

Notes on the feeding habits of a wandering spider, *Phoneutria boliviensis* (Arachnida: Ctenidae)

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Abstract. *Phoneutria* Perty, 1833 is considered one of the most toxic spider genera in the world; however, the natural history and biology of these spiders is still largely unexplored. The objective of this study was to determine the natural diet of the medically important species *Phoneutria boliviensis* (F.O.P.-Cambridge, 1897) based on prey records from Colombia, and supplemented by published records found in electronic databases as well as photographic records from the internet. We found that *P. boliviensis* is an euryphagous predator with a broad diet made up predominantly of arthropods (orders Araneae, Blattodea, Coleoptera, Hymenoptera, Lepidoptera, Mantodea, Orthoptera, and Phasmatodea) and to a lesser extent of small vertebrates (Gekkonidae, Hylidae, and Sphaerodactylidae). These results support previous evidence suggesting that *P. boliviensis* is a generalist predator that includes both invertebrates and small vertebrates in its diet.

Keywords: Colombia, diet, generalist predator, predation

Spiders are the seventh most abundant group of terrestrial predators on the planet as well as being the most diversified order (Pekár & Toft 2014). They are predators of great importance in terrestrial ecosystems where they can have significant effects on the other arthropod communities (Clarke & Grant 1968; Wilder 2011). They have been described as possible controllers of pests in crops (Sunderland & Samu 2000; Nyffeler & Birkhofer 2017). Their natural prey are mainly invertebrates—mostly springtails and other arthropods (Nyffeler & Birkhofer 2017). In addition to this, some species in the families Araneidae, Ctenidae, Nephilidae, Lycosidae, Salticidae, Sparassidae and Theraphosidae have been reported to consume small vertebrates such as lizards, frogs, fishes, bats and birds (Foelix 2010; Nyffeler & Knörnschild 2013; Nyffeler & Pusey 2014; Nyffeler et al. 2017). The possibility that spiders have for accessing different types of prey is attributed to several capture strategies that they can develop (Willemart & Lacava 2017), including the construction of webs and the use of venom to immobilize and/or kill prey (Kuhn-Nentwig et al. 2011). Spider venoms are mixtures of peptides and proteins that allow the spiders to quickly immobilize their prey, and defend themselves against possible predators (Casewell et al. 2013). So far, few studies have reported on the natural diet of venomous spiders, particularly in the Neotropical region, where feeding behavior studies have been focused mainly in some groups such as *Latrodectus* Walckenaer, 1805 (Theridiidae) and *Loxosceles* Heineken & Lowe, 1832 (Sicariidae) (Dias & Brazil 1999; Fischer et al. 2006; Pompozzi et al. 2013; García et al. 2016).

Species in the genus *Phoneutria* Perty, 1833 are considered to be one of the main groups of spiders of medical importance (Herzig et al. 2002; Foelix 2010; Torres-Sánchez & Gasnier 2010), with bites widely reported in tropical areas, particularly so in Brazil (see Herzig et al. 2002; Peralta 2013). Several studies have addressed different aspects of the biology of the

genus *Phoneutria*. Bücherl (1969), Lucas (1988), Ramos et al. (1998), and Almeida et al. (2000), have examined different aspects of activity, territorial behavior and prey, preference of ecotopes, reproduction and use of habitat, mainly from *Phoneutria nigriventer* (Keyserling, 1891).

Phoneutria boliviensis (F.O.P.-Cambridge, 1897) is a spider of medical importance with a wide distribution from Costa Rica to northernmost Argentina (Hazzi 2014). In addition, it has a powerful venom which contains a neurotoxin, similar to that produced by other *Phoneutria* spp. (Estrada-Gómez et al. 2015). In Colombia, *P. boliviensis* bites have been poorly documented. However, Flórez et al. (2003) reported 31 bite accidents in several municipalities in the department of Antioquia in one month.

Despite the importance of this group and in contrast to other medically important spiders groups such as *Loxosceles* or *Latrodectus* (see Bücherl 1969; Salomon 2011; Vetter 2015), few studies have been made regarding to the biology or natural history of *Phoneutria* spiders (Bücherl 1969; Lucas 1988; Ramos et al. 1998; Hazzi 2014) focused on observations of predatory behavior, mating and development.

