

Effects of Elevation on Salamander Life Strategies

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Abstract

The Arizona Tiger Salamander (*Ambystoma mavortium nebulosa*) is a keystone species in the Rocky Mountains. Depending on how well they grow as larvae, these salamanders can either metamorphose to have terrestrial traits at maturity or retain their juvenile aquatic traits as adults. We expect that ponds at lower elevations, which are warmer and have longer growing seasons, will support faster growth, resulting in larger paedomorphs. To test this, salamanders will be surveyed at sites ranging from about 8,000 to over 11,000 feet in areas surrounding the RMBL townsite. Using dip nets, seine nets, and fyke nets, individuals were caught, recorded whether they were metamorphic or paedomorphic, measured for snout-vent-length (mm), weight (g), and noted their sex. Findings will be compared with climate data at each site and added to the ongoing 2020-2024 dataset.

Introduction

Phenotypic variation is one of the most critical aspects of evolutionary biology. Polyphenisms, or environment-influenced polymorphisms, occur when multiple discrete phenotypes can occur from a single genotype via environmental interactions. These polyphenisms are an excellent method of studying the mechanisms behind phenotypic variation among populations because they serve as a direct link to better understanding climate change, varying phenotypes are easily identified, and they are often the result of natural selection.

Paedomorphosis is a polyphenism expressed in the Arizona tiger salamander (*Ambystoma mavortium nebulosa*), a salamander native to the Rocky Mountains and surrounding areas in Colorado. In these salamander populations, individuals will either mature into terrestrial metamorphic adults or retain their aquatic features and become paedomorphic adults. This is dependent on varying environmental conditions experienced during the larval stage, such as temperature and resource availability. The expression of these morphs is often labeled as a response to the individual's expected success in either terrestrial or aquatic environments (Whiteman et al. 2012).

Theory predicts that growth is the primary mechanism driving morph choice in juvenile salamanders (Whiteman 1994). The "best of a bad lot" mechanism states that paedomorphosis becomes the preferred life strategy when growing conditions such as prey abundance, water temperature, and population density are poor. This means that the larval salamander is unable to gain the resources necessary to undergo metamorphosis, so the individual opts to cut its losses and become sexually mature while retaining their juvenile aquatic traits. The "paedomorph advantage" mechanism states that... At intermediate growth rates, larvae reach a critical size to be able to metamorphose and gain terrestrial traits once they become mature, releasing them from aquatic competition (Whiteman et al. 2012).

At the Mexican Cut Nature Preserve, which is at the upper elevational range limit for this species, salamanders display evidence for each of the above mechanisms of morph production due to a natural gradient in growth conditions across 4 permanent ponds. In particular, Pond 1, which has the largest density of salamanders at the cut, exhibits slow growth rates amongst larvae, thus resulting in a large population of small paedomorphs, supporting the best of a bad lot mechanism. In contrast, Pond 12 shows the fastest mean growth in larvae, yielding mostly metamorphs and a few large paedomorphs, supporting the paedomorph advantage mechanism (Lackey et al. 2019, Whiteman unpublished data). In this study, we aim to observe whether elevation differences across permanent ponds in Gunnison and Saguache Counties, Colorado, drive differences in morph production and body size. Elevation affects temperature, which is a large factor in metabolic rates for ectothermic salamanders. We expect to see morph production similar to that exhibited in Pond 12 of the Mexican Cut in ponds at lower elevations, since the warmer temperatures would likely promote faster larval growth rather than ponds positioned at higher elevations, which would in turn have colder temperatures and slower larval growth rates. Thus, we would expect to find larger paedomorphs at lower elevations due to those ponds having warmer temperatures and a longer growing season.

