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Source: Journal of Orthoptera Research, 24(2) : 55-58

Published By: Orthopterists' Society

URL: <https://doi.org/10.1665/034.024.0203>

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The little walking leaves from Iguazú National Park (NE Argentina) – comparisons between subtropical and tropical *Typophyllum* species (Orthoptera: Tettigoniidae: Pterochrozinae)

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Abstract

In the woods around the famous Iguazú Waterfalls were discovered numerous individuals of a little walking leaf identified as *Typophyllum inflatum*, a species long ago described from Bolivia, and apparently never reported again. So far this population represents the southernmost known record of katydids comprising the leaf-mimicking family group Pterochrozinae or Pterochrozini. Males of *T. inflatum* produce a continuous low-ultrasound pure-tone song, which could reveal the presence of this species in other areas with suitable habitat. This song is astonishingly similar to that of *T. erosifolium*, an allopatric species distributed in northwestern South America. *Typophyllum inflatum* shares with other *Typophyllum* species the pre-copulatory riding of the tiny male on the much bigger female, but this occupies only a few hours compared to up to several days in a species from Ecuador. This could be related to a possibly lower predation pressure in the subtropical region. The same may be true of the lower variability of body color, unless this only reflects adaptation to a drier environment. In contrast to tropical species, *T. inflatum* in northeastern Argentina most likely is seasonal, with adults probably appearing during the south-hemispherical summer.

Key words

Bioacoustics, camouflage, color polymorphism, katydids, leaf mimicry, mating behavior, Pterochrozini

Introduction

The leaf-mimicking specialists of the neotropical katydid subfamily Pterochrozinae, also considered as a tribe in the subfamily Pseudophyllinae (Braun 2015a), are distributed from southern Mexico to Bolivia and Brazil. In 2011 a species of the genus *Typophyllum* was found in Iguazú National Park in the northeastern corner of Argentina in the province of Misiones, this being the first record of Pterochrozinae for the country. *Typophyllum* is by far the most diverse of the 14 genera of the group, with around 30 known species distributed over tropical South America. During the day reposing *Typophyllum* individuals are almost indistinguishable from a fallen leaf, but at night, with extended legs and raised antennae, and with the aid of a lamp, they can be found in the understorey vegetation. The species in Iguazú was identified as *T. inflatum* Vignon 1925, so far known just from a very few specimens from low elevations in eastern Bolivia: one male and two female types of *T. inflatum* and synonym *T. gibbosum* (Vignon 1925). In addition, there are three specimens belonging to the collection of the University of Michigan Museum of Zoology: two males, also from Bolivia east of the Andes, collected before 1930 (by the naturalist Joseph/José Steinbach) and in 1956 respectively (photos in Eades *et al.* 2015), and one female from southern Brazil collected in 1962 (among undetermined *Typophyllum* specimens on loan to the author). Although this latter

record from Matelândia in the state of Paraná is only 60-70 km away from Iguazú, it was surprising to find a little walking leaf during an Orthoptera survey. Revealed by its continuous low-ultrasound calling song, the species seems to be fairly common in primary forest. These findings are presented here, including a description of the song and observations on the curious mating behavior, and concluding with some comparisons with little walking leaves from tropical montane rainforest in Ecuador (Braun 2015b). A redescription of *T. inflatum* will be provided in a paper comprising all katydids found during the 2011 Iguazú survey (in prep.).

Investigation area and methods.—Fieldwork in the Parque Nacional Iguazú occurred in 2011, February 15 – March 4, and during a second visit in 2012, February 15 – March 3 (both times with subsequent recordings and mating observations of captured insects in the author's apartment). Accommodation was in the C.I.E.S. (Centro de Investigaciones Ecológicas Subtropicales), right at the starting point of Sendero Macuco, a 3.5 km long forest trail running at some distance parallel to the Río Iguazú up to a lookout point about 4 km downstream of the cataracts. Searching for katydids was mostly along this trail between dusk and midnight, using a headlamp. A few times the first 1-2 km of the Sendero Yacaratiá were also searched, a nearby dirt road through the forest, joining the other trail at the common endpoint. Temperatures around midnight were 23-25 °C. Captured individuals were accommodated in cubic mesh screen cages with 30 cm edge length (BioQuip Products) and provided with twigs, herbs and cucumber pieces. For acoustic monitoring a heterodyne ultrasound detector D200 (Pettersson Elektronik) was used. Sound recordings were made with an ultrasound detector D1000X (Pettersson Elektronik), using sample frequencies of 100 and 200 kHz. Recordings were made in the field but more particularly with males singing inside the cages. Sound analysis was by Avisoft-SASLab Pro (Avisoft Bioacoustics). Photos of all mentioned species in this paper, high-resolution photos of pinned specimens of *T. inflatum*, sound recordings of *T. inflatum* and the Ecuadorian *Typophyllum* species, as well as maps with point data of collected specimens are available in Orthoptera Species File Online (Eades *et al.* 2015).

