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Polymorphism as a precursor to speciation in a California endemic salamander

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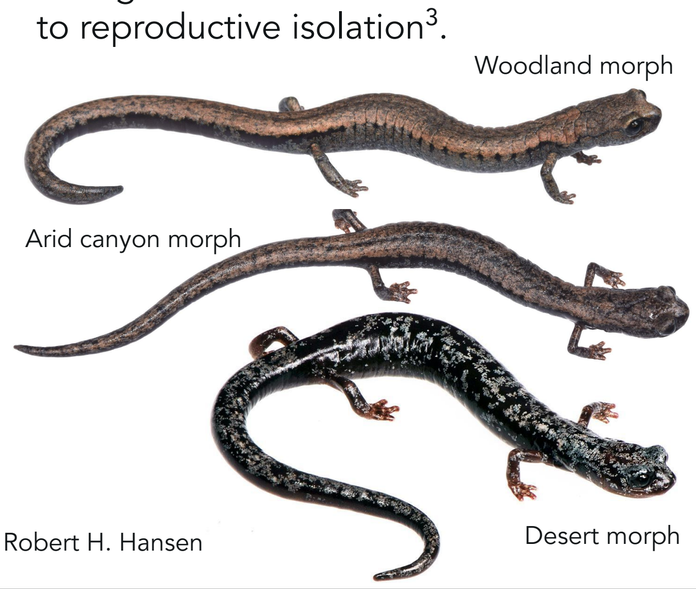
Abstract

The salamander species *Batrachoseps stebbinsi* is an underrepresented subject in morphological studies. Authors have noted morphological differences and genetic divergence between northern and southern populations. This has led to speculation as to whether or not the northern and southern populations are separate species due to their observed differences and the apparent gap in their distribution. To date, no formal analysis of range-wide morphological data has been published. In addition, this species contains distinct color morphologies that appear to be correlated with habitat. This study aims to quantify the color morphology and shape differences (body and limb proportions) between northern and southern populations of *B. stebbinsi*. The role of sexual dimorphism and size at maturity will be included in the analysis. Whether selection is driving the observed variation in color and shape differences is not yet known.

Introduction

- *Batrachoseps stebbinsi* is an endemic salamander to the Tehachapi and Piute mountains found in small segregated populations separated by the Tehachapi Valley.
- Authors have noted morphological differences and genetic divergence between northern and southern populations beyond what is expected in a single salamander species[1].
- Population polymorphism has been shown to predict the formation of new species[2]. Different phenotypes can be expressed in a single population yet face different selection pressures, leading to diverged selected traits which can lead to reproductive isolation[3].



Methods

Measurements

- Preserved *B. stebbinsi* specimens from Cheadle Center for Biodiversity and Ecological Restoration (UCSB), Museum of Vertebrate Zoology (UC Berkeley), and the Natural History Museum of Los Angeles County were imaged.
- Landmarks were added to each image (dorsal: n=29; ventral: n=15) in R package "StereoMorph"
- Obtained morphological measurements in R package "GeoMorph"from scaled landmark coordinates

Morphological measurements: Snout-vent length, head width, front limb length, hind limb length, length of the 3rd toe (longest), forefoot width, hindfoot width, body width

Sex determination

- Sexes determined by assessing cloacal morphology
  - Females: presence of cloacal rugae
  - Males: presence of papillose tissue
  - Specimen with no distinct cloacal morphology were determined as juveniles/sexually immature

Results

Morphometrics

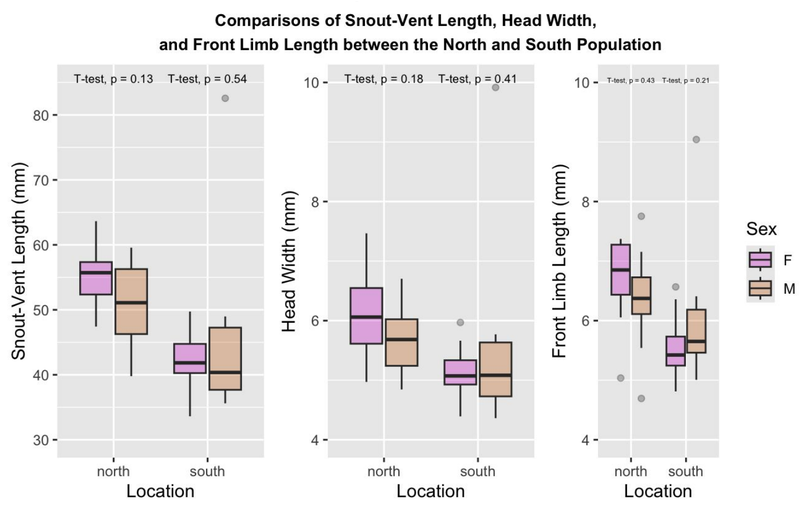


Figure 1: Significant size difference was found between north and south populations for SVL ($p<0.001$), HW ($p<0.001$), and FLL ($p<0.001$). No evidence was found for size differences between sexes within north and south populations.

