REPTILES & AMPHIBIANS

Combat Wounds in Dwarf Glassfrogs, *Teratohyla spinosa* (Centrolenidae)

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About 160 species of glassfrogs in the family Centrolenidae (Frost 2023) are assigned to two currently recognized subfamilies (Centroleninae and Hyalinobatrachinae) (Guayasamin et al. 2009). These nocturnal, arboreal, and epiphytic anurans have transparent skin on parts of their venters, the variation of which can be used to distinguish species (Guayasamin et al. 2009, 2020).

Territorial behavior has arisen in anurans due to temporal and spatial permanence of breeding or feeding sites (McDiarmid and Adler 1974). In most cases territoriality involves defense of calling-sites by species that use the same calling site during part or all of the mating season (Duellman and Savitzky 1976).

Some species of glassfrogs exhibit territorial behavior, which can result in fighting, especially when a male enters the calling territory of a conspecific male. To date, this behavior has been recorded in only 17 centrolenid species (Barría et al. 2023), three of which are known to incur injuries inflicted during territorial behavior such as the bruising and tearing of skin from the hand in Buckley's Glassfrog (*Centrolene buckleyi*) (Bolivar-G. et al. 1999), scarification on the head and body of the Gecko Glassfrog (*Centrolene geckoideum*) (Bolivar-G. et al. 1999), and bruise-like lesions on the body of a Red-spotted Glassfrog (*Nymphargus grandisonae*) (Hutter et al. 2013). Males in all three of these species bear humeral spines, which are used to fend off rivals (Krohn and Voyles 2014).

The Dwarf Glassfrog, *Teratohyla spinosa* (Taylor 1949), a relatively small species (SVL 17–20 mm in males, 20–23 mm in females), ranges from Honduras to Panama in Central America (McCraine and Wilson 2002; Savage 2002; Kubicki 2007; McCraine 2007; Sunyer and Köhler 2007; Sunyer et al. 2009) and occurs in Colombia (Ruiz-Carranza et al. 1996) and a few locations in Ecuador, South America (Cisneros-Heredia and McDiarmid 2007; Cisneros-Heredia 2009). The elevational range extends to 650 m asl in Costa Rica and 800 m asl in Panama (IUCN SSC Amphibian Specialist Group 2020). One characteristic of this species is the distinctive prepollex (prepollic spine) (Fig. 1), which is present in both females and males (Taylor 1949; Savage 2002; Guayasamin et al. 2020), with no evident differences between the sexes (Hayes and Starrett 1980). These spines typically are in sheaths of skin, although the prepollices in some males pierce the skin, leaving the spiny tip exposed (Taylor 1949). We herein document scars on the head, behind the eyes, and on the dorsum and sides of *T. spinosa*, suggesting that these are caused by using the prepollex during combat. Such scarifications have not been recorded in any centrolenid species with distinctive prepollices.