Results

The katydids.—Walking at night along the Macuco and Yacaratiá trails, 16 males and 12 females of *Typophyllum inflatum* were found. As typical for the genus, the tiny males are of only about half the size of the large females, with a length of tegmina 13-15 mm vs 24-27 mm (Fig. 1A,B). There was also seen one male nymph, probably subadult (Fig. 1F). The coloration is variable, ranging from different

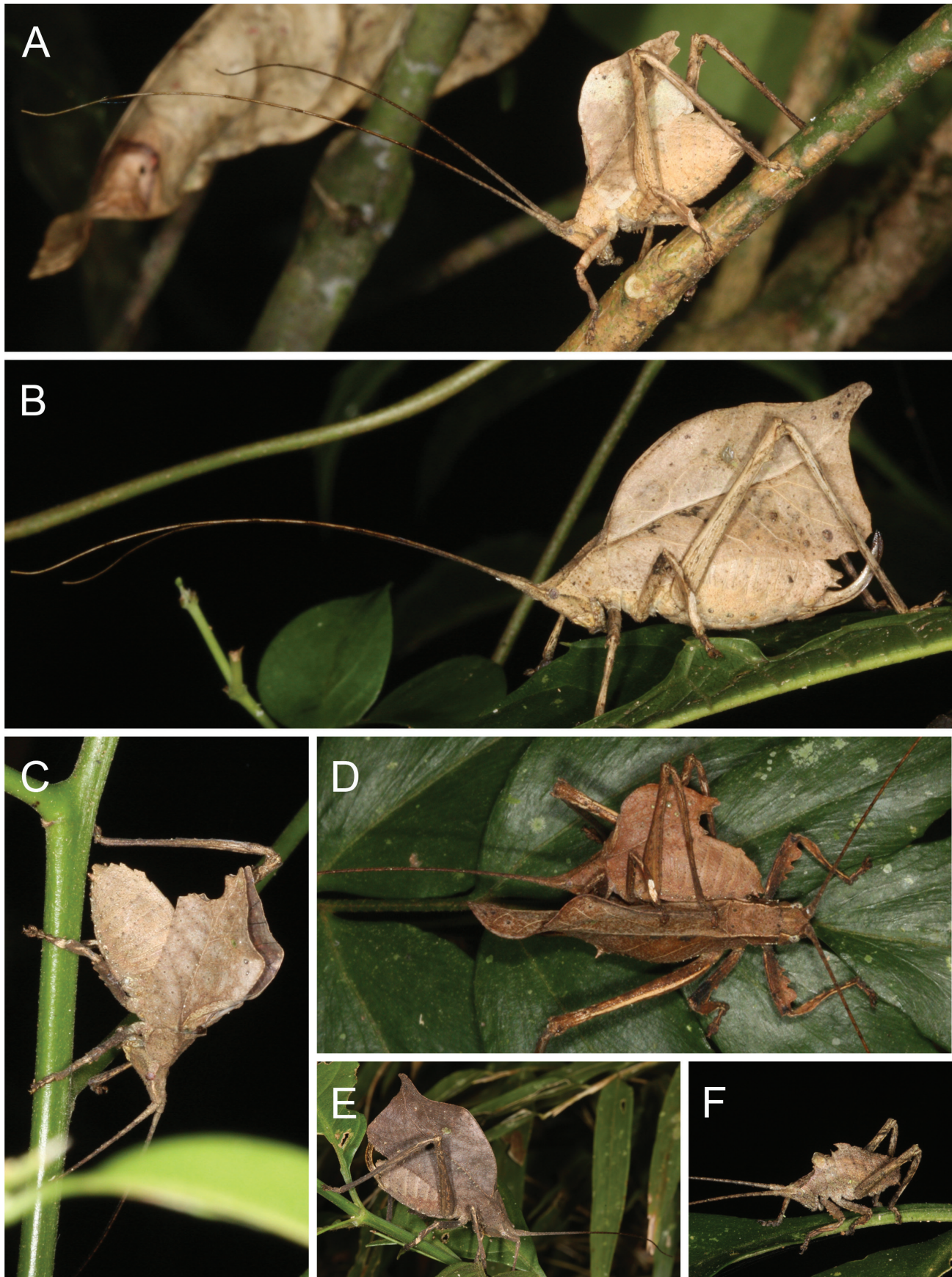


Fig. 1. *Typophyllum inflatum* individuals as found at night in the forest: A,B. male and female to same scale (the species name refers to the distally inflated lower margin of the female's tegmina); C. calling male; D. pair with male in piggyback position, female in dorsal view; E. dark brown female; F. male nymph. For color version, see Plate II.

shades of light brown to dark brown, sometimes with light patches on darker tegmina (Fig. 1A-E). All individuals were found low in the understorey, 30 cm to 1.5 m above ground. They were usually standing on twigs of woody vegetation, bushes or small trees, and never on herbaceous vegetation. On one occasion a pair was found on a fern (but on the way to a broad-leaved bush, Fig. 1D). Some of the individuals, all caught as adults, lived on for considerable time: one male four months, another almost six months, and a third over six months. A female lived almost four more months.

Song.—Numerous sound recordings of at least 10 different males were made. The calling song is very continuous, performed over minutes, with very few pauses. It consists of double pulses with a mostly regular repetition rate (Fig. 2A). The length of the individual pulses at 25°C ranges from 25 to 40 ms, with the second one sometimes being slightly shorter (Fig. 2B,C). The spectrum shows a very sharp peak, slightly varying between individual males, at 20–21 kHz, 21–22 kHz, or 22–23 kHz, hence entirely in the ultrasound (Fig. 2D). Over an individual pulse there occurs an oscillating frequency modulation with amplitude of 1–2 kHz (Fig. 2E). At very close distance to a calling male (up to 1 or 1.5 m in a quiet environment) a very faint and unlocalizable whistling is perceptible to the unaided ear, probably corresponding to