Because knowledge of the natural diet provides important information on spiders' trophic ecology (Pekár et al. 2017), the aim of this research was to describe the feeding habits of the medically important wandering spider *Phoneutria boliviensis* based on field observations, a literature search, and photographic records found on the internet. Taking into account the lack of information about spiders of the genus *Phoneutria*, we expect this study will contribute to the knowledge of this important group of spiders.

METHODS

We evaluated the composition of the diet (consumed prey) in populations of *P. boliviensis*, present in rural and urban



Figure 1.—Prey reported for *Phoneutria boliviensis*. A. Phasmatoidea. B. Saturniidae (source: www.flickr.com/andreaskay/albums). C. *Phyllophaga* sp. D. *Acheta* cf. E. Orthoptera. F. Odonata remains. G. *Blatta* cf. H. *Gonatodes albogularis* (female) (source: www.flickr.com/Diegophidio/albums). I. *Ctenus* sp. J. *Periplaneta americana*. K. *Hemidactylus frenatus* (female). L. *P. boliviensis*.

areas of two localities in Colombia: Oporapa (Huila, 2°1'40.5"N; 75°59'43"W) and Ibagué (Tolima, 4°26'16"N; 75°12'02"W). Between June of 2017 and August of 2018, four field trips were made, three to Oporapa and one to Ibagué where spiders were collected on roadsides and close to coffee crops and pastures. In Oporapa four collectors sampled spiders in a 10 km² area during 12 days. In Ibagué, two collectors sampled spiders in 1 km² area during two days. Observations were made between the hours of 21:00 and 05:00, using headlights, as *Phoneutria* spiders are mainly nocturnal (Hazzi 2014). Spiders and their prey were photographed *in situ* with a Nikon D7000 digital camera, equipped with a 60 mm Nikkor lens; a millimeter paper was used as a reference to establish predator:prey size ratio using the software ImageJ (Rueden et al. 2017). We identified the sex and measured the length of the spider's body (prosoma+opisthosoma length) and the total body length of the prey when possible. When

prey remains could not be identified, these were not measured. To analyze the relationship between the spider's body length and prey size, we used a linear regression using the statistical software R version 3.5.0 (R Core Team 2018). Prey items captured by *P. boliviensis* were classified to the lowest taxonomic level allowed by their condition and grouped into morphospecies. *Phoneutria boliviensis* was identified using the key proposed by Martins & Bertani (2007) and confirmed by specialists on this group. Sampled individuals were deposited in the entomological collection of the University of Tolima.

In addition, we conducted a literature search based largely on the Thomson-Reuters data base (Web of Science), Google Search, Google Scholar, Google Books, Google Pictures, ProQuest Dissertations & Theses, Scielo.org, ScienceDirect and the hosting website Flickr image following the methodology suggested by Nyffeler & Knörnschild (2013). Three photographs were selected where *P. boliviensis* could be

Table 1.—Prey reported for *Phoneutria boliviensis* from selected electronic databases and records supporting two new distributional data for Colombia.