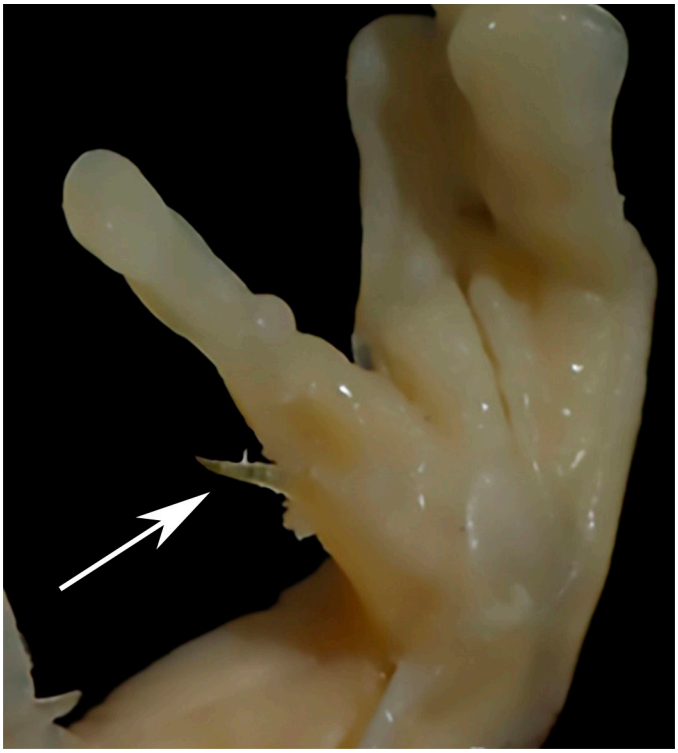

Figure 1. The prepollex of an adult male Dwarf Glassfrog (*Teratohyla spinosa*) (Vertebrate Museum of the University of Panama AS-166). Photograph by Erick Barría.

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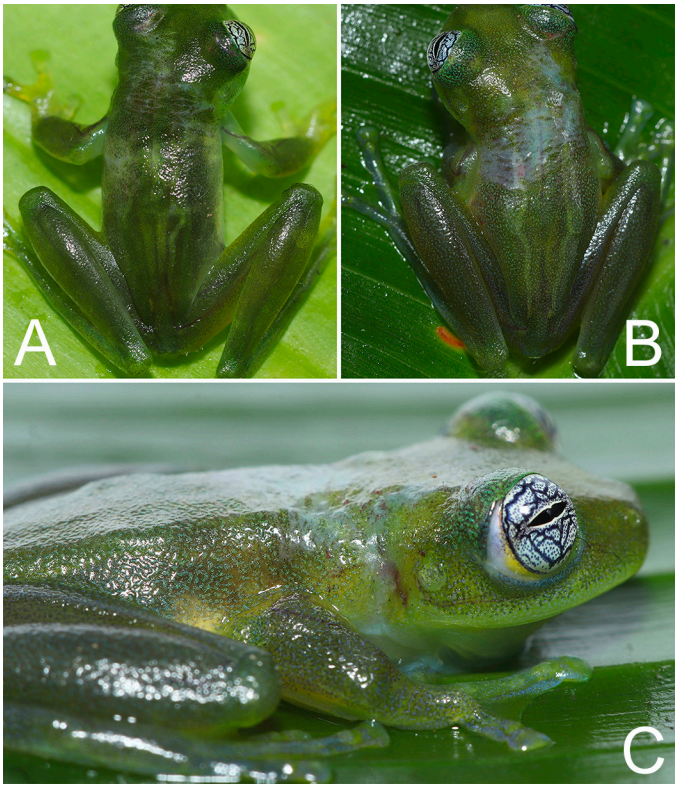

Methods

In October, November, and December 2021 and January 2022 on the "Frog Trail" of the General de División Omar Torrijos Herrera National Park, Coclé Province, Republic of Panama (8.67148, -80.59040), we photographed glassfrogs, measured snout-vent lengths with a ruler (mm), and subsequently calculated the proportion of scratched areas using the "quick selection" tool in Adobe Photoshop 2021.

Results and Discussion

During our first visit to Omar Torrijos Herrera National Park on 23 October 2021, we heard a *T. spinosa* vocalizing in an unusually constant and frenetic manner about 2 m above the ground and 3 m from the banks of the Peñitas River. We followed the calls and quickly found the individual, which showed some unusual whitish to rosy scratch-shaped marks on its back (Fig. 2A). A few minutes later, we heard another male (Fig. 2B)

Figure 2. Scars on a male Dwarf Glassfrogs (*Teratohyla spinosa*) showing a pattern consistent with venter-to-venter wrestling. The first male that subsequenly disappeared (A); the second male that continued defending its territory for months (B & C); note the dorsal and lateral scars and the bloody marks behind and below the tympanum. Photographs by Erick Barría.