the very low peak above 10 kHz, which seems to be a suppressed fundamental frequency. Males start to call shortly after nightfall. Listening with the small heterodyne bat detector, numerous males could be heard calling in the forest – sometimes even two males from the same spot. Often it was impossible to hear distantly calling males, drowned by loud broadband noise from large cone-head katydids (*Neoconocephalus* sp.) calling at the side of the trail and from clearings. Otherwise it

might have been possible to detect at least one calling *Typophyllum* male from any spot within the woods.

Mating behavior.—One pair, with the male riding sideways on the female, was found in the forest at 8:30 p.m. (Fig. 1D). Also in the forest a female was found with a spermatophore and a nearby male at 10:45 p.m. At least ten matings of caged individuals were observed. In the piggyback position the small male sits perpendicularly on one side of the female's tegmina, in line with the main radial vein, the head and antennae directed rearward. The time males spent in this position ranged from at least 40 minutes to slightly over 3 hours, mostly 2–3 hours. After this time the male descended and the pair copulated. According to two observations the transfer of the spermatophore took 20 minutes to 1 hour. Sometimes males resumed calling shortly afterward. In two cases the males descended without copulation, respectively after about 4.5 hours and 2 days of riding.

Discussion

Bioacoustics.—The generation of almost pure tones just above the 20 kHz-boundary to ultrasound is typical of forest-dwelling *Typophyllum* species (discussed in Braun 2015b). Moreover, the song of *T. inflatum* is very similar to the one of *T. erosifolium*, distributed in Colombia, Ecuador and Peru (op. cit.). Both species call untiringly, producing continuous series of double pulses over minutes. The relative repetition rates of these double pulses are identical, but *T. inflatum* sings "faster". Comparing two recordings made at the same temperature of 23°C, for 20 double pulses a male of *T. inflatum* needed 6 seconds, in contrast to a male of *T. erosifolium* which required 9 seconds. Such similarities in allopatric species are