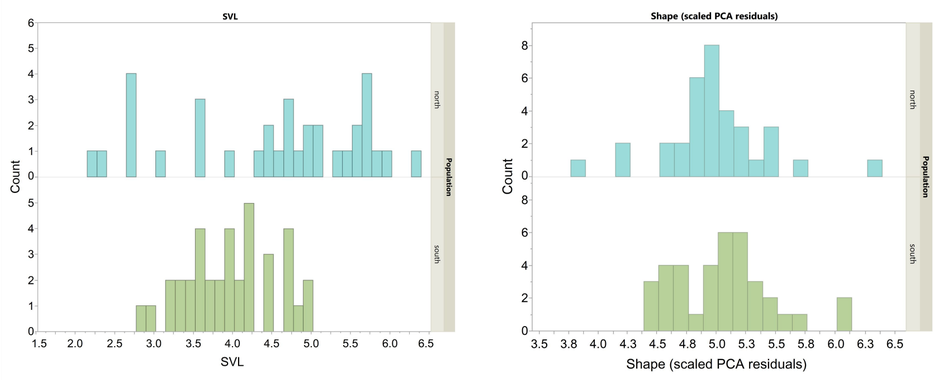


Figure 2: Histograms of standard length, SVL, and shape for all specimens sampled. While a significant difference in SVL is noted above, there is no difference in morphological proportions between the two populations, PC1 residuals of all measurements against SVL then scaled for adults ($p = 0.89$).

Size at sexual maturity

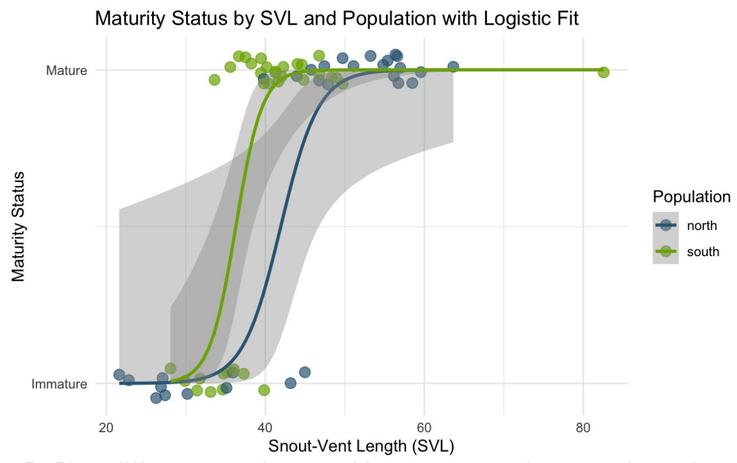


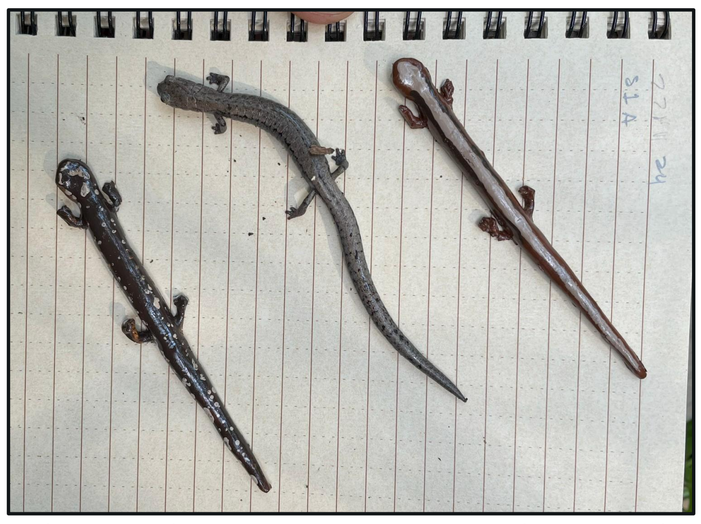
Figure 3: Size differences observed between northern and southern populations are partly explained by individuals in southern populations (GLM with a binomial response, SVL: $p=0.0343$)

Discussion

- *Batrachoseps* species show interspecific divergence in morphological traits including SVL, head width, and limb length
- Our data do show a statistically significant morphological divergence between the northern and southern populations in size but not shape
- Previous studies have found sexual dimorphism within the *Batrachoseps* genus
  - Our results do not find statistically significant differences in any of our measurements between sexes in the same population
- We find evidence of size differences at sexual maturity, suggesting that observed differences in size between northern and southern populations are not due to sampling error.
- We find further support for the validity of divergence toward speciation in *B. stebbinsi* based on morphological and developmental differences.

Future Directions

- Measurements of LACM and Cheadle Center specimens will be added to the dataset . Only MVZ data are presented here.
- Explore if this species' color polymorphism is due to adaptive crypsis to their unique habitats by using soft clay models made to resemble the most abundant color morph of each population and testing differences in predation-attempt rate within each population
  - This data can give insight on different predation pressures within populations forcing the populations to adapt differently, possibly leading to speciation.
- Incorporate images of live animals in the field
  - Will allow for determining the frequencies and geographical distribution of the different color morphs among the populations and a larger sample size for morphometric data collection



Northern population (Kern County; 1385m elevation) oak woodland morph *B. stebbinsi* in between two clay models made to represent the desert morph (left) and oak woodland morph (right).

References

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