

Trophic interaction between *Thamnophis sumichrasti* (Squamata, Natricidae), *Isthmura gigantea* (Caudata, Plethodontidae), and *Megacormus gerstchi* (Scorpiones, Euscorpiidae)

Interacción trófica entre *Thamnophis sumichrasti* (Squamata, Natricidae), *Isthmura gigantea* (Caudata, Plethodontidae) y *Megacormus gerstchi* (Scorpiones, Euscorpiidae)

Rubén Alonso Carbajal-Márquez¹, José Jesús Sigala-Rodríguez^{1,*}, Jaime A. Escoto-Moreno¹, Leonardo Fernández-Badillo^{2,3} Fernanda Chávez-Samayoa¹ & Stephen F. Spear⁴

¹Universidad Autónoma de Aguascalientes, Centro de Ciencias Básicas, Departamento de Biología, Colección Zoológica, Aguascalientes, Aguascalientes, 20100, México.

²Predio Intensivo de Manejo de Vida Silvestre X-Plora Reptilia, Metztitlán, Hidalgo, 43350, México.

³Centro de Investigaciones Biológicas, Universidad Autónoma del Estado de Hidalgo, Mineral de la Reforma, Hidalgo, 42180, México.

⁴La Crosse, Wisconsin, USA.

*E-mail: jesus.sigala@edu.uaa.mx

ABSTRACT

We report for the first time multitrophic interaction among *Thamnophis sumichrasti* (Squamata, Natricidae), *Isthmura gigantea* (Caudata, Plethodontidae), and *Megacormus gerstchi* (Scorpiones, Euscorpiidae), three endemic, rare and endangered species that inhabit cloud forests and pine-oak forests from Sierra Madre Oriental in México, which provides novel data on their natural history and distribution.

Keywords: multitrophic interaction, prey, salamander, scorpion, snake.

RESUMEN

Reportamos por primera vez la interacción multitrófica entre *Thamnophis sumichrasti* (Squamata, Natricidae), *Isthmura gigantea* (Caudata, Plethodontidae) y *Megacormus gerstchi* (Scorpiones, Euscorpiidae), tres especies raras, amenazadas y endémicas que habitan los bosques de niebla y de pino-encino en la Sierra Madre Oriental de México, aportando nuevos datos sobre su historia natural y distribución.

Palabras clave: escorpión, interacción multitrófica, presa, salamandra, serpiente.

A key ecological characteristic of every species is their dietary niche and their potential predators, which together form the food webs of communities. Therefore, a better understanding of the identity of these links in trophic networks have the potential to reveal key information in community and ecosystem ecology (Elton 1927; Thomas 2014). By assessing species and their interactions at appropriate scales, while acknowledging that above and belowground biota are ecologically linked, conservation and restoration strategies can be improved (Van der Putten *et al.* 2004).

Detailed information on the diet and feeding ecology of many species is scarce or null, particularly for many snakes, and this is likely due to the fact that many species are rare or difficult to detect, documentation of predation events in nature are infrequent and unpredictable, and because the number of prey items found in digestive tracts of snakes housed in scientific collections is commonly low. Therefore, new diet records, even isolated, are valuable contributions to the understanding of trophic interactions in living and extinct snakes (Smith & Scanferla 2016; Guedes 2021).

Here we report for the first time the multitrophic interaction between *Thamnophis sumichrasti* (Cope, 1866), *Isthmura gigantea* (Taylor, 1939), and *Megacormus gerstchi* Díaz-Nájera, 1966. The Sumichrast's Garter Snake (*T. sumichrasti*) is a semiaquatic snake that occupies cloud forest and humid pine-oak forest and commonly associated with cascading mountain streams. It is endemic to México, distributed along the slopes of the Sierra Madre Oriental from northeastern San Luis Potosí and Querétaro to northern Oaxaca, from 1365 to 2400 m (Rossman *et al.* 1996; Heimes 2016), and is listed in the Red List of the International Union for the Conservation of Nature (IUCN) as Least Concern (Canseco-Márquez & Flores-Villela 2007), considered to be threatened (A = amenazada) in México (SEMARNAT 2010), and Highly Vulnerable according to the Environmental Vulnerability Score (15) (Johnson *et al.* 2017).

