Body Condition in Larval and Adult *Gyrinophilus porphyriticus* linked to Stream Environment

Kai Barreras 22', Data Science Major Capstone

Research Question

Question 1: Are certain environmental conditions associated with body condition measured by snout-vent length in larval and adult *Gyrinophilus porphyriticus* salamanders?

Question 2: What role do environmental conditions play in predicting salamander life stage?

Background

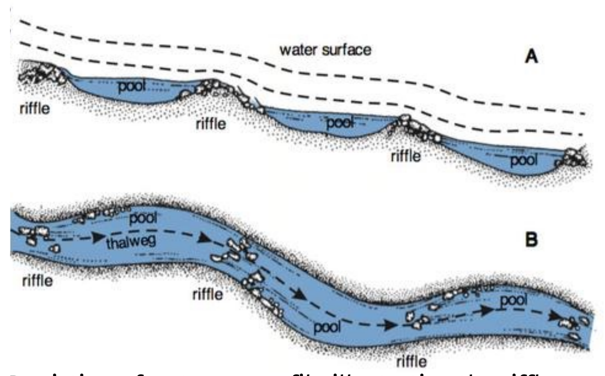
The Northern Spring salamander, otherwise known as *Gyrinophilus porphyriticus* are largely found in headwater streams along the Appalachian Mountains of the United States and just North to the Adirondack Mountains. In their larval stage salamanders are exclusively aquatic. After undergoing metamorphosis their external gills meld back into their skin and as they transition into adulthood develop the proper respiratory system to be able to survive terrestrially. Salamanders are typically found under rocks, fallen trees, leaf litter, and any other damp and dark areas near streams.[1]

A stream's **mesolocation** is described by:

- **Thalweg** - The thalweg refers to the point in the stream with the greatest water depth.
- **Wetted Edge** – The wetted edge refers to the shallowest point, along the edge of the bank.[2]

A stream's **latitudinal location** is described by:

- **Riffle** - Shallow places along the stream with higher water speeds.
- **Pool** - A still or slow moving part of the stream. [3]



Depiction of a stream profile illustrating the riffle, pool, and thalweg.[4]

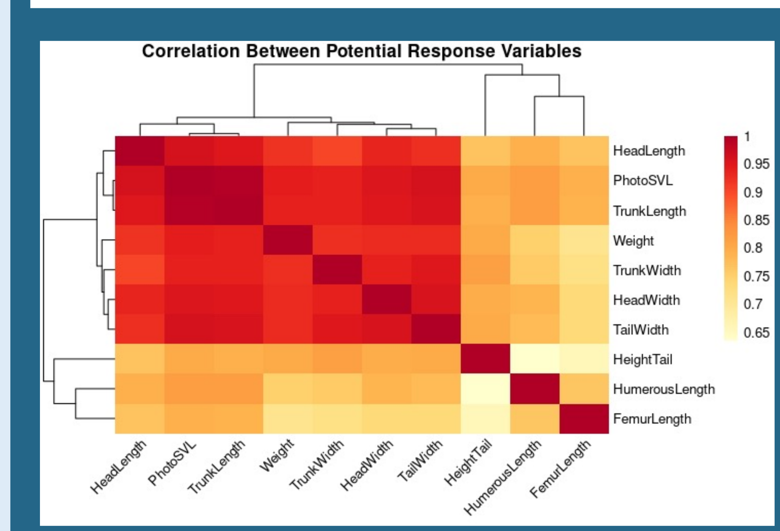
Data Collection and Description

Observations of 718 distinct salamanders were sampled from six different streams in the Hubbard Brook Ecological Forest during capture mark and recapture surveys. Surveys took place along 500-meter stretches of each stream site. For every one meter, a rock within the stream path was randomly flipped. If a salamander was found under the rock, its capture would be attempted. Environmental data was collected immediately after capture (or loss) of salamander. If the salamander was caught, and had no pre-existing pittag associated, it was then pittagged and measured, or its old pittag number was recorded and its measurements were noted. Each salamander was returned to its original location under the same rock they were found after processing.

