EEB313 Mid-Project Update: Group A – Shahd Daoud, Abby Frix, and Sylvia Sun

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Introduction

The main question we are exploring is how the different morphologies of the Eastern salamanders change, specifically the 'red-backed' and 'lead-backed' ecomorphs under various climate scenarios. We hypothesize that the growth rates of the lead-backed morphs will be higher with increased air temperatures. Based on previous research, we found a study that concluded no consistent results between morphs regarding thermal niche selection[1]. However, another study found that unstriped (lead-backed) salamanders prefer to reside on soil surfaces and may thrive at higher temperatures[2], reinforcing our hypothesis. Based on survey data specific to the Eastern Redback salamanders and their two ecomorphs occurrence in specific plots with consistent environmental variables measured, we are interested in using that raw data to infer annual growth rates for both ecomorphs and construct a mathematical model that accounts for the relationship of the two ecomorphs, their growth rates, and how they are affected by various environmental variables. We anticipate that this model may be utilized to examine how salamander abundances change under different climate conditions.

Progress to Date

The data we have used for all subsequent analyses and graphs have been obtained from the Government of Canada's Eastern Red-Backed Salamander Open Access Data on November 12, 2024[3]. After uploading the data, as a first step, we worked on filtering the raw dataset from any points without any total Salamander abundance, specific redback abundance, or specific leadback abundance (i.e. NAs and 0s). After that, we worked on calculating the total annual ecomorph abundance – this was done by grouping by year and daily count for each ecomorph. We multiplied the values of the daily counts by the number of occurrences (tally), which gave us the total abundance for each ecomorph for each year. Making a new data frame that includes the year and total abundances for each ecomorph by year, we started working on our second step: inferring annual growth rates.

To calculate the annual growth rates, we used a basic geometric growth function: $N / N_{t+1.}$ Using this function, we obtained only positive growth rates. Adding the annual growth rates as a new column into our previous data frame, we obtained a final data frame (named: byyear_both) with these columns: Year, Redback Abundance, Leadback Abundance, Redback Annual Growth Rate, and Leadback Annual Growth Rate. After this, we were interested in incorporating environmental variables like air temperature, precipitation, and soil moisture into our data.

As a first variable, we tried tackling air temperature as a proxy for environmental temperature; we calculated the annual mean temperature for both ecomorphs and added this as a new column in our byyear_both data frame. After that, we were interested in plotting the growth rates of the two ectomorphs as a function of temperature; we created two separate scatterplots, plotting average temperature on the x-axis with the calculated lambda value for the redback and leadback morph forms plotted on the y-axis. The generated plots did not display any clear patterns. From here, we realized that the data points had been summarized and nested so that any potential relationships could be overseen.

For our next steps, we want to focus on individual plots in the original dataset. Since there are different survey locations, we want to investigate differences across locations to get a clearer idea of the temperature-growth rate relationship. In other words, our original scatterplots likely were confounded by unaccounted-for environmental differences across the different survey plots, and we will account for these differences in our future data wrangling and analysis. After confidently deciphering the growth rates, we will incorporate them within our model.

Model

The model we have decided to use to represent and analyze our data is the Lotka-Volterra Competition model. This model can represent the competition between two species, in our case, the two salamander morphs. Using this model, we would be given a logistical growth rate dependent on another species' growth rate. We would also be able to treat the growth rate as a function of temperature and our other environmental variables, like precipitation. This function can be seen mathematically below:

Leadback form:

$$\frac{dS_{\text{lead}}}{dt} = r(t)_{\text{lead}}\, S_{\text{lead}} \left(1 - \frac{S_{\text{lead}} + \alpha_{\text{leadred}} S_{\text{red}}}{K_{\text{lead}}}\right)$$

Where:

- dS_{lead}/dt is the logistic growth rate of the leadback morph salamanders
- $r(t)_{lead}$is the per capita growth rate of salamanders of the leadback morph as a function of temperature
- S_{lead} is the population size of salamander leadback morphs
- $\alpha_{leadred}$ is the effect the leadback morph has on the redback morph
- S_{red} is the population size of salamander redback morphs
- K_{lead} is the carrying capacity of the leadback morph salamanders

Redback form:

$$\frac{dS_{\text{red}}}{dt} = r(t)_{\text{red}}\, S_{\text{red}} \left(1 - \frac{S_{\text{red}} + \alpha_{\text{redlead}} S_{\text{lead}}}{K_{\text{red}}}\right)$$

Where:

- dS_{red}/dt is the logistic growth rate of the redback morph salamanders
- $r(t)_{red}$ is the per capita growth rate of salamanders of the redback morph as a function of temperature
- S_{red} is the population size of salamander redback morphs
- $\alpha_{redlead}$ is the effect the redback morph has on the leadback morph
- S_{lead} is the population size of salamander leadback morphs
- K_{red} is the carrying capacity of the redback morph salamanders

We plan to modify the model accordingly when we have a clearer idea of how the environmental variables could predict the logistic growth rates of each morph.

Some **assumptions** of this model include:

- ***Species***: The model assumes that only two species are interacting
  - Here being two ecomorphs: Redback and Leadback salamanders
- ***Resources***: Both ecomorphs have access to unlimited resources
- ***Time***: The model assumes that population changes occur continuously over time.
- ***Response***: The model assumes that both ecomorph populations react instantly to changes in the other population.
- ***Carrying Capacities***: The model assumes that the carrying capacities are constant.
- ***Effect***: The model assumes that the effect of one ecomorph on the other is linear.
- ***Competition***: The model assumes that competing ecomorphs use some of the resources available to an ecomorph as if there were more individuals of that ecomorph.

References

1. Petruzzi, Erin E., et al. "The Role of Thermal Niche Selection in Maintenance of a Colour Polymorphism in Redback Salamanders (Plethodon Cinereus)." *Frontiers in Zoology*, vol. 3, no. 1, July 2006, p. 10. *Springer Link*, https://doi.org/10.1186/1742-9994-3-10.
2. Straub, Cory S., et al. "Habitat Selection and Refuge‐use by a Color Polymorphic Salamander Reveal Behavioral Niche Differences." *Ecology and Evolution*, vol. 1
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4. Canada, Parks. *Eastern Red-Backed Salamander - Bruce Peninsula - Eastern Red-Backed Salamander - Bruce Peninsula - Open Government Portal*. https://open.canada.ca/data/en/dataset/3571474b-8d75-491d-816e-f84677b81a7c/resource/18cac61e-b5b9-45aa-a043-5f5c9d8923f3. Accessed 12 Nov. 2024.