The Giant False Brook Salamander (*I. gigantea*), is a plethodontid salamander associated with cloud forest and pine-oak forest and with moist places on limestone slopes, where cracks are covered by moss (Ramírez-Bautista *et al.* 2014); it is endemic to México, distributed in Hidalgo, Veracruz and northern Puebla, from 930 to 2062 m (Badillo-Saldaña *et al.* 2015; Ramírez-Bautista *et al.* 2014; Lemos-Espinal & Dixon 2016; Frost 2021). This salamander is listed in the Red List of the International Union for the Conservation of Nature (IUCN) as Endangered (IUCN SSC Amphibian Specialist Group 2020), is not protected by the laws in México (SEMARNAT 2010), and is Highly Vulnerable according to the Environmental Vulnerability Score (16) (Johnson *et al.* 2017).

The scorpion *M. gerstchi*, is a species that use microhabitats with high relative humidity like leaf litter, outcrop crevices, moss carpets, decaying logs and caves which occurs in oak pine, cloud and evergreen tropical forest in the slopes of the Sierra Madre Oriental (González-Santillan *et al.* 2017). It is endemic to México, distributed in the states of Hidalgo, Puebla, Querétaro, San Luis Potosí, Tamaulipas and Veracruz from 800 to 2000 m (Francke 1979; González-Santillan *et al.* 2017). This scorpion is not considered in any risk category internationally or locally.

During a field survey on 27 June 2022, at 12:10 h we found an adult female *Thamnophis sumichrasti* (snout-vent length = 557 mm, total length = 683 mm; ventrals = 155, subcaudals = 57; spotted morph; UAA-REP 955) coiled on the surface on a forested hillside near a dirt road 1.2 km airline N from Huayacocotla, Municipality of Huayacocotla, Veracruz, México (20.552757°N, 98.482557°W; WGS84; 2020 m elev.). After gentle palpation the snake regurgitated

the partially digested tail (tail length = 116 mm) of a *Isthmura gigantea* (the only salamander of that size in the area), and also defecated (Fig. 1a). We recovered the scat and later analyzed it in the laboratory and found remains of arthropods including the Blattaria (pronotum and tegmina cockroach), Coleopterans of the family Curculionidae (head, elytra and thorax) and Scarabaeidae (elytra), Orthopterans of the family Acrididae (femurs, tibiae and metathoracic legs), and one scorpion *M. gerstchi*, all of them being a secondary ingestion (Fig. 1b), and assumed to be consumed in the first instance by the *I. gigantea*.

Additionally, at 13:30 on 27 June 2021, we found a juvenile male *T. sumichrasti* (snout-vent length = 420 mm, total length = 550 mm; ventrals = 158, subcaudals = 75; spotted morph; UAA-REP 948) basking on the side of a dirt road 2 km airline N from Huayacocotla, Municipality of Huayacocotla, Veracruz, México (20.548398°N, 98.486106°W; WGS84; 2091 m elev.). We palpated the snake to stimulate it to defecate, and later analyzed the scat in the laboratory. We found remains of arthropods consisting of ant heads (Formicidae), wings parasitoid wasp (Hymenoptera), and elytra of unidentified beetles (Coleoptera), that are probably secondary ingestion, however, we found no remains of the prey that consumed them, which indicates that it was probably an amphibian. The specimens and the contents were deposited at the Colección Zoológica, Universidad Autónoma de Aguascalientes (CZUAA).