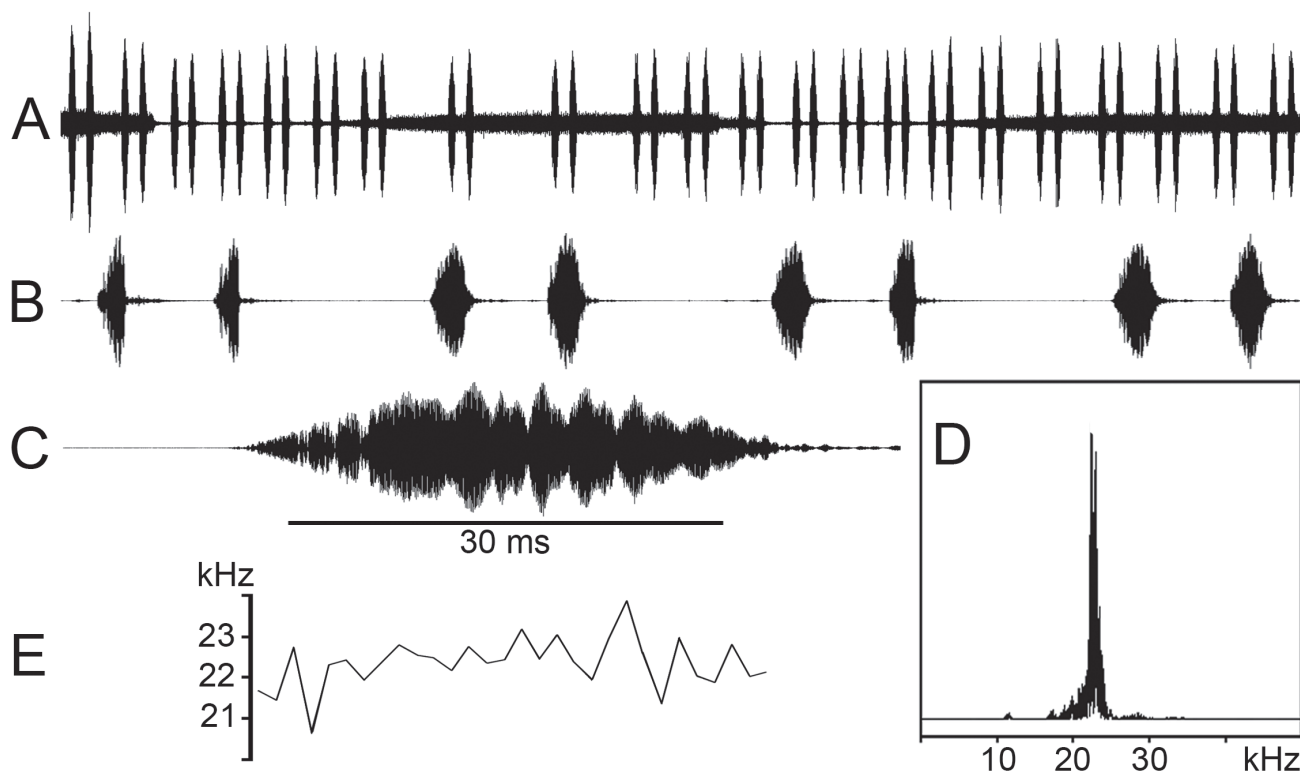


Fig. 2. Song of *Typophyllum inflatum*: A. 7-second oscillogram fragment of field recording (different katydid species calling in background), Sendero Macuco, 11 February 2011, around 10:00 p.m., 25.5°C (recording M00045); B. 1-second fragment of continuous calling of different male in cage, 25°C (M00167); C. one pulse from this recording; D. linear spectrogram; E. zero-crossing analysis of pulse in C.

already reported for crickets, with similar songs in different *Anaxipha* species from Panama and Ecuador, and also from two *Phyllolpalpus* species from Panama and Argentina (Riede 2009).

The slight oscillatory frequency modulation must be related to an oscillation of tooth density along the stridulatory file. Such alternating changes in tooth density were found in two other species of *Typophyllum*, which produce pure-tone calling songs with frequency modulation, and it has been shown that higher tooth-density corresponds to higher carrier frequency and vice versa (Montealegre-Z 2005).

