

FORAGING BEHAVIOR OF THE RESTINGA TYRANNULET (*PHYLLOSCARTES KRONEI*) (AVES, TYRANNIDAE)

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Resumo. – Comportamento de forrageamento da maria-da-restinga. – O presente estudo foi realizado no município de Ilha Comprida (24°20'–25°03'S; 47°25'–47°55'W), estado de São Paulo, Brasil, em áreas de floresta de restinga, entre agosto de 2008 e julho de 2009. Foram coletadas informações sobre 613 amostras de comportamento de forrageamento, através do método animal-focal, mantendo-se um intervalo mínimo de 5 minutos entre cada observação, com o objetivo de caracterizar o comportamento de forrageamento de *Phylloscartes kronei*. Esta espécie captura suas presas principalmente em folhas verdes, entre 0,5 e 15 m acima do solo, utilizando a manobra investir-atingir. Em 40 ocasiões foi possível identificar as presas capturadas, incluindo representantes das ordens Lepidoptera, Orthoptera e duas espécies de frutos (*Clusia criuva* e *Ternstroemia brasiliensis*).

Abstract. – This study was conducted at Ilha Comprida (24°20'–25°03'S; 47°25'–47°55'W), São Paulo state, Brazil, in areas of restinga forest between August 2008 and July 2009. A total of 613 foraging maneuvers were observed, keeping a minimum of five minutes between each observation, with the aim of characterizing the foraging behavior of *Phylloscartes kronei*. This species captures prey mainly with sally-strikes on green leaves between 0,5 and 15 m above the ground. On 40 occasions, it was possible to identify the captured prey, which included Lepidoptera, Orthoptera, and two species of fruits (*Clusia criuva* and *Ternstroemia brasiliensis*). Accepted 30 August 2011.

Key-words: Restinga Tyrannulet, *Phylloscartes kronei*, feeding habits, foraging tactics, Tyrannidae.

INTRODUCTION

The Tyrannidae is represented by 215 species in Brazil (CBRO 2009) and is one of the most diverse bird families in the world. Studies on the foraging behavior of tyrant flycatchers may help to understand the adaptive radiation in this group (Fitzpatrick 1980). The genus *Phylloscartes*, which is exclusively found in forests, comprises 22 species including 13 reported in Brazil (Sick 1997, CBRO 2009, Remsen *et al.* 2009). Studies on foraging behavior are very important to understand the ecological requirements of bird species as well as to understand intra-, interspecific, and

environmental relations, among other aspects (Volpato & Mendonça-Lima 2002).

The Restinga Tyrannulet (*Phylloscartes kronei*) is a recently described species (Willis & Oniki 1992) similar to the Mottle-cheeked Tyrannulet (*P. ventralis*), but differing in several aspects, such as the color pattern of the supraloral, thighs, and neck, a shorter tail and larger beak (except the beak height of females), and mainly differences in vocal repertoire (Willis & Oniki 1992, Sick 1997, Clay *et al.* 1998). An interesting behavioral characteristic that differentiates both species is the habit of keeping the tail oriented in the same level of the body in *P. kronei*, while *P. ventralis*

keeps its tail raised (Willis & Oniki 1992, Fitzpatrick 2004). According to Willis & Oniki (1992), males are slightly larger than females and juveniles have a paler plumage than adults (Fitzpatrick 2004). The adults have a total length of about 12 cm and a body mass of 8–9 g (Willis & Oniki 1992).

The area of occurrence of the Restinga Tyrannulet is estimated to comprise 5500 km², between 23°S and 28°S (Fitzpatrick 2004, BirdLife International 2011). A total of 23% of its distribution is concentrated in protected areas (Paglia *et al.* 2004), which does not mean that protection is currently sufficient. *Phylloscartes krontzi* is distributed from the southeast coast of the state of São Paulo, with type-locality found in the city of Ilha Comprida (24°S), to the northeast of Rio Grande do Sul state (28°S), inhabiting mainly areas of lowland and restinga forests (Sick 1997, Bencke *et al.* 2000, Bencke 2001). According to Willis & Oniki (2003), individuals of this species occur up to 600 m a.s.l. in the mountains of the coast of Santa Catarina (27°S). Bornschein (2001) reports that *P. krontzi* occurs in the state of Paraná (25°S) in altitudes ranging from 0 to 150 m a.s.l. It is considered as a globally threatened species in Brazil and in the states of São Paulo, Paraná, and Rio Grande do Sul and is also classified as ‘Vulnerable to Extinction’ (IUCN 2010, Machado *et al.* 2005, Silveira *et al.* 2009, Mikich & Bérnils 2004, Marques *et al.* 2002). The restinga forest is a threatened ecosystem inserted in the Atlantic Forest which has been severely degraded and devastated (Ribeiro *et al.* 2009). As recently estimated by earlier studies, 11.73% of the original Atlantic Forest is remaining, from which only 0.47% is represented by the restinga forest. Habitat loss and fragmentation, mainly due to housing and opening of roads, degradation of the restinga habitat, and fire are the main causes of concern regarding the conservation of this species (Willis & Oniki 1992, Stotz 1996,

