.e. the beginning of the rainy season. As alates are rich in proteins and lipids (Nutting 1969), their predation during the breeding season of birds seems to be important to supplement their energy and protein demands. The Rufous-collared Sparrow was recorded feeding on alates of *Neocapritermes* sp. at the time that this species reproduces in the central state of Minas Gerais (Vasconcelos 1999). Melo-Júnior (2001) observed the Three-toed Jacamar (*Jacamaralcyon tridactyla*), a rare bird species endemic to the Atlantic Forest, also feeding on termites during its breeding season.

In the case of ground-foraging birds, such as the Red-winged Tinamou (*Rhynchotus rufescens*) and the Dwarf Tinamou (*Taoniscus nanus*), there are reports that these species dig termite mounds with their beaks to feed on those insects (Teixeira & Negret 1984, Sick 1997). Sick (1997) mentioned that this work is facilitated when mounds were previously damaged by other predators (such as anteaters) and repaired by termites with still fresh material. Other species of tinamous (Tinamidae) probably also exhibit this behavior, but have not yet been observed. When birds dig termite mounds, they can feed on other castes (workers and soldiers) and immatures (as nymphs, which are rich in fat and protein). Probably, the termites also enrich the diet of other groups of flying birds that burrow into

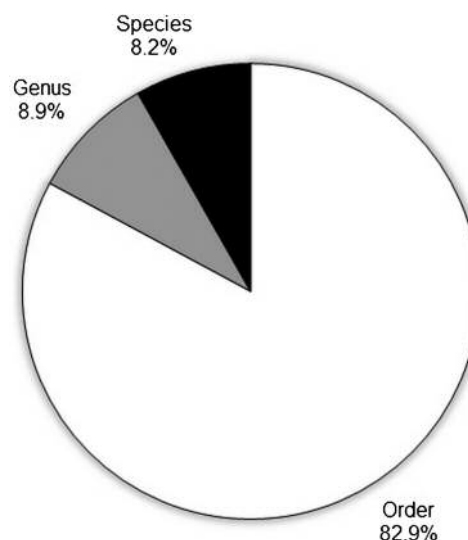


Figure 5. Percentages of identification, in different taxonomic levels, of the termites that build termitaria used as nest site by birds in Brazil.

mounds for nesting sites, such as parrots (Psittacidae), woodpeckers (Picidae) and trogons (Trogonidae) (see Euler 1900, Schubart et al. 1965, Sazima 1989, Dubs 1992, Naka 1997, Sick 1997).

3. Termitaria as nest sites for Brazilian birds

Termitaria were recorded as nesting sites for 45 species of Brazilian birds of 16 families (Table 1). The most representative families are: Psittacidae (13 species), Trogonidae (5), Picidae (4), Strigidae, Hirundinidae, Bucconidae and Tyrannidae (3) (Figure 4). These families are represented by several species that nest in holes in trees or natural walls. In general, birds of the families Alcedinidae (kingfishers) and Galbulidae (jacamars) nest in holes dug into ravines, being noteworthy Sick's (1997) observations on one species of each family nesting in termite mounds.

Again, little is known about the termite species that build termitaria used by birds as nest sites. Among the 146 records, in 121 (82.9%) termites were identified at the order level; in 13 (8.9%), at the generic level and only in 12 (8.2%), at species level (Figure 5).

Concerning the types of termitaria used by birds, from 146 records, 84 (57.5%) are arboreal, 50 (34.3%) are epigeal and only one (0.7%) is rupicolous. In 11 records (7.5%) termitaria types were not mentioned (Figure 6). In the only record of rupicolous mound, Rodrigues & Costa (2006) described the Peach-fronted Parakeet (*Eupsittula aurea*) nesting on a termitaria built on rocky walls of a canyon in the Serra do Cipó/MG.

Nesting inside termitaria can offer advantages to birds, as protection against predators and propitious micro-climate (Sick 1997). However, it is not always possible to know whether a bird that nests inside the termitaria dig its own nest or use a cavity excavated by another bird. Woodpeckers (Picidae), parrots (Psittacidae), trogons (Trogonidae) and puffbirds (Bucconidae) were reported excavating termitaria for nesting (Sazima 1989, Dubs 1992, Sick 1997). On the afternoon of 6 August 1999, for about 15 minutes, MFV observed a male of the Surucua Trogon (*Trogon surrucura surrucura*) digging an arboreal termitarium of *Nasutitermes* sp. at Morro do Diabo State Park, Teodoro Sampaio/SP. This termitarium was about

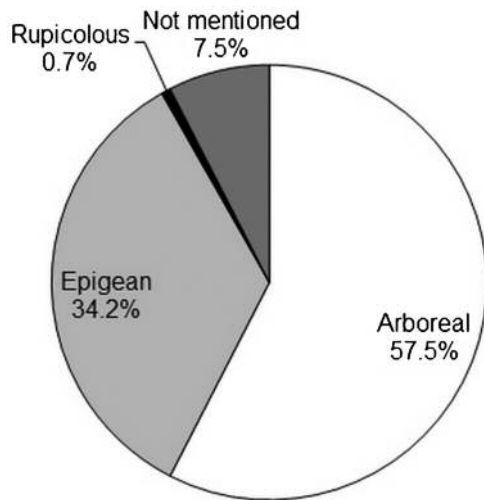


Figure 6. Percentages of termitaria types used by birds as nest sites in Brazil.