This finding represents the first record of *I. gigantea* in the diet of *T. sumichrasti*, as well as the first records of the scorpion *M. gerstchi*, and Coleopterans of the family Curculionidae and Scarabaeidae in the diet of *I. gigantea*. The information on the natural history of *T. sumichrasti* is scarce. Benítez-Gálvez (1997) mentioned that it feeds mostly of leeches, earthworms, small fish, tadpoles, anurans, salamanders, small mammals and birds. However, to date, only the Leprous False Brook Salamander (*Pseudoeurycea leprosa*) (Lemos-Espinal *et al.* 2000), *Pseudoeurycea* sp. (Dixon & Lemos-Espinal 2010), the Granite-colored salamander (*Pseudoeurycea granitum*) (García-Bañuelos *et al.* 2020) and the Large-crested Toad (*Incilius cristatus*) (Cerón-De la Luz *et al.* 2020) have been reported as a prey. Similarly, little is known about the natural history of *I. gigantea*, and regarding its diet, it is known to feed on worms and beetles (Coleoptera) (Guzmán-Guzmán 2011), cave crickets, grasshoppers (Orthoptera), cockroaches (Blattaria), ants (Formicidae) (Badillo-Saldaña *et al.* 2015), and insects and their larvae, such as crickets, caterpillars, beetles, cockroaches, and bedbugs (Cázares-Hernández *et al.* 2021).