Variables measuring **environmental conditions** are as follows: **Rock Size, Meso-Location, Longitudinal Location,** and **Latitudinal Location.**

Variables measuring **body condition** are as follows: **Snout-Vent-Length** (in cm), **Stage** (categorical, levels: A, Adult and L, Larvae), Weight (in grams), Head Length, Head Width, Trunk Length, Trunk Width, Humerous Length, Femur Length, Tail Width, and Tail Height (all in cm).

Variable Selection



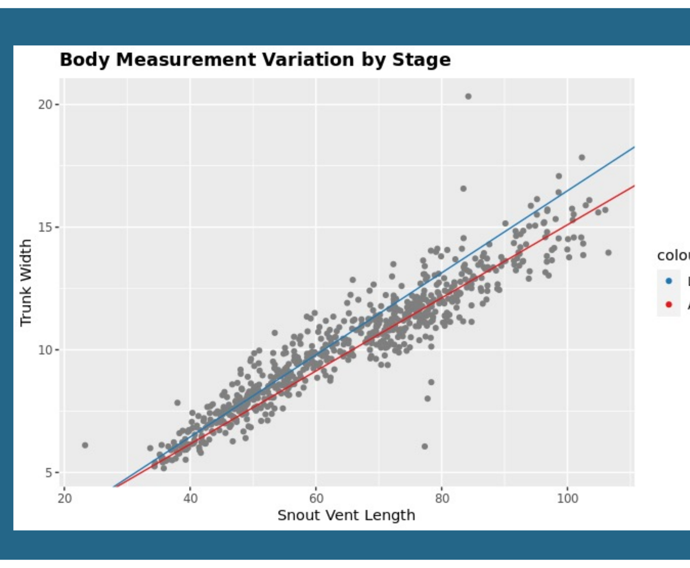


Figure 1&2. Heatmap indicates high correlation between potential body condition variables, ranging from 0.65 and upwards. Then examined the regression lines of stage on SVL and TrunkWidth.