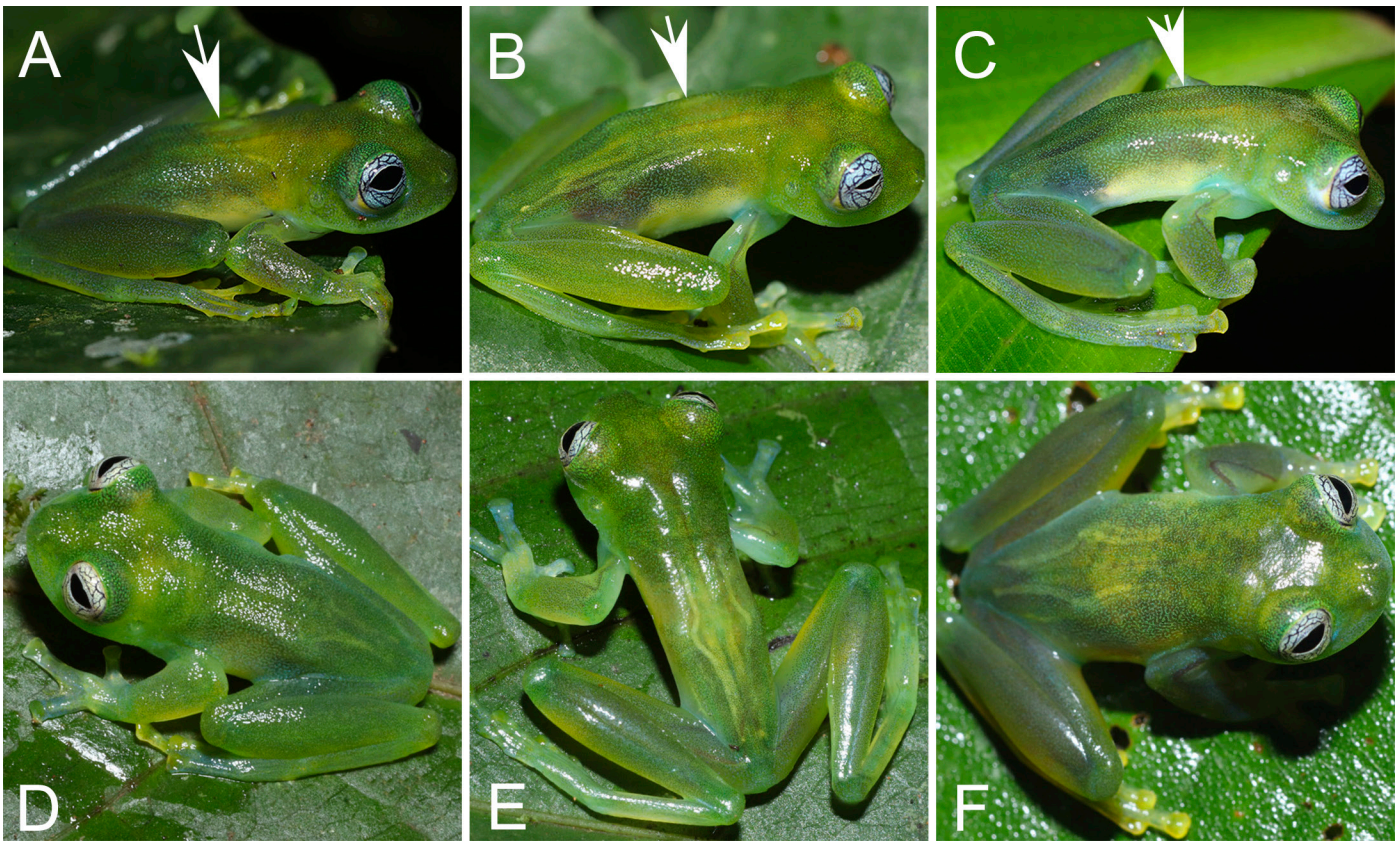

Figure 3. The three images in the top row of an adult male Dwarf Glassfrog (*Teratohyla spinosa*) (the second individual illustrated in Fig. 2) show three months of scar-recovery (disappearing light patch) after the initial encounter in October: November (A), December (B), January (C). The three images in the lower row show differences in the dorsum of three individuals found in Palmaraso (D & E) and Nueva Estrella (F): pale-yellowish color posterior to the eyes (D); pale-yellowish color on the posterior dorsum (E); and scars on the dorsum from behind the eyes to above the hindlimb insertions (F). Photographs by Erick Barría.

vocalizing in a similar fashion about 3 m away and 0.5 m above the ground. This frog had markings on its back resembling those of the first individual.

