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CONSERVATION AND NATURAL HISTORY

Cannibalism in Cuba: First Direct Observations of Cuban Treefrogs (*Osteopilus septentrionalis*, Hylidae) Feeding on Conspecifics in Their Native Habitat, with a Brief Review of Anurophagy and Cannibalism in Treefrogs

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The Cuban Treefrog (*Osteopilus septentrionalis*) is a large hylid frog (maximum SVL to 165 mm) native to Cuba (including Isla de la Juventud), the Cayman Islands, and some of the Bahamas (Meshaka 2001). It is a very successful colonizer, whose ability to stow away as humans transport goods has allowed it to become established in the U.S. states of Florida, Georgia, and Hawaii (Oahu), as well as in many parts of the Caribbean, including Anguilla, Antigua, the British Virgin Islands (Tortola), Costa Rica (Puerto Limón), the Netherlands Antilles (Curaçao, Saint Maarten, Saba), Puerto Rico, the Turks and Caicos Islands (North Caicos), the Grenadines (Mustique), and the U.S. Virgin Islands (Henderson and Breuil 2012; Frost 2015). Because of its wide distribution, abundance, and as an introduced pest in Florida, the species' ecology has been studied quite well (e.g., Meshaka 2001). Nevertheless, its natural history in its native habitat is not known as comprehensively. Thus, even limited observations are of interest. We here report on the first direct observations of cannibalism by *O. septentrionalis* in its native habitat in Cuba.

Frog Eats Frog

That adult frogs opportunistically prey on other frogs is well known, and Toledo et al. (2007) reported that in their study of frogs as prey of other vertebrates, 33 of 243 records (13.6%) were frogs eating frogs. Of the frog-eat-frog incidents considered by Toledo et al. (2007), only one involved a hylid treefrog (*Hypsiboas faber*) as predator. More recently, Measey et al. (2015) showed that in 355 literature records representing 228 species, 40,238 examined frog stomachs included 855 post-metamorphic frogs (2.1%) and 855 incidences of egg or larval consumption, but that in relative terms 77 of 355 papers (22%) reported frog-on-frog predation. By this count, the authors concluded that frog-on-frog predation was not particularly unusual. Their analysis of the literature further suggested that frogs in the family Hylidae exhibited elevated levels of anurophagy (Measey et al. 2015: Fig. 1B), although no specific taxa were listed. However, reports of treefrog-on-treefrog predation have steadily accumulated over the years (e.g., *Hypsiboas albomarginatus* on *Scinax littoralis*, Centeno et al. 2010; *Hypsiboas albomarginatus* on *Dendropsophus decipiens*, Figueiredo-de-Andrade et al. 2012; *Hybsiboas faber* on *Dendropsophus meridianus*, Figueiredo-de-Andrade et al. 2012; *Hypsiboas faber* on *Scinax granulatus* and *Aplastodiscus perviridis*, Solé et al. 2004; *Hypsiboas faber* on *Scinax* aff. *perereca,* de Moura and Feio 2010; *Osteopilus septentrionalis* on *Hyla cinerea*, Johnson 2013). In the specific case of Florida populations of *O. septentrionalis*, Meshaka (2001) and Meshaka and Mayer (2005) reported that 40 of the 427 (9.4%) Cuban Treefrogs they examined had consumed anurans (41 of 1,104 prey items), whereas Glorioso et al. (2012) reported anurophagy for 29 of 767 sampled individuals (3.8%).

Frog Eats Conspecific

Cannibalism in frogs is also quite well known, and the circumstances for its occurrence among conspecific tadpoles or between tadpoles and conspecific eggs have been reported,

studied, and reviewed with some frequency (e.g., *Ranitomeya ventrimaculata*, Poelman and Dicke 2007; *Hyla intermedia*, Grant and Halliday 2011; *Leptodactylus vastus*, Silva et al. 2005, Bahiense Guimarães et al. 2015; *Peltophryne peltocephala*, Rivalta et al. 2003; *Spea bombifrons*, Pfennig et al. 1993). Crump (1992) reported that cannibalism occurred in a majority of anuran families (12 of 21 families, or 57%), and the large data set of Measey et al. (2015) included 28 of 355 records in which cannibalism was reported. Our focus on cannibalism in hylid frogs revealed only eight instances (*Acris crepitans*, McCallum et al. 2001; *Gastrotheca cornuta*, Gagliardo et al. 2010; *Hyla cinerea*, Höbel 2011; *Hypsiboas faber*, Maffei et al. 2014; *Osteopilus septentrionalis*, Herman et al. 2015, Königstedt and Königstedt 1982, Meshaka 1996a, 2001, Peters 1974, Wyatt and Forys 2004), of which four (*G. cornuta* and *O. septentrionalis* in Peters 1974, Königstedt and Königstedt 1982, and Wyatt and Forys 2004) occurred in captivity; the other records for *O. septentrionalis* were indirect records derived from analyses of stomach contents, with one consumed conspecific reported from Havana, Cuba (Meshaka 1996a), and three in Florida (Meshaka 2001). Johnson (2013) mentioned that *O. septentrionalis* is cannibalistic, but cited no evidence.