Methods

This study was conducted at eight different montane and subalpine ponds throughout the Crested Butte and Gunnison area, not including the ponds at the Mexican Cut. These elevations range from the Mexican Cut Nature Preserve at 11,200 ft elevation to the lowest site at 8,000 ft elevation. Each site was sampled using dip nets, seine nets, and fyke nets to collect salamanders. Individuals were measured and identified by snout-vent length (mm), weight (g), sex, and whether they were a metamorph or a paedomorph, then released back into their ponds. Data was then added to the 2020-2024 dataset to see yearly differences in morph choice and climate conditions. Upon processing, salamanders were then released back into their ponds. Climate data was also collected from databases including DAYMET (Thornton et al. 2022) and the Western United States Daily Snow Reanalysis (Fang and Margulis 2022) at each site to account for factors such as temperature, solar radiation, amount of snow present, and slope aspect.

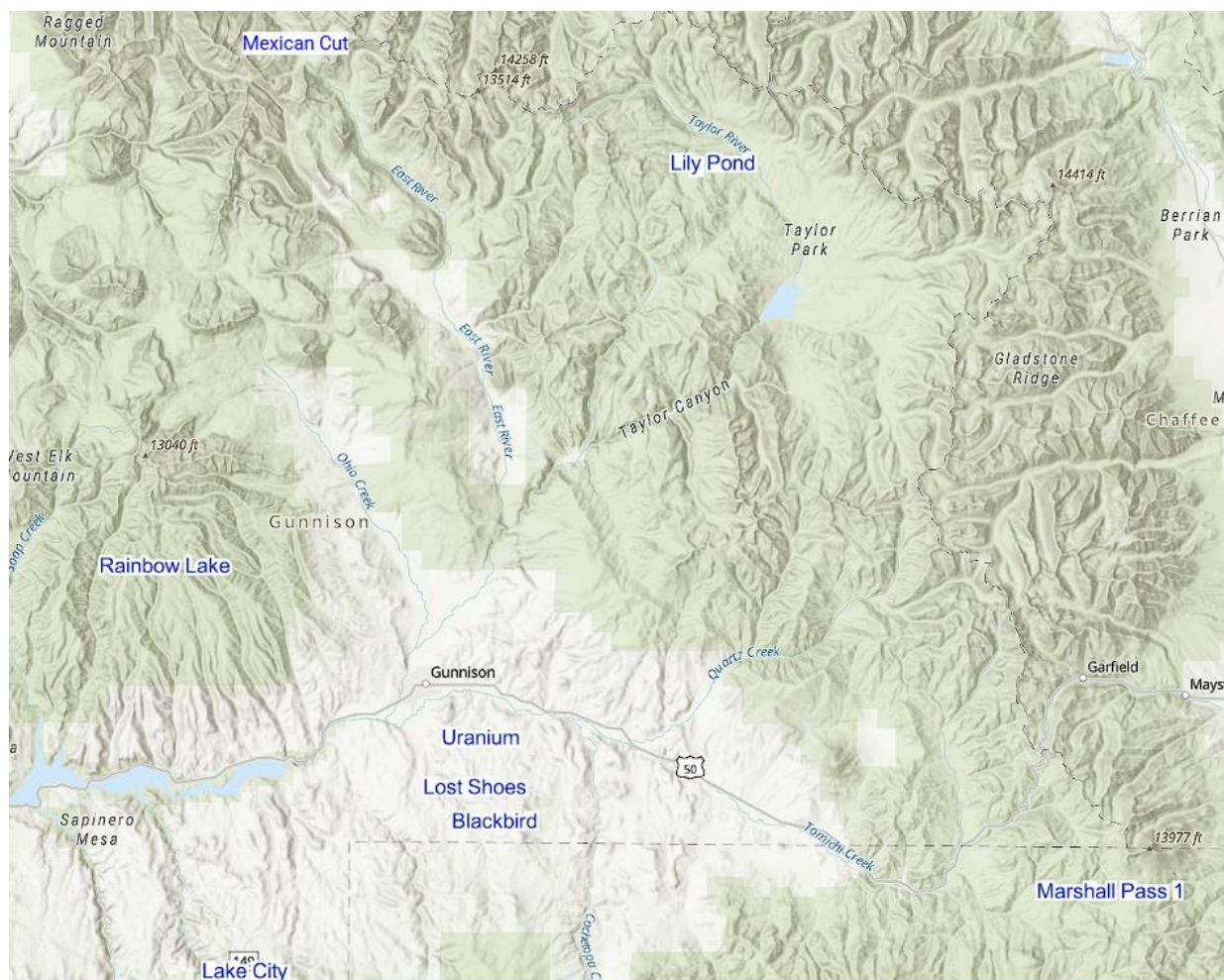


Fig 1. Sites were sampled throughout the Gunnison Basin and surrounding areas. MCNP- 11,200ft, RB- 10,900ft, LP- 10,509ft, MP1- 10,100ft, BB- 9,100ft, LC- 8,963ft, LS- 8,600ft, U- 8,000ft.

