The Effect of Microhabitat and Body Size on Toe Pad Size in Arboreal, Semi-arboreal, and Torrential Frogs

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Introduction

- Frog species can be classified into five major microhabitats: arboreal/semi-arboreal, aquatic/semi-aquatic, terrestrial, burrowing, and torrent. In each microhabitat, frogs evolve similar phenotypical characteristics that are specialized for combatting the ecological conditions of their microhabitat[5].
- Arboreal frogs dwell in trees and surrounding ground flora in rainforests, semi-arboreal frogs spend substantial time in both trees and on the ground, and torrential frogs live in fast-flowing freshwater streams and waterfalls[2,5].
- Arboreal, semi-arboreal, and torrential frogs have enlarged pads on the distal tips of the digits for adhesion to substrates[1,4]. Recent work supports that these frogs employ wet adhesion, meaning that they use surface tension with a thin, fluid layer between the pads and substrate[1,2].
- At steep angles, arboreal frogs depend on pad adhesion and lose ventral contact, whereas torrential frogs increase ventral contact[2]. Lower dependence on pads in torrential species in contrast to high dependence in arboreal species could lead to reduced size in torrential pad area.

Do frogs with similar adhesive adaptations that occupy different microhabitats display similar toe pad areas?

- We hypothesized that arboreal species would have greater toe pad area in relation to body size than torrential species and semi-arboreal species.

Figure 1: Arboreal species *Litoria infrafrenata*[8].

Figure 2: Torrential species *Litoria nannotis*[6].

Methods

- We measured finger/toe pad area of 172 arboreal, 27 semi-arboreal, and 31 torrential species. The median sample size was 4. We acquired specimens from 21 herpetological collections and a previously published data set.
- We photographed toe pads with a Canon EOS 6D with a 100mm Canon EF Macrolens and a Canon Macro Twin Lite MT-24 EX flash system (Fig. 3).
- To measure toe pad area (mm^2), we traced the circumference of the toe pads with the polygon tool in the program ImageJ[7] (Fig. 4). We measured SVL with a Mitutoyo digital caliper to the nearest 0.01 mm (Fig. 5).
- We used a general linear model as implemented in R version 3.5.2 (R Core Team, 2018) and log transformed the resulting figures.
- Our analyses represent summed hand pad and foot pad area compared to body size.

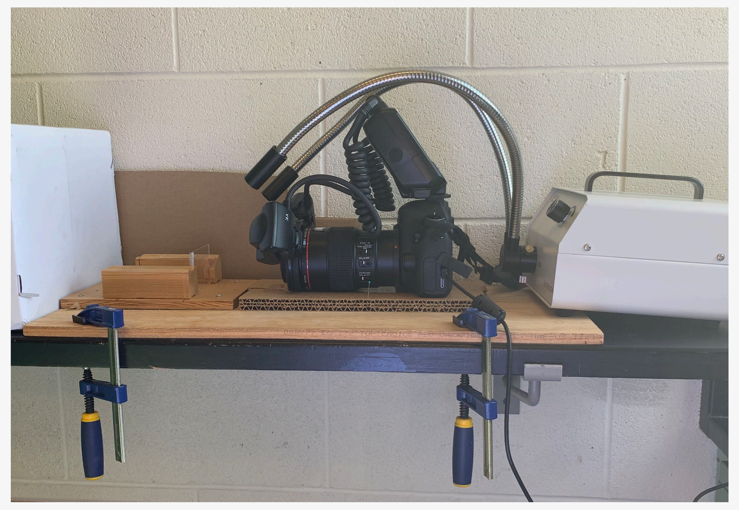

Figure 3: Canon EOS 6D with a 100mm Canon EF Macrolens and a Canon Macro Twin Lite MT-24 EX flash system.

Figure 4: We used the polygon tool in ImageJ to trace the circumference and calculate the area of toe pads. The pictured species is *Amolops wuyiensis.*

Interaction Model

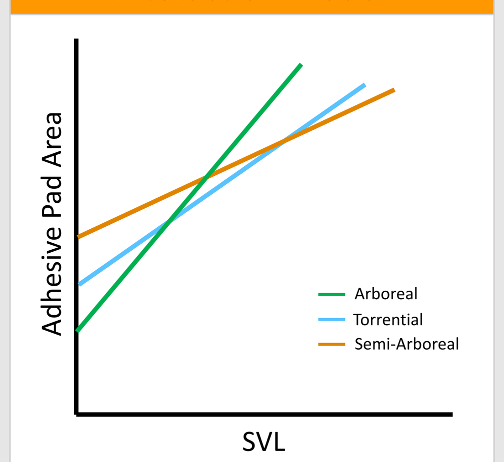

Figure 6a: The effect of microhabitat only is significant.