Cuban Treefrog Cannibalism in Cuba

In the following paragraphs we report on three cannibalistic encounters between Cuban Treefrogs in their native habitat. The first two are unsuccessful attempts by females to consume conspecifics, including potential suitors during a time of heightened breeding activity in the first encounter. The third episode concluded with an adult consuming a froglet.

Attempted cannibalism, female on male (Pinar del Río).— During an evening survey on 29 May 2011 in the Sierra de Guacamaya, Pinar del Río Province, Cuba (22.685491°N, 83.561904°W; datum WGS84, location specified via Google Maps), we encountered a series of adult Cuban Treefrogs involved in reproductive activity just before midnight. As we canvassed the area, we noted that one female (sex determined based on the individual's size, color pattern and absence of nuptial pads) was holding in its mouth a smaller conspecific (a male, based on color pattern and the presence of nuptial pads) in a clear display of predatory activity (Fig. 1A; 2350 h). The captive struggled as the female attempted to draw him in head-first, but rapid, continual movements by arms and legs (e.g., angled position of legs in Fig. 1B; 2356 h) coupled with considerable inflation of the lungs (Fig. 1A,B), led to its release and escape at 2357 h (Fig. 1C). The individual sus-

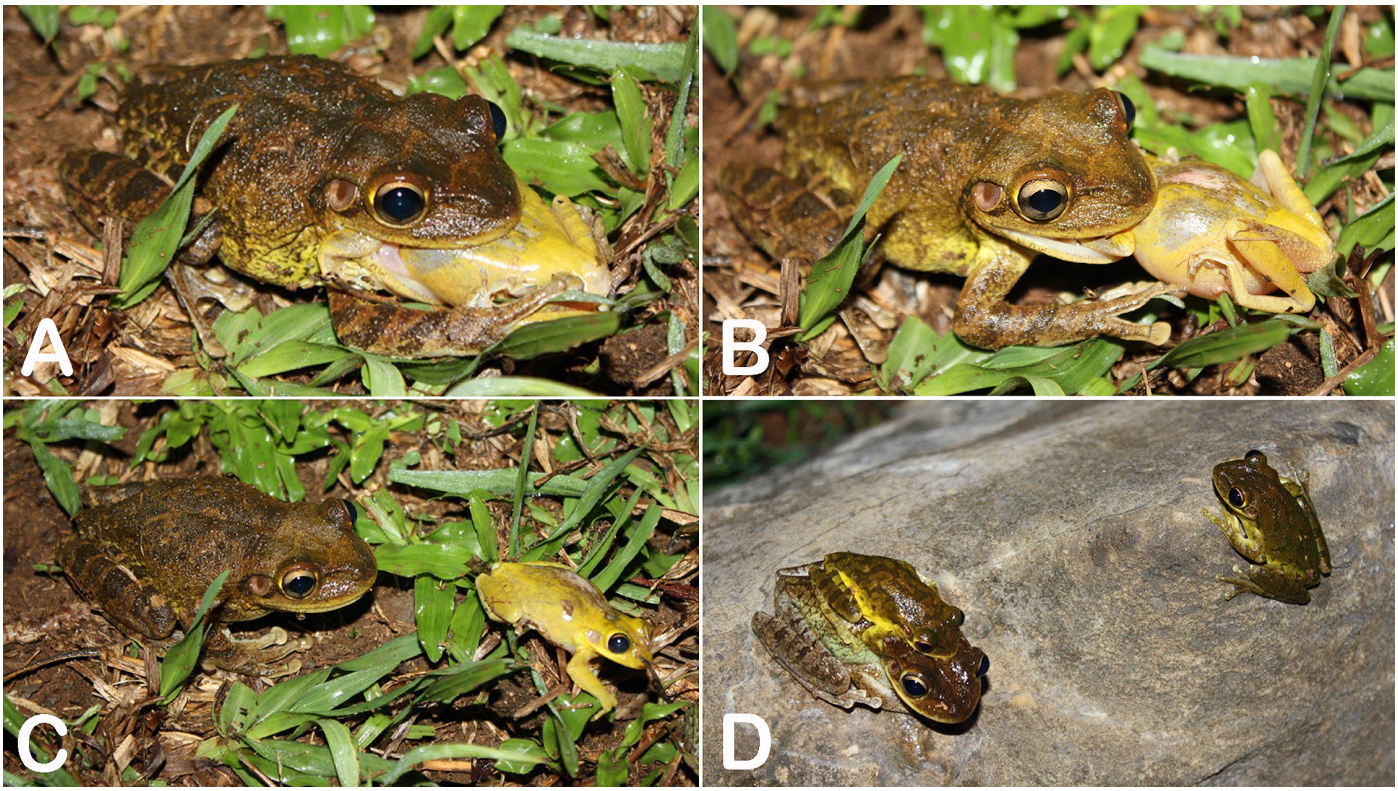

Fig. 1. (A–C) Attempted cannibalism by a female Cuban Treefrog (*Osteopilus septentrionalis*) in the Sierra de Guacamaya, Pinar del Río Province, Cuba. The series of images was taken just before midnight on 29 May 2011. In (A), the female is seen at 2350 h attempting to predate a male in breeding colors, having succeeded in drawing over half of the male's body into its maw. (B) The continuing, frantic movement of arms and legs allowed the male to back out of the female's jaws by 2356 h, albeit with a series of abrasions. (C) The male ultimately made its escape at 2357 h. (D) Nearby, several male and female Cuban Treefrogs were courting or mating. The males involved in the attempted cannibalism (A–C) and successful amplexus (D) were essentially similar in size. Photographs by Ariel Ruiz Urquiola.

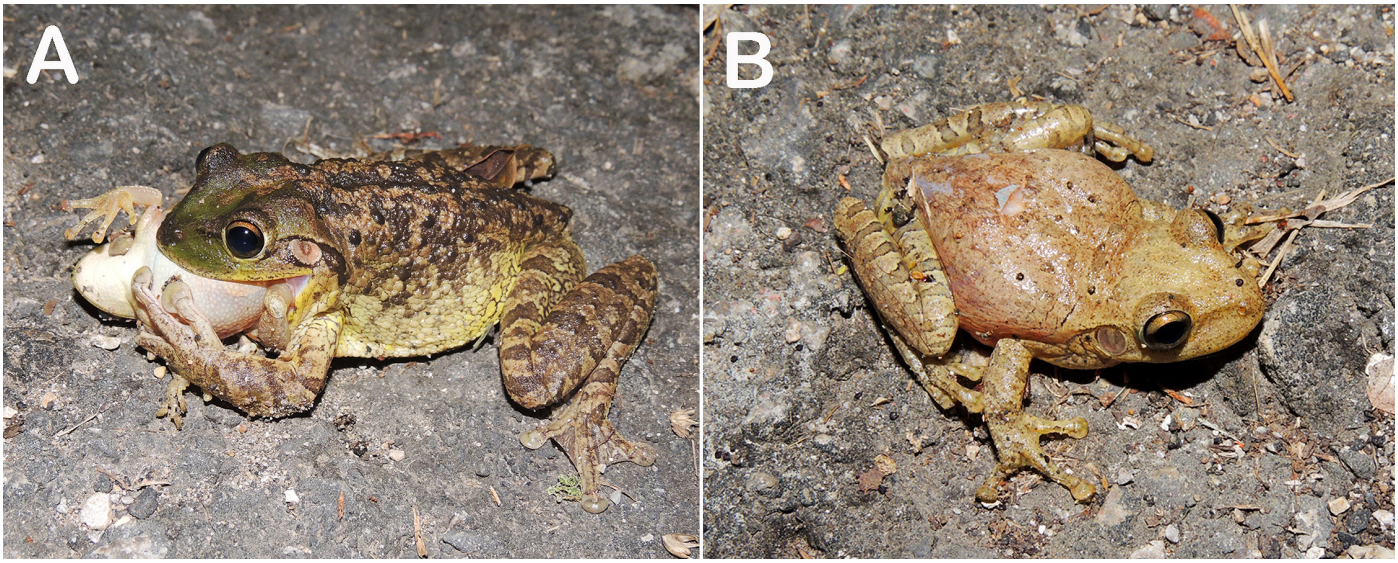

Fig. 2. (A) Attempt by a female Cuban Treefrog (*Osteopilus septentrionalis*) to swallow a smaller conspecific at the Cienfuegos Botanical Garden, Cienfuegos, Cuba. (B) The smaller frog with damaged skin after having escaped. Photographs by Tomás M. Rodríguez-Cabrera.