Results

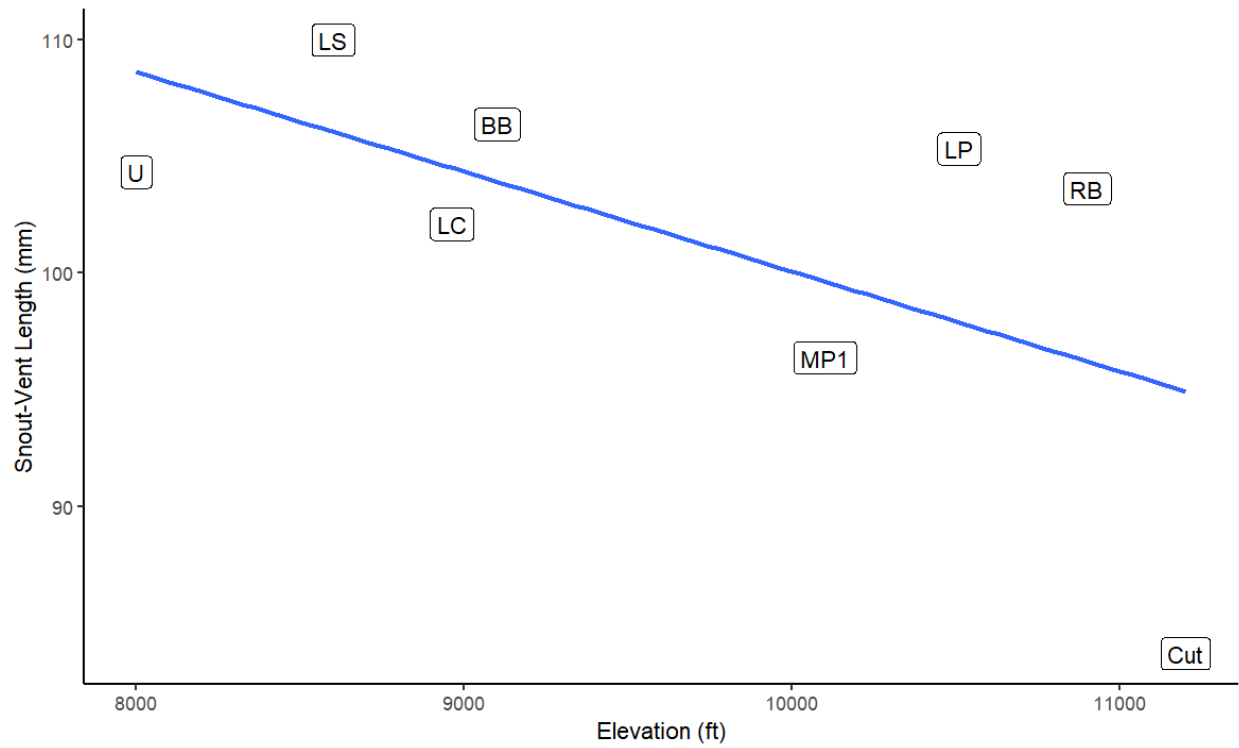


Fig 2. Relationship between SVL and Elevation. P-value = 0.108

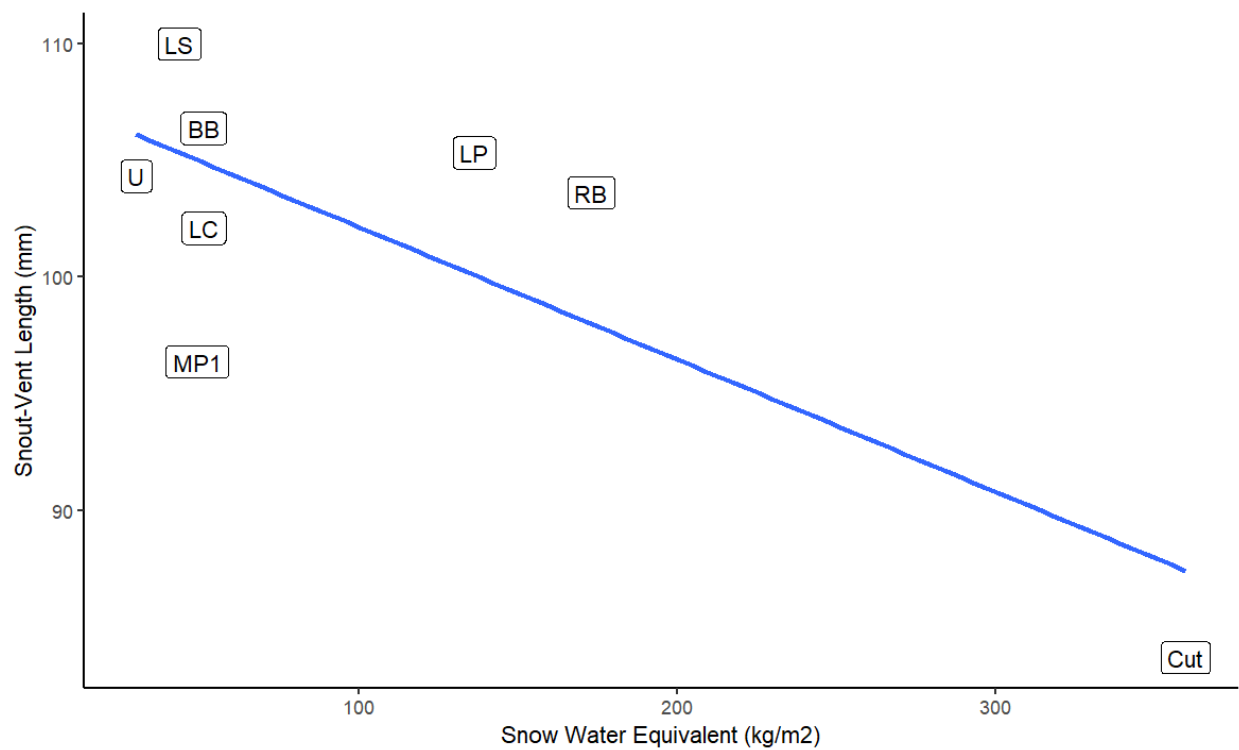


Fig 3. Relationship between SVL and Snow Water Equivalent. P-value= 0.022

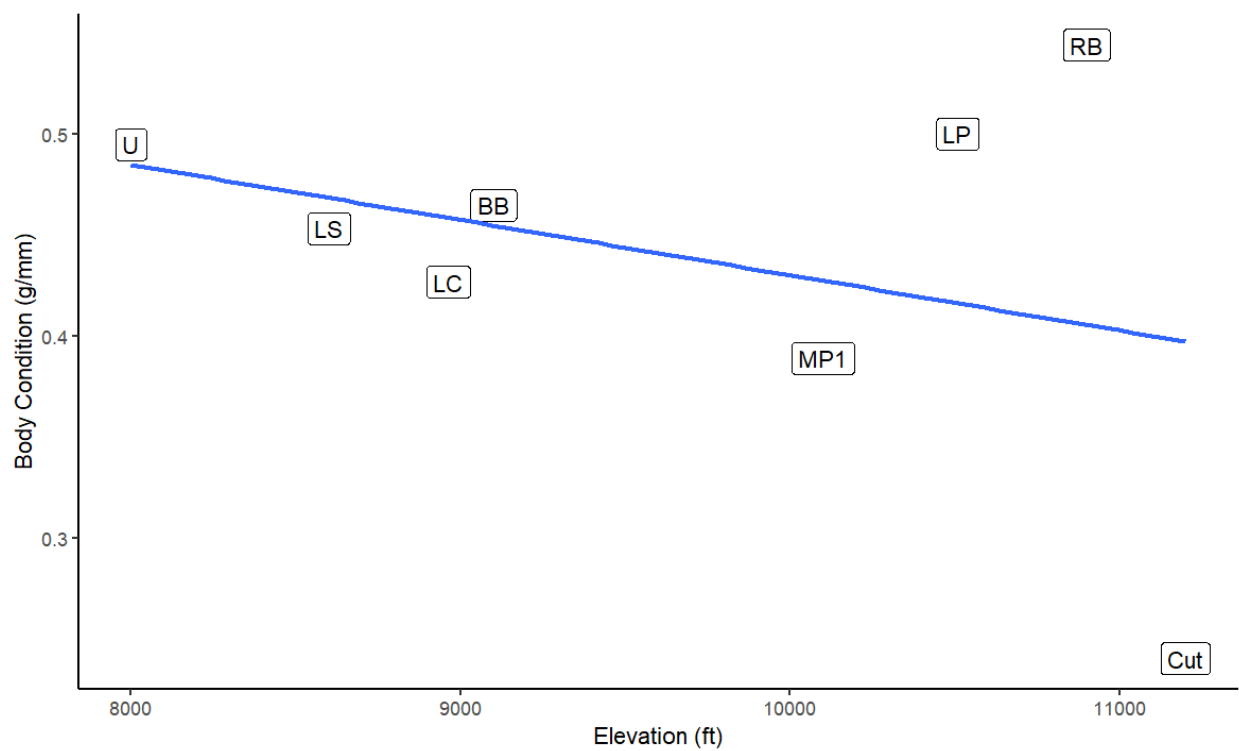


Fig 4. Relationship between Body Condition and Elevation. P-value= 0.408

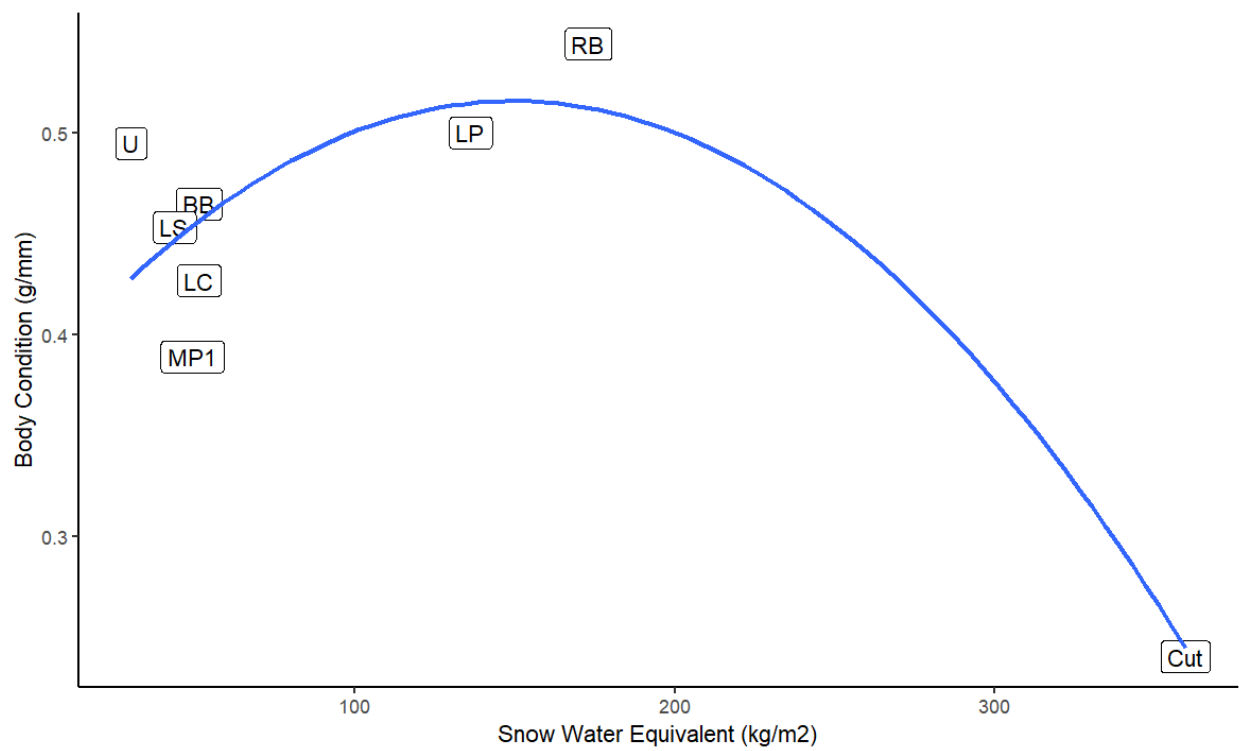


Fig 5. Relationship between Body Condition and Snow Water Equivalent. P-value for snow water equivalent = 0.024, p-value for square of snow water equivalent = 0.016

Linear models were used to identify trends in the dataset. Upon analysis, it was found that elevation does not pose a significant effect on paedomorphic body sizes, yielding a p value of 0.1081 (Fig. 1). The