Logistic Regression Visualization

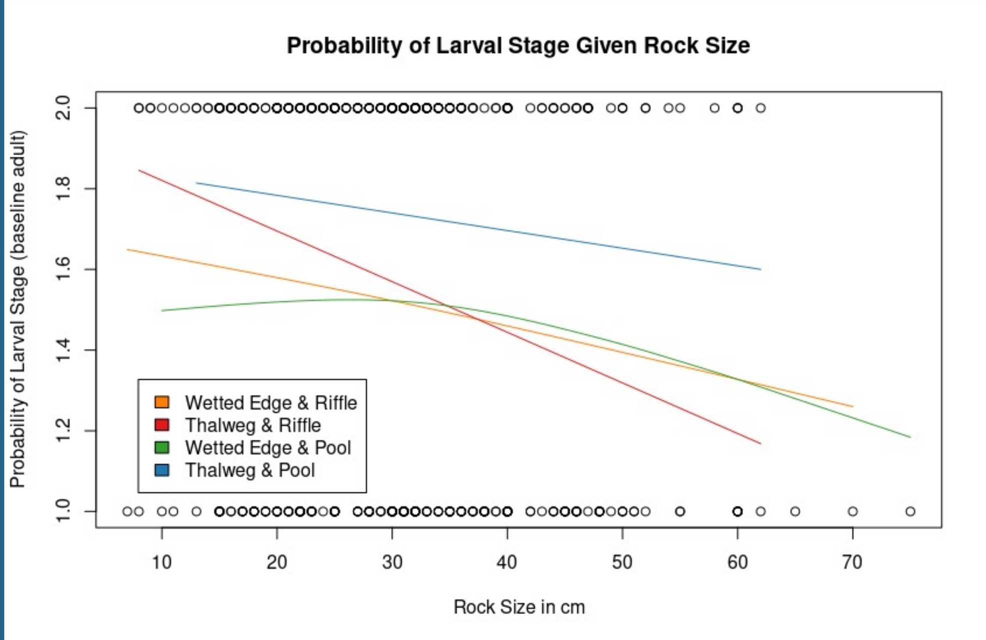
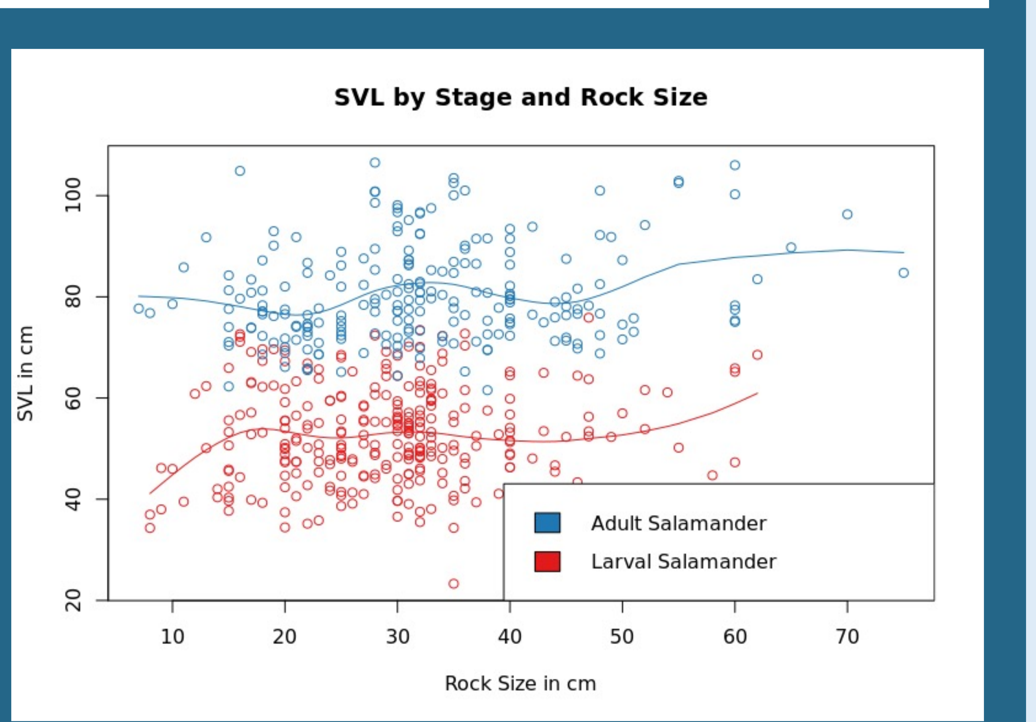


Figure 3. Given baseline stage is adult, the probability of falling into the larval stage for almost all stream locations: is reduced as Rocksize grows larger. However, for the stream location, Thalweg & Pool, the probability of falling into the larval stage is relatively high regardless of rock size.

Summary statistics for the final model: RockSize: p=0.00130, LatLocWE: p=0.00411, MesoLocationRF: p=0.14246.

Multivariate Regression Visualization

Figure 4. Examine Regression Assumptions: The slope of the regression lines for each stage appear to vaguely follow a similar pattern but may not be convincing enough to consider parallel. As such, We may want to consider fitting interaction terms.