tained several injuries to the skin on its back and flanks (Fig. 1C). A survey of nearby, reproductively active treefrogs (e.g., Fig. 1D; 30 May 2011, 0013 h) showed that the size difference between the male that nearly served as prey and the cannibalistic female falls well within the size ranges of reproductively active (and successfully amplexing) pairs.

Attempted cannibalism, female on smaller female (Cienfuegos).—On 13 January 2016 at 1945 h, we observed an adult female Cuban Treefrog (81 mm SVL, 45 g) trying to ingest a smaller female conspecific (43 mm SVL, 7 g) at the Cienfuegos Botanical Garden (22.12722°N, 80.33056°W, datum WGS 84), Cienfuegos Province, Cuba. We determined the sex of both frogs by ventral incision and examination of gonads. When encountered, the frogs were on the blacktop surface of a small road within the Botanical Garden (Fig. 2A). The larger individual had swallowed almost half of the smaller, starting with the hindlimbs (Fig. 2A). The smaller frog displayed two basic defensive mechanisms by inflating its body and emitting frequent release calls. Despite the continuous attempts by the female to swallow its potential prey by pushing it farther into its mouth using its forelimbs, the smaller individual was able to escape after nearly 20 minutes, albeit with some damage to the skin of the dorsum and hindlimbs (Fig. 2B). The two specimens were collected and deposited in the herpetological collection of the Museo de Historia Natural "Felipe Poey" (MFP), Faculty of Biology, University of Havana, Cuba (accessioned as MFP 11.604–605).

Successful cannibalism, female on froglet.—During a nature walk on the edge of a dry coastal forest, ca. 7 km (by air) east of Playa Larga, Ciénaga de Zapata Municipality, Matanzas Province, Cuba (22.28795°N, 81.139582°W; datum WGS84, location specified via Google Maps), on 11 July 2015 at 0820 h, we observed several Cuban Treefrog froglets (Fig. 3A) that were individually distributed on the leaves of bushes at heights of 0.5–2.0 m above ground level. While these individuals could clearly be identified as froglets, they had already resorbed their tails. We estimated SVLs to be ~15 mm. On one of these bushes, we also observed an actively moving adult *O. septentrionalis* (estimated SVL 50 mm, and, based on size, likely a female; Fig. 3B) at a distance of one leaf from one of the froglets. Neither individual appeared to have been disturbed by our observation, which included photography.

The movement of the froglet appears to have registered in the peripheral vision of the adult (based on their respective positions on the bush; Fig. 3C) and captured its attention. As the adult began to turn counter-clockwise toward the froglet, the latter jumped onto a set of small, unstable branches (Fig. 3D). With the froglet forced to compensate for the instability of the branches to remain on its precarious perch, its movements allowed the adult to target its position (Fig. 3E). Having fully turned toward the froglet, the adult suddenly launched itself in that direction, grabbed the froglet by its head, and swallowed it in two gulps, the first gulp leaving only the hindlimbs exposed. In the last photograph (Fig. 3F), the adult can be seen sitting among the fallen thin branches with a visibly enlarged stomach.

Additional, unverified records.—We know of two other cases of cannibalism by Cuban Treefrogs, but for neither are vouchers or photographs available. In November 2007, we observed an individual (ca. 80 mm SVL, presumably a female based on size) swallowing a smaller conspecific in a building at the Universidad Central "Marta Abreu" de Las Villas, Santa Clara, Villa Clara Province, Cuba (22.44577°N, 79.89538°W, datum WGS 84; location determined via Google Maps). In March 2008, a large female (ca. 100 mm