3 m above the ground in a tree at the edge of secondary forest. The bird perched on the termitarium like a woodpecker, grabbed by its feet. It also used its tail as a support, working its rectrices (Figure 7). The female remained perched in a nearby tree and watched the work carried out by the male, without participating in the excavation.

Among parrots, R. Silva e Silva (*pers. comm.*) observed the following bird species nesting in mounds of *Cornitermes* sp.: Peach-fronted Parakeet (in Tapira/MG) and Yellow-faced Parrot (*Alipiopsitta xanthops*; at Emas National Park, Mineiros/GO). In the *cerrado* region of Minas Gerais state, the Peach-fronted Parakeet is also commonly observed nesting in arboreal termite nests of *Constrictotermes cyphergaster*, in Sete Lagoas, Paraopeba and Inhaúmas (Figure 8). This parakeet was recorded nesting in these termitaria between the months of April and July (MFV *pers. obs.*).

It is noteworthy that termites restore the termitaria walls that were excavated by birds, but generally respects the birds'



Figure 7. A male of the Surucua Trogon (*Trogon surrucura surrucura*) digging an arboreal termitarium of *Nasutitermes* sp. at Morro do Diabo State Park/SP, showing the working of its rectrices that support him in the termitaria. Photo by Marcelo Ferreira de Vasconcelos.



Figure 8. In the *cerrado* region of Minas Gerais state, the Peach-fronted Parakeet (*Eupsittula aurea*) is commonly observed nesting in arboreal nests of *Constrictotermes cyphergaster*. This nest was found in July 2007 in the *cerrado* of Inhaúma/MG. In its interior it was found a single white and rounded egg. Photo by Marcelo Ferreira de Vasconcelos.

incubatory chamber (Sick 1997) and it remains unchanged even after the nest is abandoned by the birds. Naka (1997) reported that termites also restored the exterior walls damaged in arboreal termitaria which were used for nesting by the Cactus Parakeet (*Eupsittula cactorum*). In this context, it is noteworthy that parrots have a preference for active termitaria, *i.e.*, those occupied by termites, since abandoned termitaria are very dry and break easily (Hardy 1963).

Sick (1997) mentioned the following bird species that use excavations in termitaria previously made by other birds: the American Kestrel (*Falco sparverius*), the Tropical Screech-Owl (*Megascops choliba*), the Ferruginous Pygmy-Owl (*Glaucidium brasilianum*), the Toco Toucan (*Ramphastos toco*), the White-rumped Monjita (*Xolmis velatus*), the Brown-chested Martin (*Progne tapera*) and the Chopi Blackbird (*Gnorimopsar chopi*). In Catalão/GO, R. Silva e Silva (*in litt.*) photographed one specimen of the Chestnut-eared Aracari (*Pteroglossus castanotis*) leaving its nest, located in a mound of *Cornitermes* sp., which was probably dug by another bird. This species can nest in both epigean and in arboreal termitaria (Sick 1997). Bird species reported by Sick (1997) as diggers of holes in termitaria which are later used by other species were parakeets (Psittacidae) and woodpeckers (Picidae), especially the Peach-fronted Parakeet and the Campo Flicker (*Colaptes campestris*). The Burrowing Owl (*Athene cunicularia*) is also mentioned as an excavator of termite mounds, but also exploits pre-existing holes, so that a couple simply extend it, using their feet and beaks (see Euler 1900, Cunha 1961, Negret & Teixeira 1983, Sick 1997).

It is also noteworthy that termitaria appear to be a critical resource for maintaining populations of many species of birds that nest in cavities. This is because large trees, which forms potential hollows for nesting-cavity birds, are extremely scarce in secondary forests, as well as in the *cerrado* of central Brazil (Negret & Teixeira 1983, MFV *pers. obs.*).

Despite birds use termitaria as nest sites, there is a recent report of termites (*Microcerotermes* cf. *exiguus*) using an abandoned nest of the Pale-legged Hornero (*Furnarius leucopus*) in the Caatinga of northeastern Brazil (Silva et al. 2013).