Develey 2004, Fitzpatrick 2004, Bencke *et al.* 2006, BirdLife International 2011). Its population has been estimated to range between 2500–9999 individuals and is declining (Fitzpatrick 2004, BirdLife International 2011). The population density of this species has been estimated at 1 pair/ha, with territories spaced between 100 and 200 m (Willis & Oniki 1992, Fitzpatrick 2004, Piacentini *et al.* 2008, BirdLife International 2011).

The Restinga Tyrannulet feeds mainly on arthropods (Willis & Oniki 1992, Fitzpatrick 2004) and rarely eats fruits (Fontana *et al.* 2003, Sigrist 2005, Staggemeier 2008). Although little is known about the foraging behavior of the Restinga Tyrannulet, a better understanding of this behavior could indicate whether this species will survive in degraded environments, and if so, how it may respond to high levels of degradation.

To date, there have been only two specific publications on the Restinga Tyrannulet (Willis & Oniki 1992, Remold & Ramos-Neto 1995) and, in addition to these, there is information about the species in other references not dedicated directly to this bird (e.g., Collar *et al.* 1992, Sick 1997, Fontana *et al.* 2003, Sigrist 2005, Staggemeier 2008). Given the presented scenario, few data exist on the natural history of *P. krontzi*. Therefore, our study aimed to gather detailed results on the natural history of this threatened species, i.e., characterizing its foraging behavior.

METHODS

Study area. This study was conducted from August 2008 to July 2009 at Ilha Comprida (24°20′–25°03′S; 47°25′–47°55′W), São Paulo state, Brazil, located in the IBA (Important Bird Area) SP12 “Ilha Comprida e Cananéia” (Bencke *et al.* 2006), in areas of restinga characterized as lowland forests on sandy soils near the coast. Ilha Comprida is a 74 km long island, with a width varying between

2 and 4 km and its limits are imposed by the Barra do Icapara (north) and Barra de Cananéia (south), totaling up to 20,000 ha of area (Besnard 1950, SEMA 1989). The extent of the study area was approximately 15 km². The vegetation of the island is composed by mangrove and restinga formations (Kirizawa *et al.* 1992). The average annual temperature is 24.3° C and average annual rainfall is 2300 mm, classifying it as Af climate *sensu* Koeppen (CEPAGRI 2010).

Foraging behavior. In the present study the authors defined foraging behavior of the target species as the complex set of behaviors designed to obtain food or any movements that culminate in the capture of prey (see Williamson 1971, Hartley 1985). From August 2008 to July 2009, data were collected on a monthly basis (5 to 17 days each month), totaling 392 hr of observations distributed in 142 days of sampling. Active search was carried out looking for individuals of *P. krontei* between 05:00 h and 18:00 h. Efforts were mainly concentrated before sunrise and 10:00 h, as well as in the late afternoon between 16:00 h and 18:00 h. The main aim was to collect information on the foraging behavior with the use of binoculars (10x42). The individuals were observed using the focal-animal method (Altmann 1974, Martin & Bateson 1986). Each individual was followed for as long as possible. Foraging tactics were observed keeping a minimum of five minutes between each observation, so that they were considered independent as proposed by Alves and Duarte (1996). Any attempt to capture, regardless of success, was treated as a sample of foraging (see Fitzpatrick 1980). In each sampling period, an effort was made in order to sample as many individuals as possible, by visiting a large area with at least 50 pairs of the studied species.

The maneuvers were classified according to Remsen & Robinson (1990), and the following parameters were reported for each observation: substrate (tree, shrub, or herbaceous), substrate characteristics (presence of green leaves, dry leaves, and/or twigs), the position of the bird in the substrate (indoor/outdoor canopy), starting perch (characteristics, height, inclination - horizontal = between 0° and 15°, inclined = between 16° and 70°, vertical = between 71° and 90°), returning perch (characteristics, height, and inclination), prey-capture substrate (air, green leaf, dead leaf, branch, inflorescence; height), distance from starting perch to returning perch, distance to prey and from the prey to new perch, prey height location, identification of the prey (when possible), return (or not) to the starting perch, maneuver used to capture the prey, and, in case of aerial maneuvers, the inclination and direction of flight. The heights above the ground and the inclination and direction of flight were visually estimated. The distances were estimated based on the total length of the Restinga Tyrannulet. Whenever possible, intervals between catches were reported with the objective of determining the frequency of prey capture.