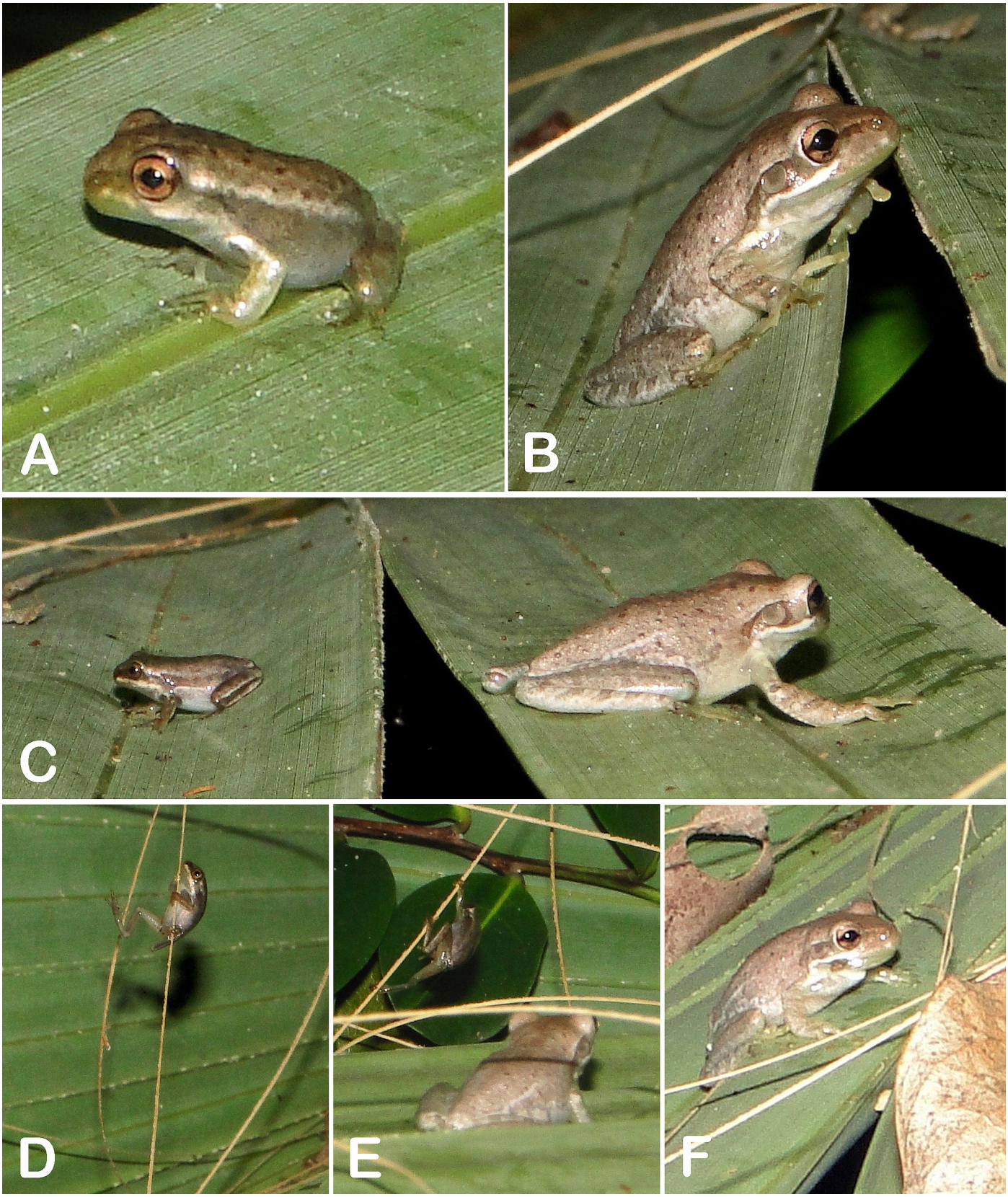

Fig. 3. (A) One of several Cuban Treefrog (*Osteopilus septentrionalis*) froglets observed on the morning of 11 July 2015 near Playa Larga, Ciénaga de Zapata Municipality, Matanzas Province, Cuba. Estimated SVL was 15 mm. (B) Diurnally active adult observed on a broad leaf. (C) The individual in (B) reacting to the movement of a second froglet on an adjacent leaf. (D) The froglet in (C) has jumped onto small hanging branches, perhaps in an effort to escape the attentive adult. (E) The adult in (C) lining up for an attack on the froglet, seen suspended from the two branches and struggling to maintain its position. (F) The adult leapt, captured, and swallowed the froglet. The branches from which the froglet had been suspended are lying on the leaf. The adult's stomach is extended when compared with (B). Photographs by Hinrich Kaiser.