Location (province, country)	Habitat	Spider predator (sex)	Prey species	Relation Predator/prey length	Observation	Source
Oporapa (Huila, Colombia)	Leaf litter	<i>P. boliviensis</i> (female)	<i>Acheta</i> sp. (Gryllidae)	0.83	Field observation	This study
Oporapa (Huila, Colombia)	Rural road	<i>P. boliviensis</i> (-)	Mantidae	-	Field observation	This study
Oporapa (Huila, Colombia)	Pastureland	<i>P. boliviensis</i> (female)	<i>Phyllophaga</i> sp. (Scarabaeidae)	0.63	Field observation	This study
Oporapa (Huila, Colombia)	Rural road	<i>P. boliviensis</i> (male)	<i>Ctenus</i> sp. (Ctenidae)	0.52	Field observation	This study
Oporapa (Huila, Colombia)	Leaf litter	<i>P. boliviensis</i> (female)	<i>P. boliviensis</i> (female) (Ctenidae)	1.10	Field observation	This study
Oporapa (Huila, Colombia)	Leaf litter	<i>P. boliviensis</i> (female)	Orthoptera	1.19	Field observation	This study
Ibagué, (Tolima, Colombia)	Leaf of a living plant	<i>P. boliviensis</i> (female)	Tettigoniidae	2.18	Field observation	This study
Ibagué, (Tolima, Colombia)	-	<i>P. boliviensis</i> (female)	<i>Hemidactylus frenatus</i> (female)	3.27	Web search	This study, Valenzuela-Rojas et al. (2019)
Oporapa (Huila, Colombia)	Pastureland	<i>P. boliviensis</i> (female)	Phasmatodea	2.74	Field observation	This study
Oporapa (Huila, Colombia)	Pastureland	<i>P. boliviensis</i> (female)	<i>Periplaneta americana</i> (Blattodea)	-	Field observation	This study
Oporapa (Huila, Colombia)	Pastureland	<i>P. boliviensis</i> (female)	<i>Blatta</i> cf. (Blattodea)	0.99	Field observation	This study
Cimitarra (Santander, Colombia)	Wall of a house	<i>P. boliviensis</i> (female)	<i>Gonatodes albogularis</i> (female) (Sphaerodactylidae)	2.92	Field observation	www.flickr.com/Diegophidio/albums
Orkidea Lodge, Puyo (Heredia Pastaza, Ecuador)	Leaf of a living plant	<i>P. boliviensis</i> (female)	Saturniidae	2.14	Web search	www.flickr.com/andreaskay/albums
Reserva Biológica Tirimbina, (Heredia Province, Costa Rica)	-	<i>P. boliviensis</i>	Araneae	-	Web search	Lapinski & Tschapka (2013)
Reserva Biológica Tirimbina, (Heredia Province, Costa Rica)	-	<i>P. boliviensis</i>	Araneae	-	Web search	Lapinski & Tschapka (2013)
Reserva Biológica Tirimbina, (Heredia Province, Costa Rica)	-	<i>P. boliviensis</i>	Araneae	-	Web search	Lapinski & Tschapka (2013)
Reserva Biológica Tirimbina, (Heredia Province, Costa Rica)	-	<i>P. boliviensis</i>	Hymenoptera	-	Web search	Lapinski & Tschapka (2013)
Reserva Biológica Tirimbina, (Heredia Province, Costa Rica)	-	<i>P. boliviensis</i>	Orthoptera	-	Web search	Lapinski & Tschapka (2013)
Reserva Biológica Tirimbina, (Heredia Province, Costa Rica)	-	<i>P. boliviensis</i>	Orthoptera	-	Web search	Lapinski & Tschapka (2013)
Reserva Biológica Tirimbina, (Heredia Province, Costa Rica)	-	<i>P. boliviensis</i>	Orthoptera	-	Web search	Lapinski & Tschapka (2013)
Brazil	Leaf of a living plant	<i>P. boliviensis</i>	<i>Scinax ruber</i> (Hylidae)	-	Web search	Melo-Sampaio et al. (2012)
Costa Rica	On the floor	<i>P. boliviensis</i>	Orthoptera	-	Web search	www.alamy.com/stock-photo-brasilianische-wanderspinne-phoneutria-boliviensis-auf-dem-boden-costa-120491517.html

identified with the help of the authors of the photos (Figs. 1B, H, Table 1). In addition, the locality of Cimitarra (Santander, Colombia) was visited to identify the species of spider that was found preying on a gekkonid, because the actual individual in the picture was not examined (Fig. 1H, Table 1). All individuals collected in Cimitarra were taken to the laboratory (Universidad de Ibagué) and identified as *P. boliviensis*.

The timespan 1900–2019 was searched with the keywords—both in English and Spanish—“Wandering spiders feeding”, “*Phoneutria* feeding”, “*Phoneutria boliviensis*”, “*Phoneutria boliviensis* feeding”, “*Phoneutria boliviensis* frog”, and “predation by *Phoneutria*”.

RESULTS

The results of this study are summarized in Table 1, discriminating by field and literature records. Overall, 21 prey types were recorded; diet was composed predominantly of arthropods (86%) and to a lesser extent, small vertebrates (14%). The natural diet of *P. boliviensis* included the orders Araneae, Blattodea, Coleoptera, Hymenoptera, Lepidoptera, Mantodea, Orthoptera, and Phasmatodea. Furthermore, the diet of this spider is shown to include lizards (Gekkonidae and Sphaerodactylidae) and frogs (Hylidae). Among the spiders recorded with prey, the majority (85%) were adult spiders, with female spiders predominating (15 female vs. 2 males; Table 1). It should be added that in our study in Colombia only ~10% of the 200 observed spider individuals were found consuming a prey.

In relation to the predator:prey size ratios, we found that *P. boliviensis* is able to consume prey up to three times its body size. We found a significant relationship between spider body length and prey length ($F_{(1,9)} = 7.16$, $R = 0.663$, $R^2 = 0.440$, $P = 0.025$).