To quantify the availability of prey-capture substrates in the study area, a 4.5 m long rod was used, and all vegetable elements that reached the stick were accounted in four different height classes: 0.01–1 m; 1.01–2 m; 2.01–3 m; > 3.01 m. Besides, the availability of green leaves, branches, and dead leaves on the environment were evaluated. It was not possible to split branches with green or dry leaves, due to the difficulty of observing these characteristics in the field during the collection of data on foraging behavior. This methodology was adapted from Sutherland *et al.* (2004).

Statistical analysis. The software Bioestat 5.0 (Ayres *et al.* 2007) was used to perform statis-

tical analysis. For all statistical analysis, fixed values of $\alpha = 0.05$ were established to evaluate the results gathered. When investigating the relationship between foraging height and height of the tree where individuals were foraging, a Pearson's Correlation analysis was conducted. We considered the null hypothesis (H_0) that there is no relationship between the variables tested.

When investigating the relationship between foraging behavior and season (reproductive and non-reproductive), comparisons between the frequency of maneuvers used to capture prey, the prey-capture substrates, the food handling, and the period of the year (reproductive and non-reproductive) were conducted. In this case, the null hypothesis (H_0) was that there is no difference on these three aspects over the year. This hypothesis was tested using chi-square tests. In the present study, September to December accounted for the reproductive season and the remaining months represented the non-reproductive season, as suggested by Fitzpatrick (2004).

RESULTS

Individuals of the Restinga Tyrannulet were observed during all months of the year in Ilha Comprida, confirming the resident status. A total of 613 foraging maneuvers were observed. The studied species foraged mainly in trees and shrubs with green leaves (97.5% of total events) between 0.5 and 15 m above the ground (mean \pm SD = 4.1 m \pm 2.4, median = 3.5 m). Approximately 79.6% of all captures were held into the trees and bushes, and the species used preferentially branches with green leaves as starting and returning perches (79.1% and 80.1%, respectively). The height of the starting perches ranged from 0.7 to 15 m (mean \pm SD = 4.0 \pm 2.3 m, median = 3 m), while the height of returning perches ranged from 0.5 to 15 m (mean \pm SD = 4.0 \pm

3.4 m, median = 3 m). Most of the perches employed (86.8%) were inclined branches, with only a small proportion being represented by horizontal and vertical branches.

The Restinga Tyrannulet used mainly sally-strikes (63.3% of the total foraging samples) to capture prey in green leaves (71.3% of the prey-capture substrates), both in the abaxial and axial face of the leaves. Most flights directed to the prey were tilted oriented (81.2%). A total of 10.6% of flights had horizontal direction and 8.2% were vertical. A total of 65.7% of flights had tilted orientation up, while 24.0% were down, 5.8% were horizontal, 0.7% were oriented vertically downward, and 3.8% were vertically upward. The maneuvers and prey-capture substrates are presented in Tables 1 and 2, respectively. The distance from the starting to the returning perches ranged from 2 cm to 6 m (mean \pm SD = 41.1 \pm 66.6 cm, median = 25 cm), from the bird to prey ranged from 1 cm to 3 m (mean \pm SD = 29.6 \pm 28.5 cm, median = 25 cm) and from prey to new perch ranged from 0 to 6 m (mean \pm SD = 38.4 \pm 67.3 cm, median = 25 cm). In only 19.6% of the aerial maneuvers, individuals returned to the starting perch ($n = 449$). The prey were caught between 0.7 and 15 m above the ground (mean \pm SD = 4.2 \pm 2.4 m, median = 3.5 m).

The heights of foraging had a significant relationship with the height of the tree ($r^2 = 0.88$, $P < 0.001$), indicating that the studied species is not a specialist in foraging at certain heights in the environment. There was no significant difference in the frequency of maneuvers ($P = 0.082$, $\chi^2 = 15.33$), prey-capture substrates ($P = 0.103$, $\chi^2 = 7.72$), and forms of food handling ($P = 0.590$, $\chi^2 = 1.91$) when comparing the reproductive and the non-reproductive seasons.