The scratches on the first individual were dispersed across a large part of the dorsum, whereas those on the second individual were deeper and concentrated in the center of the back. The second individual also had numerous bloody marks on the back, in the postocular region, and adjacent to the tympanum (Fig. 2C). The proportional scarred dorsal areas in the two frogs were 46.93% and 36.12%, respectively.

During the three subsequent field trips, we found the second individual defending the same site. We identified this frog by the unique pattern of reticulations of the eyes and scratches on its back that had turned into yellowish-green scars by November (Fig. 3). During December, the difference in color between healing and unscratched skin became less obvious. By January, the affected skin was completely healed, with no evidence that it had been scratched. Because we did not find the first individual during subsequent trips and assuming it had not been removed by other means, we suggest that the second frog won the territorial fight, perhaps benefiting from a calling site closer and directly above the water.

We have observed scarring and subsequent healing in other Dwarf Glassfrogs at Palmaraso, Coclé Province (8.73658, -80.64483), and Nueva Estrella, Bocas del Toro Province (8.94298, -82.20096) (Fig. 3). All were < 3 m from banks of small streams with weak currents even during the rainy season. We found that males usually do not vocalize on the banks of streams > 4 m in width, moving instead to smaller streams in the presence of larger centrolenids (e.g., White-spotted Glassfrog, *Sachatamia albomaculata*; Ghost Glassfrog, *Sachatamia ilex*; or Emerald Glassfrog, *Espadarana prosoblepon*) vocalizing in the same vertical segment (1–3 m above the ground) known to engage in both intra- and interspecific male-male combat (Jacobson 1985; Kubicki 2007; Rojas-Runjaic and Cabello 2011; Sorokin and Steigerwald 2017; Barría et al. 2023).

Scarifications, presumably inflicted by prepollices while wrestling with conspecific males, had not been described in *T. spinosa*. However, venter-to-venter combat between males dangling from vegetation has been documented in Centroleninae (Duellman and Savitzky 1976; Ruiz-Carranza and Lynch 1991; Bolivar-G. et al. 1999; Guayasamin et al. 2009; Barría et al. 2023), Hyalinobatrachinae (Delia et al. 2010), and treefrogs in the subfamily Phyllomedusinae (Caldwell et al. 2010; Dias et al. 2017; and our observations Fig. 4). However, scars produced by prepollices have not been recorded in any centrolenid, although similar scarifications