4. Termitaria as perching sites for Brazilian birds

Termite mounds can also be used as perching sites for birds. In some cases, these mounds are marked by manure of birds that use them (Fontes 1998a: 218). Thus termitaria provide for birds of prey, such as the Southern Caracara (*Caracara plancus*) and the Burrowing Owl, strategic points to search for preys in the open landscapes of Brazil, represented the various grassland and savannah natural physiognomies of the *cerrado* region and man-made pastures (Cunha 1961, Redford 1984, Develey & Endrigo 2004, Silva e Silva 2004; MFV pers. obs.). Some species also use termitaria as a spot to feed on alates in flight, like the Swallow-tailed Kite (*Elanoides forficatus*) and the Channel-billed Toucan (*Ramphastos vitellinus*) (Sick 1997). Importantly, in the *cerrado* of central Brazil, the termite mounds are important perching sites for two species of endangered birds that are endemic to this region (following Silva 1995, Silva & Bates 2002, Machado et al. 2005): the White-winged Nightjar (*Hydropsalis candicans*) and the Campo Miner (*Geositta poeciloptera*) (Rodrigues et al. 1999, Rensen Jr. 2003, Silva e Silva 2004). The Campo Miner perches on mound in the *cerrado* to sing and to perform a wing display which is related to territoriality and attraction of sexual partners (Rensen Jr. 2003). Similar behavior has been recorded for the Red-legged Seriema (*Cariama cristata*), which perches on top of mounds of *Cornitermes cumulans* to vocalize its territorial song (Redford 1984).

5. Conclusions and perspectives for future researches

Based on the present review, we conclude that the small number of bird species recorded using termites, for the purposes above described, reflects the lack of observations and the limited published data on natural history. In several bird families recorded in those interactions, other species have the same feeding and breeding habits of the recorded species. Thus, the consumption of termites and the use of termitaria should be more widespread than that reported in the literature. For example, in the families Hirundinidae (swallows) and Apodidae (swifts), with several species represented exclusively by aerial insectivorous, a higher number of species that feed on alates is expected. The same applies to other aerial insectivores, like the nightjars (Caprimulgidae) and tyrant-flycatchers (Tyrannidae). Similarly, it is also expected that many more bird species use termitaria as nest sites or perches in comparison to the current knowledge.

Furthermore, there are other interactions between birds and termites, not addressed in this review, which should be better studied. For example, Sick (1997) mentions that barbets (Capitonidae) hammer termite mounds with their beaks in search for arthropods and that the Lineated Woodpecker (*Dryocopus lineatus*), puffbirds (Bucconidae) and trogons (Trogonidae), use arboreal termitaria as roosting sites.

The majority of termite species used by Brazilian birds was not identified even at the family or generic levels. This shows a lack of basic natural history information in Brazil. Studies on molecular biology and modeling algorithms are now highly valued, while those on the basic interactions between organisms in nature are declining. Worse, thousands of hectares of native

vegetation are destroyed each year in Brazil and we passively watch the biodiversity loss without knowing basic interactions between species. In future studies on termites as food resource or on termitaria as nesting or perching sites for birds, we suggest the collection and identification of these insects. Alates may be easily collected. Sometimes the exit holes can be found in the ground or in the mounds or nests (see Vasconcelos 1999), and this will be an opportunity to also obtain specimens of the soldier caste and the workers, which greatly facilitates the taxonomic identification.

All termite castes (soldiers, workers, nymphs, alates) should be collected preferably with delicate forceps or with small brushes impregnated with alcohol. Termites must be kept in 70–80% alcohol (Fontes 1995) for later identification with the aid of keys and illustrations (see Mathews 1977, Fontes 1992, 1995, 1998b, Constantino 1999, Milano & Fontes 2002) or should preferably be sent to taxonomists. It is important to stress that collection should be conducted with permission provided by the Instituto Chico Mendes de Conservação da Biodiversidade (ICMBio), the Brazilian environment agency that deals with scientific collection activities.

Since different species of birds change their foraging behavior when feeding on alates (Eisenmann 1961, Belton 1994, Olson & Alvarenga 2006; MFV pers. obs.), foraging tactics of each species must be described in detail (see Fitzpatrick 1980, Rensen Jr & Robinson 1990). Photographs of birds feeding on termites or using termitaria as nesting or perching sites are also recommended in new publications.

Termitaria used by birds as nest sites should be photographed with details of the surface, and eventually one similar mound or nest may be collected or dissected and documented, since the architectural pattern is useful for the recognition of the termite species (see Mathews 1977, Fontes 1995). It is also important to record at the time of the bird nesting, if the mound was active (occupied by termites) or abandoned. Detailed measurements of the nest entrance, the access tunnel and the incubation chamber should be made carefully. It is also desirable to conduct schematic drawings showing the position of the incubation chamber, as well as the direction of the access tunnel inside the termitarium (see Naka 1997). Moreover, it is necessary to study the material that constitutes the incubation chamber (if present) and describe details about the nest according to the recent review on this subject (Simon & Pacheco 2005). In case of arboreal termitaria, it is always suggested to note its height from the ground, the tree species support and the direction of the nest entrance (north, south, east or west).

Finally, we conclude that there is still a gap in understanding various aspects concerning the natural history and the ecology of interaction between birds and termites. These are some of the challenges that must be faced by naturalists and field biologists in the future.

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