Color variation and camouflage.—In some *Typophyllum* species living in tropical rainforest in Ecuador the color variation is extraordinary. In the high-elevation species *T. egregium* there occur medium or dark brown, grey and light green individuals, and sometimes different colors are mixed in the same insect, like light green with brown or reddish portions (Braun 2015b). Brown and green individuals are known also from *T. onkiosternum*, *T. erosifolium* and *T. bolivari* in Ecuador (op. cit.) as well as from *T. trapeziforme* in French Guiana (Xiberras & Ducaud 2014). In contrast *T. inflatum* individuals with different shades of brown show a rather modest variation. Only one of the females is ever so slightly greenish brown. Since one explanation for color polymorphism is to prevent the development of a "search image" by predators (as discussed in Braun 2015b), the predation pressure in the subtropical forest could be less extreme than compared to the tropics. It could also be that the little walking leaves in Iguazú have themselves simply adapted to a differently colored environment, which is much drier, comprising less vivid green plants, in comparison to Ecuadorian rainforest with its lush tropical vegetation throughout the year.

Mating behavior.—The pre-copulatory riding behavior is also typical of *Typophyllum* species (Braun 2015b). However, in *T. inflatum* the duration is very short, compared to *T. egregium* from Ecuador, where the pair never copulates on the same night the male climbs onto the female, the former remaining in piggyback position for one to several days (op. cit.). Since this behavior could be an anti-predator adaptation on the part of the female (only the male sitting on a "leaf" would be attacked), the short piggyback time could be another indication of lower predation pressure than in the tropics. So what sense can be made of this behavior when it is restricted to a short period at night and no visually oriented predators can see it? Does the female somehow assess the quality of the male, or vice versa? The few instances where male and female separated without copulation could be interpreted accordingly.

Phenology.—While in the Ecuadorian *Typophyllum* species no seasonality could be observed with adults and nymphs found throughout the year (Braun 2015b), the population in northeast Argentina is most likely seasonal. This is indicated in that practically all individuals found in February and March were adult. According to climate diagrams and tables found on the Internet, in Iguazú the mean temperatures are lower in winter, though still high enough that katydids should be able to survive. But extreme values are reported of 0°C in winter (online newspaper La Voz de Cataratas, July 2013), so it seems unlikely that the katydids can survive until August, like two males caught in February. In relicts of Selva Paranaense at the Esteros del Iberá, about 300 km further south than Iguazú, deciduous trees just start to develop leaves in September, and no forest katydids are present then, not even nymphs (pers. obs. 2015; with the bromeliads on the trees one could imagine it as good habitat for little walking leaves).

Distribution.—All *Typophyllum* species are recorded from primary forest, except for *T. mortuifolium*, which was also found in secondary growth (Morris *et al.* 1989). *Typophyllum inflatum* occurs from eastern Bolivia, most probably throughout Paraguay, certainly southern Brazil (Paraná, probably Mato Grosso do Sul), to the northeastern edge of Argentina in the north of Misiones. Unfortunately the forest seems to be severely fragmented, with only small patches left over most of the area, according to satellite photos on Google Earth. Perhaps *T. inflatum* also occurs in forest in the north of the province of Corrientes, which needs to be investigated in summer.

Another ecoregion where little walking leaves could be expected are the yungas in the Argentine Northwest. This type of montane forest is somewhat similar to montane rainforest in Ecuador, and shares several species of birds (pers. obs.). Unfortunately the access in summer appears complicated, with the steep dirt roads becoming impassable due to rainfall. If a continuously calling species of *Typophyllum* lives there, it could be detected with the aid of a bat detector tuned to 20 kHz.

Acknowledgements

Investigation and collecting permit was provided by the Administración de Parques Nacionales (Proyecto Número NEA 269 Rnv.1: Diversidad de Ortopteroides de la Selva Paranaense Argentina). In 2011 some *Typophyllum* individuals were found by the survey companions and grasshopper specialists Martina Pocco and Elio Castillo. Fieldwork in 2012 was possible while investigating with Glenn Morris the bioacoustically remarkable clear-wing katydid (*Xiphelimum*). Glenn also provided useful suggestions to improve the English, and Klaus-Gerhard Heller reminded me of the frequency modulation, which I had forgotten in the first draft.

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