On 40 occasions, it was possible to identify the captured prey: six adult undetermined insects, an adult Lepidoptera (Heterocera), two Orthoptera (one undetermined and one

TABLE 1. Maneuvers used by the Restinga Tyrannulet (*Phylloscartes krontei*) for prey capture in the areas of restinga forest, Boqueirão Sul, Ilha Comprida, SP, Brazil, between August 2008 and July 2009. The nomenclature follows Remsen & Robinson (1990).

| Maneuvers | Percentage of total maneuvers (n = 613) |
|--------------|--|
| Glean | 3.4% (n = 21) |
| Hang-down | 0.2% (n = 1) |
| Hang-up | 0.5% (n = 3) |
| Lunge | 10.1% (n = 62) |
| Reach-down | 0.6% (n = 4) |
| Reach-out | 6.2% (n = 38) |
| Reach-up | 5.7% (n = 35) |
| Sally-hover | 7.7% (n = 47) |
| Sally-pounce | 2.3% (n = 14) |
| Sally-strike | 63.3% (n = 388) |

Anaulacomera sp., Tettigoniidae, Phaneropterinae; the latter escaped and was collected for later identification), 29 insect larvae (26 of Lepidoptera with length ranging from 1 to 3 cm; mean \pm SD = 1.53 ± 0.66 cm), and two fruits. In 84.6% of occasions, the larvae were smashed against a branch, in 3.8% they were gulped, and it was not possible to observe the food handling in the remaining occasions. Caterpillars accounted for 4.2% of food items captured and 65% of all items identified in the field. Five of the captured larvae contained numerous bristles on the back, and in these cases, individuals of *P. krontei* just beat these prey against a branch a few times before swallowing. In one of the frugivory events, the individual ingested a seed of *Clusia criuva* (Clusiaceae) and in the other an individual ingested a seed of *Ternstroemia brasiliensis* (Theaceae). In 93.6% of all feeding events, the food handling (n = 613) consisted of engulfing, in 3.9% of gulping, in 2.3% of the events prey were smashed against a branch, and in 0.2% of the events the birds shook the prey. On four events, individuals captured two prey items in a sequence in the same aerial maneu-

TABLE 2. Prey-capture substrates of the Restinga Tyrannulet (*Phylloscartes krontei*), Boqueirão Sul, Ilha Comprida, SP, Brazil, between August 2008 and July 2009.

| Prey-capture substrates | Percentage of total prey-capture substrates (n = 610) |
|-------------------------|--|
| Air | 18.7% (n = 114) |
| Green leaves | 71.3% (n = 435) |
| Dead leaves | 0.2% (n = 1) |
| Branches | 9.5% (n = 58) |
| Inflorescences | 0.3% (n = 2) |

ver. On an isolated event, three prey items were captured in the same flight.

In 63.6% of occasions (n = 303 observations), *P. krontei* foraged in pairs, on 29.0% alone, and during the remaining time (7.4%) in groups of three or four individuals, including pairs with one or two young that had already left the nest. The average capture rate was 2.12 captures/min, and the intervals between captures ranged from 1 s to 122 s (mean \pm SD = 20.9 ± 19.0 s, median = 15 s, n = 360). The frequency of prey capture in the non-reproductive season was 1.91 captures/min, and there was a 25% increase on the frequency of captures during the reproductive season (2.40 captures/min). This observation may be related to the capturing of prey to feed the nestlings.

DISCUSSION

Although Remsen & Parker III (1984) considered a species as a specialist in one behavior only when the latter has at least 75% attendance, the Restinga Tyrannulet seems to be a specialist in using sally-strikes to capture prey on green leaves. However, if we consider the available prey-capture substrates in the environment, the green leaves were the most abundant resources (50%) (Table 3). The predominance of tilted upward flights

TABLE 3. Availability of prey-capture substrates by the Restinga Tyrannulet (*Phylloscartes keronei*) in the areas of restinga forest, Boqueirão Sul, Ilha Comprida, SP, Brazil.

| Height classes | Prey-capture substrates | | |
|----------------|-------------------------|-----------------|---------------|
| | Green leaves | Branches | Dead leaves |
| 0.01–1 m | 51.19% (n = 43) | 42.86% (n = 36) | 5.95% (n = 5) |
| 1.01–2 m | 50% (n = 14) | 50% (n = 14) | 0% (n = 0) |
| 2.01–3 m | 53.66% (n = 22) | 46.34% (n = 19) | 0% (n = 0) |
| 3.01–4,5 m | 58.98% (n = 46) | 41.02% (n = 32) | 0% (n = 0) |

was also observed in the Minas Gerais Tyrannulet (*P. roquettei*) (Maldonado-Coelho 2009).