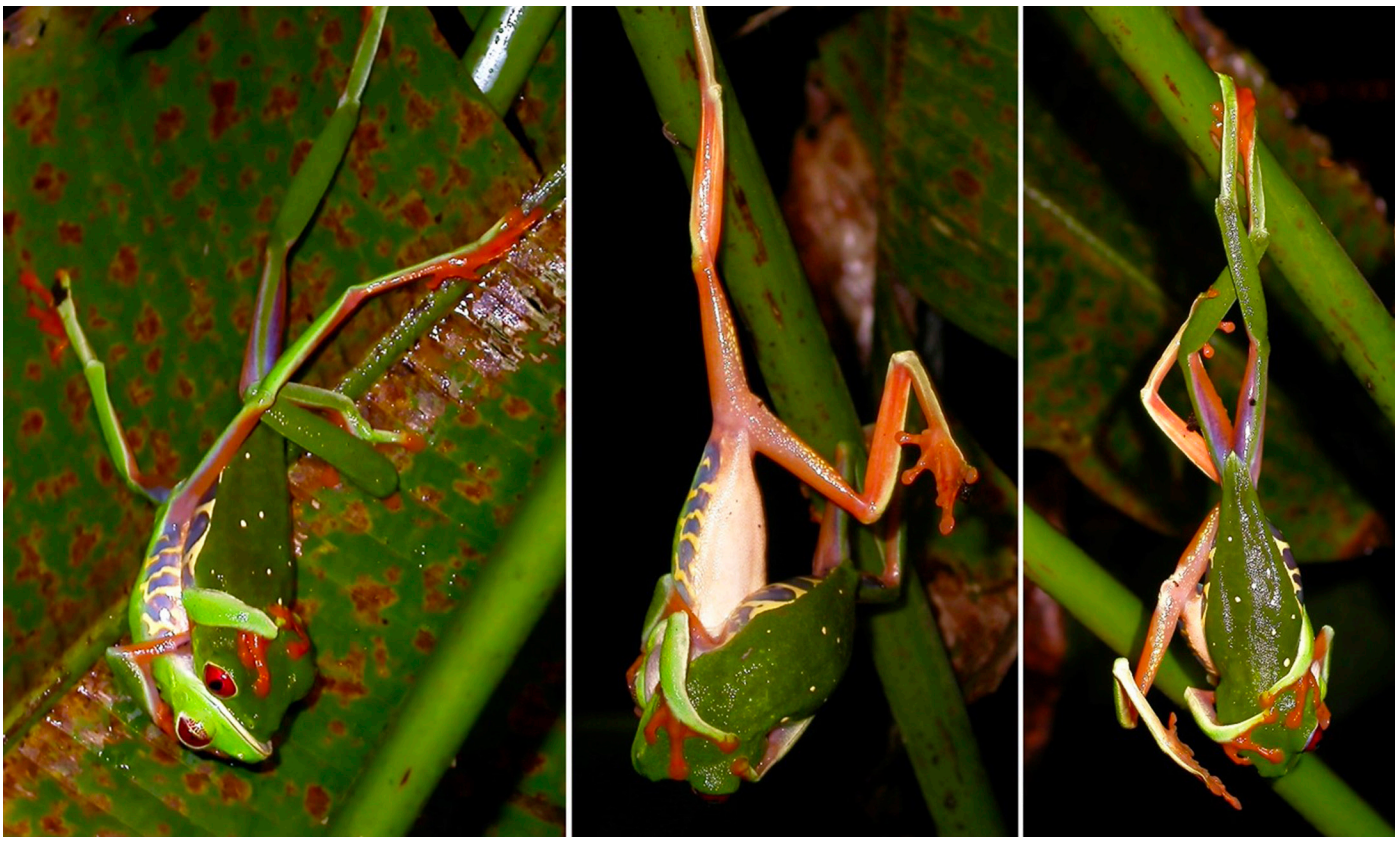

Figure 4. The presumptive venter-to-venter wrestling in Dwarf Glassfrogs (*Teratohyla spinosa*) that would leave scars attributed to the prepollices likely would look very much like this bout between two male Red-eyed Treefrogs (*Agalychnis callidryas*) fighting near receptive females after a heavy downpour at ca. 1800 h on 30 January 2007. A subsequent drizzling rain appeared to initiate an explosive multi-species breeding event at the Atlantida Lodge, Cahuita, Costa Rica, next to dining tables placed under vegetation and around a fountain filled with plants used extensively by frogs. Photographs by Konrad Mebert.

are known in the Ecuadorian Giant Glassfrog (*Centrolene geckoidea*), but they are attributed to humeral spines, since the prepollices of that species are concealed (Bolivar-G. et al. 1999; Guayasamin et al. 2020).

The use of prepollices by *T. spinosa* could be a facultative behavior, which would explain why some males had covered prepollices and those of others were exposed (Taylor 1949), piercing the protective sheath only when engaging in combat with other males, possibly followed by rapid healing of the sheath when no longer used. The markings found on *T. spinosa*, however, are comparable to those found on some species of gladiator frogs in the genus *Boana* (Family Hylidae), which are produced by the prepollices used during venter-to-venter wrestling in male combat, when males rotate their wrists to scratch and stab the rival's back and sides (Kluge 1979; Shine 1979; Candaten et al. 2020).

Our observation that healing was essentially complete after two months is unlike male gladiator frogs (*Boana curupi*) in southern Brazil, which apparently fight frequently over rare resources (e.g., spawning sites) and accumulate scars so consistently that > 90% of males bear the marks of such injuries (Candaten et al. 2020). The availability of spawning sites also appears to determine the frequency of scars in male *B. rosenbergi* (Kluge 1981; Höbel 2000).

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