Non-Interaction Model

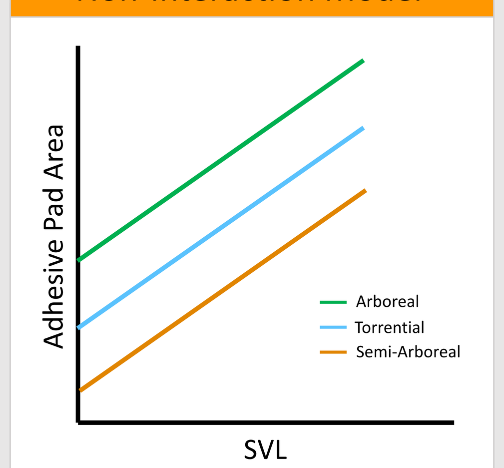

Figure 6b: The effects of microhabitat and body size are significant.

SVL Only Model

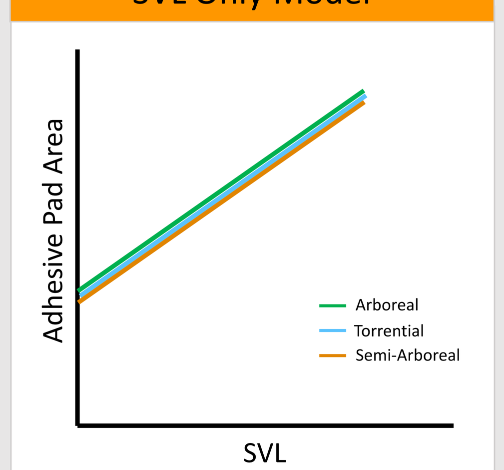

Figure 6c: The effect of SVL only is significant.

Figure 6: We predicted three models that represent the potential significance of microhabitat and SVL on toe pad area.

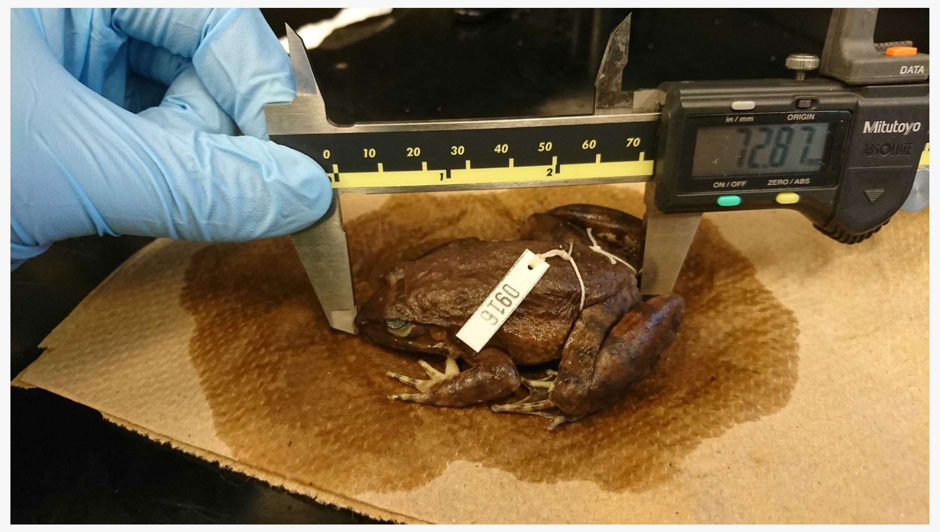

Figure 5: We measured SVL (snout-vent length) with a Mitutoyo digital caliper to the nearest 0.01 mm.