According to Willis & Oniki (1992) and Fitzpatrick (2004), the Restinga Tyrannulet forages alone or in pairs, capturing prey on the leaves of small trees and shrubs. The species performs maneuvers ‘sally,’ ‘snatch,’ and ‘hover-glean’ to capture prey on the surface of leaves, running short-distance attacks (Fitzpatrick 2004). The maneuver ‘sally’ is the primary maneuver used by individuals of the Restinga Tyrannulet in Ilha Comprida. According to Sigrist (2005), the Restinga Tyrannulet uses the canopy of the forest, alone or in pairs, following mixed flocks in search of insects and a few fruits. Naka *et al.* (2000) showed that the species forages from 1 to 4 m above the ground in small trees, capturing prey on exposed branches. Unlike observed by those authors in Santa Catarina, we found that in Ilha Comprida the species forages mainly into the canopy, reaching heights of 15 m above the ground. Clay *et al.* (1998) observed that the species actively forages in the canopy of low trees. According to BirdLife International (2011), individuals of the species use ‘gleaning’ and ‘sally’ to capture prey. The maneuver ‘gleaning’ in the present study corresponded to only 3.4% of the total catch (n = 613), meanwhile the maneuver ‘sally’ was the most used one by the species to capture prey. The latter is the most frequent maneu-

ver used by species of the genus *Phylloscartes* (Fitzpatrick 2004).

The foraging heights observed in this study agree with those of other species of the genus *Phylloscartes* (see Narosky & Yzurieta 1987, Robbins *et al.* 1987, Parker III 1992, Ridgely & Tudor 1994, Willis & Oniki 2003, Fitzpatrick 2004, Sigrist 2005, Maldonado-Coelho 2009). As observed for the Restinga Tyrannulet in the present study, several species of *Phylloscartes* often capture their prey in leaves and twigs (see Fitzpatrick 2004), and the food items observed in this study are similar to those reported to other related species. Arthropods are the most frequent prey of most species of the genus *Phylloscartes* (see Fitzpatrick 2004), and few species so far have been observed feeding on fruits. The Rufous-browed Tyrannulet (*Phylloscartes superciliaris*) eventually feeds on fruits of *Miconia* (Melastomataceae) and *Trema* (Ulmaceae) (Fitzpatrick 2004). Guerra & Marini (2002) found *P. ventralis* feeding on fruits of *Struthanthus concinnus* (Loranthaceae) which were collected using the gleaning maneuvers. Martins *et al.* (2007) reported that *P. ventralis* feeds on fruits of *Trichilia clausenii* (Meliaceae), consuming parts of the fruit pulp. According to Sigrist (2005), the Serra do Mar Tyrannulet (*P. difficilis*) and the Bay-ringed Tyrannulet (*P. sylvicolus*) can ingest small fruits. Pineschi (1990) recorded *P. ventralis* feeding on fruits of *Rapanea lineata* and *P. difficilis* feeding on fruits of three species of *Rapanea* (*R. gardneriana*, *R.*

lineata and *R. villosissima*). To date, only two species of fruits, *Myrcia pulchra* (Myrtaceae) and *Schinus* sp. (Anacardiaceae), were identified in the diet of *P. kromei* (Fontana *et al.* 2003, Staggemeier 2008). The present study adds two species of fruits consumed by the Restinga Tyrannulet (*Clusia criuva*, *Ternstroemia brasiliensis*).

Few species of *Phylloscartes* have been studied in detail concerning their foraging behavior. Gabriel & Pizo (2005) showed that the Oustalet's Tyrannulet (*P. oustaleti*) captures its prey predominantly on leaves, mainly using sally-strikes, similar to that observed for *P. kromei* in this study. For the Bahia Tyrannulet (*P. beckeri*), Gonzaga & Pacheco (1995) reported that individuals foraged between 6 and 12 m above the ground. Most of the maneuvers were sally-hovers oriented sideways or slightly upwards, semicircular, and flights were up to 50 cm long. Most of the catches were made at/near leaves and branches of trees in the periphery, where they collected small insects. Collar *et al.* (1992) provided data on the foraging behavior of the Alagoas Tyrannulet (*P. ceciliae*), reporting that this species forages between 6 and 15 m above the ground, capturing prey in rapid movements directed towards the axial and abaxial surface of leaves, similar to that observed for *P. kromei* in the present study. A detailed study of the foraging behavior of the Minas Gerais Tyrannulet (*P. roquettei*) was performed by Maldonado-Coelho (2009), and samples were collected concerning 91 events of prey capture. In this last mentioned study, it was found that the species has a preference for capturing prey in green leaves, using short flights inclined upward and sally-strikes. Several parameters for the Minas Gerais Tyrannulet (*P. roquettei*), especially the techniques used to capture prey and prey-capture substrates, show a strong resemblance to those found in the present study for the Restinga Tyrannulet.

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