relationship between elevation and body conditions of paedomorphs was also found to be insignificant, yielding a p value of 0.4079 (Fig. 3), ultimately rejecting the original hypothesis. It was found that the amount of snow present at a site does have an effect on paedomorphic body sizes. Paedomorphs at sites with higher mean daily snow water equivalent had smaller snout-vent lengths, showing a p value of 0.02231 (Fig. 2). Body condition also decreased non-linearly with snow (first order term p-value = 0.024, second order term p-value = 0.016).

Discussion

At sites with a higher amount of snow, snout-vent lengths tended to be lower. This suggests that more snow at a site means that the salamanders will have less time for optimal growth, meaning that they are more likely to choose the best of a bad lot strategy and forfeit size for sexual maturity. This shorter growing season is caused by a variety of factors, one of the primary ones being that these ponds will have colder water temperatures. These results are consistent with the best of a bad lot strategy being utilized at sites with more snow and the paedomorph advantage strategy being preferred at sites with less snow.

It is important to note that due to the Mexican Cut's location in Elko Valley, the weather patterns this site experience are drastically different than those exhibited at other sites. For example, Rainbow Lake shares a similar elevation as the Mexican Cut, yet receives far less snow each year. This proves that there are a variety of factors that come into play when it comes to the growth conditions present in a pond.

This study could be expanded by further exploring other factors that contribute to growth conditions. Measuring the proportions of paedomorphs to metamorphs across sites would likely support these findings, as the paedomorph advantage strategy is often exhibited in ponds that produce more metamorphs (Whiteman et. al 2012). A dietary analysis of salamanders at each site would help to see how prey abundance plays a role in growth conditions and if it is affected by snow. Measuring population density at each site would help to clarify the growth conditions of each pond as well, something that has been done extensively at the Mexican Cut.

References

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