SVL) collected at the same location was found to contain the remains (bones and skin fragments) of a conspecific in its stomach.

Filial vs. Heterocannibalism

Mating frenzies or the emergence of froglets create opportunities for any anurophagous predator, including conspecifics. Given that Meshaka (2001) reported that *O. septentrionalis* in Florida consumed very few conspecifics (occurring in the stomachs of three of 41 individuals sampled), the observations we made in Cuba are not surprising. However, opportunities to actually observe and document such interactions are rare, and this requires further comment.

Osteopilus septentrionalis is generally nocturnal, and the activity of both froglets and a single adult in the morning was unexpected. Whereas the emergence of froglets might not be timed so closely that froglets have the option of remaining hidden until nightfall and may therefore be forced into diurnal activity, this is not normally true for an adult. We therefore wonder whether froglet activity is somehow noticeable to adults and may trigger some type of foraging behavior. We were unable to find in the literature any report that indicated whether adult *O. septentrionalis* would deliberately seek clutches of eggs near the time of emergence and await the appearance of prey; we therefore conclude that this kind of encounter is serendipitous and represents an example of dietary opportunism on the part of the adult. Furthermore, because a Cuban Treefrog parent is unlikely to remain near a clutch for an extended period of time in order to consume its own young, we have no evidence that such predatory activity represents filial cannibalism (i.e., cannibalism by a parent to reduce the fitness of its offspring, perhaps to avoid competition). Instead, we see this as an example of incidental heterocannibalism, where a non-relative has a chance encounter with prey of suitable size.

A nocturnal encounter between a large female and a small male Cuban Treefrog (Fig. 4) can be assumed to spell danger for the smaller individual, given that the profound size difference, and a serendipitous encounter during foraging may not allow a female to differentiate prey from conspecific. What

Fig. 4. Breeding pair of Cuban Treefrogs (*Osteopilus septentrionalis*) in amplexus near the Santa Cruz River, Artemisa Province, Cuba, showing the strong sexual dimorphism in body size. Photograph by Raimundo López-Silvero.

makes our observation interesting is that the attempted cannibalism occurred at a time when mating ought to have been the main interest of both individuals. The male in the interaction appears in bright yellow, full-body breeding colors (Fig. 1C) and one would assume that chemical stimuli should signal reproductive readiness. We observed several mating pairs that had successfully engaged in amplexus, indicating that encounters between females and males at that site did lead to reproduction. We do not know whether the attempted cannibalism was an aberration or whether a female makes a snap decision regarding the greater benefit of the approaching male as a mate or as a meal.

When considering the possibility of cannibalism as a viable feeding strategy, one must compare its incidence with that of generalized anurophagy. For Cuban Treefrogs, the incidence of the latter reported by Meshaka (2001) and Meshaka and Mayer (2005) involved a significant body size component, with 36 females, at an average 2.6 times the size of their anuran prey, among 41 anurophagous Cuban Treefrogs (88%). Thus, anurophagy can be a successful strategy for female Cuban Treefrogs, but apparently not for males. Furthermore, while cannibalizing conspecific froglets might be considered easy in terms of predator-prey interactions, especially given the recurring opportunity for cannibalism on froglets following every breeding episode, this strategy has not been documented in studies by Meshaka (2001) and Glorioso et al. (2012). Consequently, Cuban Treefrogs apparently do not normally choose conspecifics as prey, or perhaps Cuban Treefrogs are not easily eaten by conspecifics or behave in ways that reduce the risk of cannibalism (e.g., Meshaka 1996b).

Our observations show that *O. septentrionalis* is not forced into cannibalism by captivity (as reported by Peters 1974) or by environmental conditions in an ecosystem it has colonized (as reported by Meshaka 2001). Instead, *O. septentrionalis* can be ranked among the number of hylid frogs in which diets opportunistically include conspecifics, with errors or unknown strategies intruding into the intricacies of mating choice or as a limited food supply may dictate. No strategic prey-switching was evident; in such situations, a high density of conspecifics may support cannibalism to obtain necessary food when competition is great while simultaneously reducing competition. We also note that in a variety of reports of cannibalism, those of treefrogs included, we were unable to find a single observation that included the complete sequence of prey localization, predator positioning, and attack, as was the case with our froglet encounter.

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