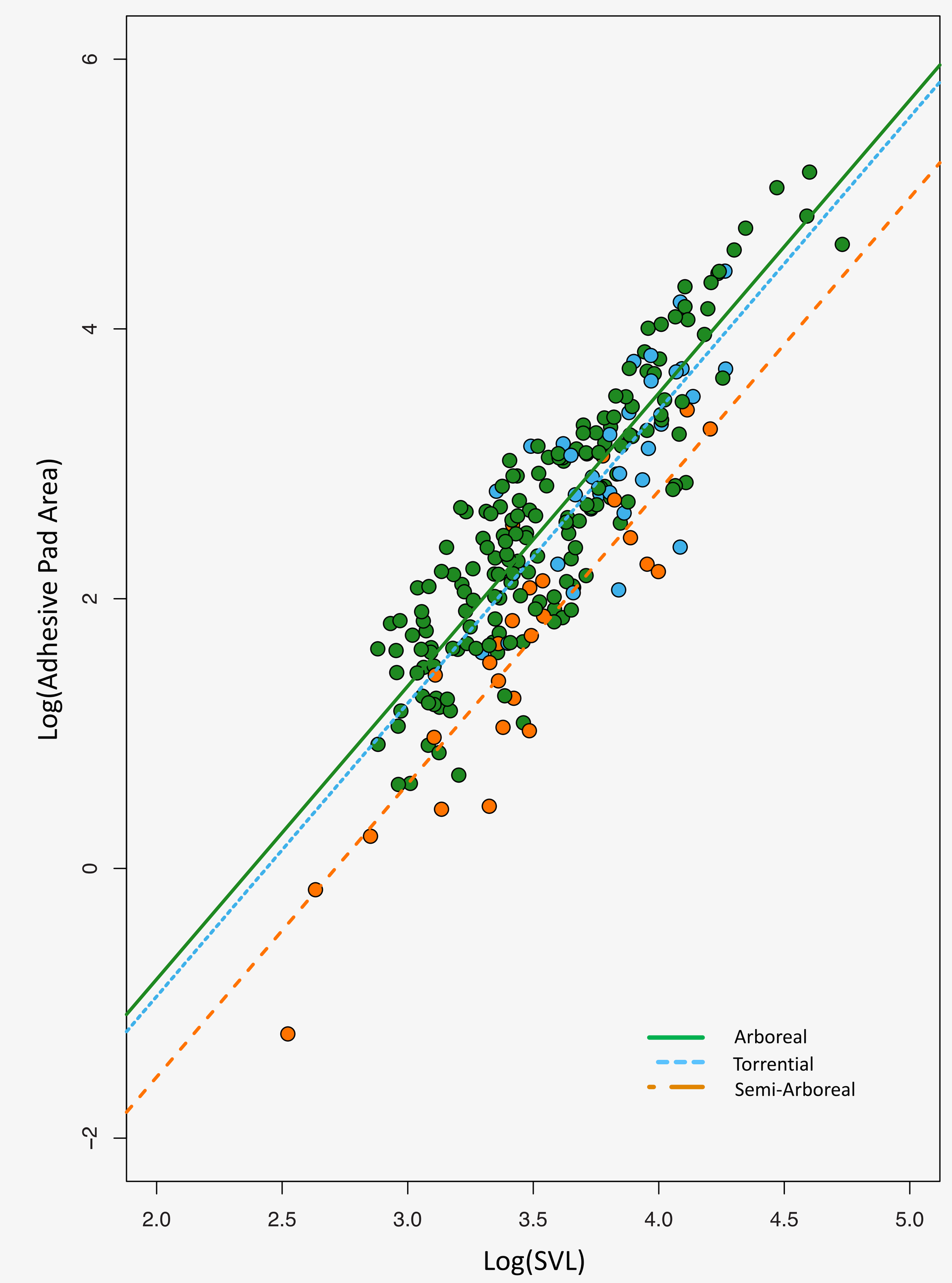

Figure 7: The non-interaction model shows body size compared to toe pad area in arboreal, semi-arboreal, and torrential frogs.

Results

- Among the interaction, non-interaction, and SVL only models, the non-interaction model performed the best (Fig. 7).
- This model explained approximately 80% of the variance in the data ($R^2 = 0.798$; Fig. 7).
- Because the data supported the non-interaction model, this indicates that pad size can be attributed to a combination of SVL and microhabitat influence.
- SVL significantly affected finger/toe pad area ($p < 0.001$; Fig. 7).
- Microhabitat significantly affected finger/toe pad area ($p < 0.001$; Fig. 7).
- There was no significant difference between toe pad area in arboreal and torrential species ($p = 0.161$; Fig. 7) but there was a significant difference between arboreal/torrential and semi-arboreal species ($p < 0.001$; Fig. 7).
- SVL and toe pad sizes in arboreal, torrential, and semi-arboreal microhabitats scaled isometrically, as toe pad area scaled with SVL squared.

Discussion

- Contrary to our predictions, torrential frogs did not have significantly smaller toe pads than arboreal species. It is possible that because both arboreal and torrential frogs heavily depend on adhesion, enlarged toe pads are essential.
- Torrential frogs have to battle flowing streams and submerged toe pads[2], so utilizing large toe pads and ventral surfaces is necessary.
- It was not unexpected that semi-arboreal species had significantly smaller toe pads, as they spend substantial amounts of time both in the trees and on the ground.
- Another possibility is that enlarged toe pads such as those in arboreal and torrential species could hinder functions in terrestrial life.
- This study could be expanded into an evolutionary context to evaluate the influence of microhabitat on evolution versus phylogeny on evolution.
- Are closely related species that reside in different microhabitats more phenotypically similar, or are distantly related species that reside in the same habitat more phenotypically similar?
- A potential study is to observe how much time semi-arboreal species spend in the trees versus the ground and analyze the effect on toe pad size.

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