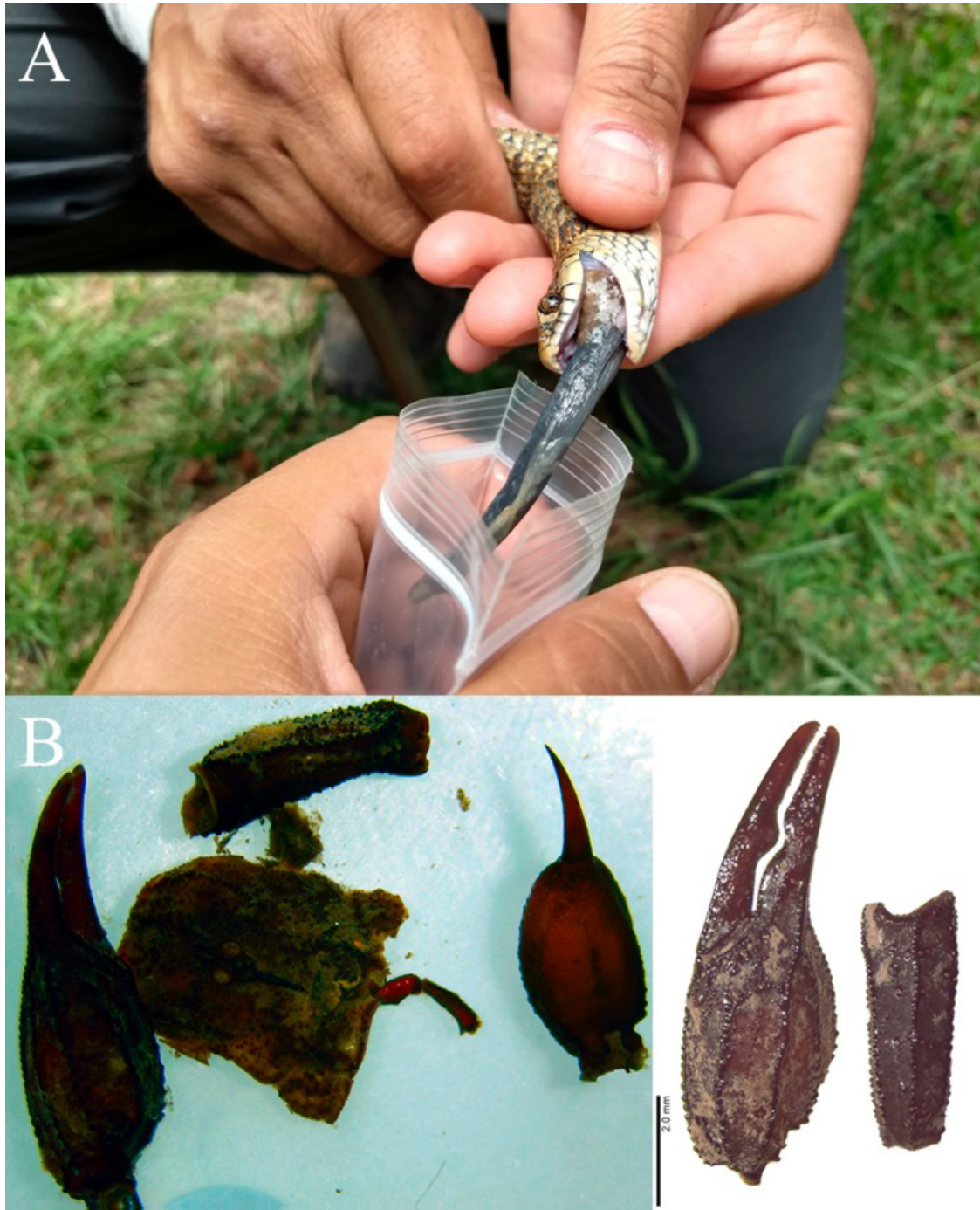


FIGURE 1. (A) Adult female *Thamnophis sumichrasti* regurgitating the tail of an *Isthmura gigantea* salamander. (B) *Megacormus gerstchi* remains found in the scat of the *Thamnophis sumichrasti* and result of the secondary ingestion by *Isthmura gigantea*. / (A) Hembra adulta de *Thamnophis sumichrasti* regurgitando la cola de una salamandra *Isthmura gigantea*. (B) Remanentes de *Megacormus gerstchi* encontrado en la excreta de la *Thamnophis sumichrasti* y resultado de la ingesta secundaria por parte de *Isthmura gigantea*.

Additionally, the encounter of *I. gigantea* and *M. gerstchi* in Huayacocotla represents new locality and municipality records for Veracruz. The record of *I. gigantea* extends the distribution 20.2 km airline to the southeast of the nearest reported locality at Sietla, Zacualtipán de Ángeles, Hidalgo (online record 41190341 provided by Naturalista, CONABIO 2022a). *Megacormus gerstchi* specifically for Veracruz, had only been previously reported for the municipalities of Soledad de Doblado and Vigas de Ramírez, and our record extends the distribution in 24.7 km airline to the southeast of the nearest reported locality at 3.5 km north of Zacualtipán, Hidalgo (González-Santillán *et al.* 2017). *Thamnophis sumichrasti* had been previously recorded for Huayacocotla (online record 71526015 provided by Naturalista, CONABIO 2022b).

These three species (*I. gigantea*, *M. gerstchi* and *T. sumichrasti*) have a distribution restricted to the pine-oak and cloud forest in the Sierra Madre Oriental, and an affinity for humid areas such as surroundings of waterfalls and streams, which facilitated this trophic interaction. However, this affinity for humid microhabitats makes them vulnerable to effects of environmental disturbances like loss of vegetation cover by deforestation, desiccation or contamination of such humid areas in addition to human persecution because they are erroneously considered harmful (Badillo-Saldaña *et al.* 2015; Cázares-Hernández *et al.* 2021).

During our surveys in Huayacocotla, we searched for amphibians and reptiles in all available microhabitats and were able to locate two *T. sumichrasti* (mentioned above), one coiled on the surface near a dirt road, and another one moving on the ground, both near small waterfalls, no *I. gigantea*, and three specimens of *M. gerstchi*, one of them under a log in a flooded area near a stream (UAA-SCO 622), and two more beneath the rocks near a small waterfall (UAA-SCO 674). Despite being a large salamander (total length up to 327 mm), *I. gigantea* is rare and usually difficult to detect, probably due to its nocturnal habits and being saxicolous, since during the day they hide under rocks, logs and in cracks (Badillo-Saldaña *et al.* 2015; Ramírez-Bautista *et al.* 2014; Cázares-Hernández *et al.* 2021). Species of the genus *Megacormus* have restricted habitats, are rare and difficult to detect (González-Santillán *et al.* 2017), which highlights the importance of dietary studies that help detect species that are rarely seen or encountered by other methods of search and capture (Schmidt 1932; Campbell *et al.* 2018), promoting a better understanding of its distribution and natural history.

Snake diet studies have reported new prey items and behaviors for several snakes, including interactions among three trophic levels (Carbajal-Márquez *et al.* 2012; Smith & Scanferla 2016; Guedes 2021), highlighting the relevance

of such studies to understand biotic interactions between snakes and their prey. Therefore, generating any information on their distribution and natural history such as microhabitats used, hours of activity, diet and trophic interactions are of utmost importance to have a better understanding of each of the species involved and to be able to generate adequate conservation strategies.

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