DISCUSSION

To our knowledge, this is the first study of the diet of *P. boliviensis*. Observations on the natural diet of some spider groups, particularly non-web building spiders which forage at night, might be especially difficult if no molecular approaches are available or if a scarce species is being studied (Pekár et al. 2017; Nyffeler & Vetter 2018). Literature survey of diet, including photographic records, has shown to be a very useful tool to describe rare predation events in spiders, such as the consumption of bats and fishes (see Nyffeler & Knörnschild 2013; Nyffeler & Pusey 2014).

Overall, we report *P. boliviensis* consuming 21 different species of mostly arthropods but also reptiles and amphibians. Arthropods recorded as prey for *P. boliviensis*, included several orders commonly consumed by other spiders such as Coleoptera, Lepidoptera, Orthoptera and other spiders (Nentwig 1987). Unusual prey among spiders, such as mantids and phasmids, were also consumed by *P. boliviensis*. This is particularly interesting as mantids are formidable predators able to retaliate against other predators (Brunner & Gandolfo 1990), suggesting that *P. boliviensis* is able to consume potentially dangerous prey. A similar trend is observed on the inclusion of other spiders such as *Ctenus* sp. and other individuals of *P. boliviensis*, which are considered harmful prey (Wise 2006). The inclusion of phasmids as part of the diet

is an unusual finding too, as these possess exceptional camouflage and some species are considered toxic (Nentwig 1990; Dossey et al. 2008), suggesting that *P. boliviensis* is able to overcome these defensive mechanisms.

Consumption of reptiles and amphibians by spiders has been reported in several groups, namely Lycosidae, Theraphosidae, Pisauridae, and Ctenidae (see Toledo 2005; Cortéz-Gómez et al. 2015), and is apparently a common phenomenon in the latter family (see: Bernarde et al. 1999; Armas 2001; Aucone & Card 2002; Prado & Borgo 2003; Menin et al. 2005; Toledo 2005; Barbo et al. 2009; Santana et al. 2009; Caldart et al. 2011; Moura & Azevedo 2011; Lanschi & Ferreira 2012; Fonseca & Rodríguez-Cabrera 2014; Amaral et al. 2015; Jablonski 2015; Pacheco et al. 2016; Foerster et al. 2017; Folly et al. 2017; Pedrozo et al. 2017; Villafañe 2018; von May et al. 2019). The inclusion of vertebrates in the diet of some spider species might help to meet the energy requirements of large species such as some web-building spiders (i.e., genus *Nephila* Leach, 1815) that occasionally prey on bats (Nyffeler & Knörnschild 2013). We hypothesize that *P. boliviensis* would consume vertebrates by similar reasons and might have access to prey such as vertebrates, due to the toxicity of its venom, similarly to *Latrodectus* spiders, which possess potent toxins that allow them to immobilize vertebrates (Garb & Hayashi 2013, Valenzuela-Rojas et al. 2019). Further studies should explore this topic.

Although prey were larger than spiders, we did not observe the predation on individuals larger than three times the size of the body length of *P. boliviensis*, a similar trend observed in other generalist spiders species (Nentwig 1986). However, in the case of web building spiders such as *Latrodectus* spp., the spiders are generally smaller than their lizard prey (O’Shea & Kelly 2017). Wandering spiders that are reported feeding on lizards tend to be of a similar or larger size than the reptile prey (Toledo 2005); our results partially confirm this pattern since *P. boliviensis* and lizards were similar in size.

Overall, we found that the spider *P. boliviensis* behaves as an euryphagous predator which is able to consume a wide variety of prey (Pekár & Toft 2014), mainly arthropods and also small vertebrates such as reptiles, agreeing with previous records for other spiders of the same genus (Santana et al. 2009; Pacheco et al. 2016; Foerster et al. 2017; Folly et al. 2017; Pedrozo et al. 2017; von May et al. 2019). The access to this wide variety of prey types might be possible because of the potent venom and probably a conditional prey capture strategy depending on prey type, such as it has been shown in other generalist spider species (Nentwig 1986). Given the lack of knowledge about the trophic ecology of *P. boliviensis* as well as other *Phoneutria* spiders, further studies should explore this topic as this might have important implications on understanding some relevant aspects such as the toxicity of this medically important group of spiders.

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