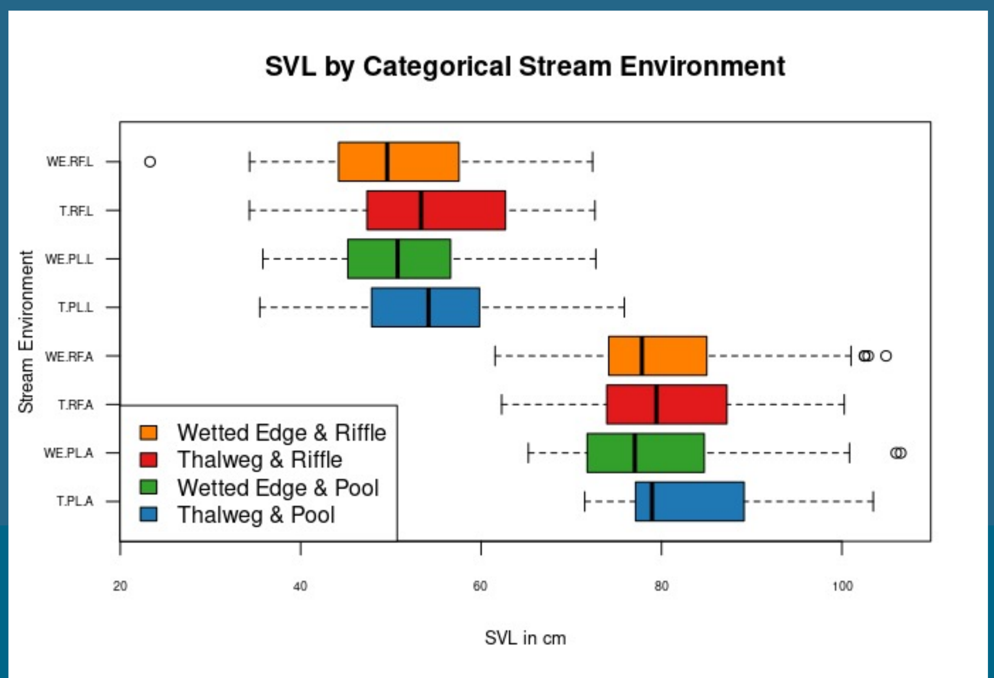


Figure 5. The boxplot of SVL by categorical stream environment suggest a potential distinction in variation in SVL by Stage between wetted edge and thalweg.

Models and Analysis

From the data collected, there were several potential outcome variables to reflect salamander body condition. A correlation matrix of the potential body condition variables confirms a high correlation between each of the variables suggesting any one of them might make for an adequate response variable in my models. After considering the context, snout-vent-length or SVL was selected as it is cited as one of the most important morphometric measurements for identification and body condition.[5]

The data set was split into training and testing sets with 504 observations and 214 observations respectively and models were fit as follows using the training set:

Coefficient	Initial Model	Interactive Model	Reduced Model
$\widehat{Intercept}$	77.934	75.620	78.060
$\widehat{Stage}$	-27.756	-23.561	-27.766
$\widehat{RockSize}$	0.115	0.155	0.115
$\widehat{LatLoc}$	-2.041	-0.965	-2.057
$\widehat{MesoLocation}$	0.156	0.712	
$\widehat{RockSize:Stage}$		-0.085	
$\widehat{LatLoc:Stage}$		-1.752	
$\widehat{MesoLocation:Stage}$		-0.925	

The three models were validated using the testing data set. The model with the highest adjusted R^2 is the reduced model. The testing and training RMSE is lowest in the interactive model, but only marginally higher in the initial and reduced model signifying a slightly larger mean prediction error in SVL. The smallest difference between testing and training RMSE corresponds to the interactive model but is only marginally better at fitting the data than the other models. The smallest BIC reinforces our final model selection of the reduced model.

Model	Adjusted R^2	RMSE (Training)	RMSE (Testing)	BIC
Initial First Order Model	0.683	9.411	8.802	3727.454
Interactive Model	0.683	9.389	8.801	3743.843
Reduced Model	0.684	9.411	8.810	3721.264

Conclusions

- **Adult** salamanders have greater chance of being found under larger rock sizes meanwhile **larval** salamanders tend towards smaller rock sizes as well as the Thalweg of the stream.
- The initial first-order model indicates a positive relationship between **SVL** and **rock size** and a negative relationship between SVL and salamander observations along the wetted edge.
- The presence of **MesoLocation** in the models consistently had no significant contribution to model fit suggesting there is no relationship between SVL and water depth.
- Northern Spring Salamander SVL may be associated with rock size as smaller **larval** salamanders have the capacity to fit under smaller rocks unseen by predators, meanwhile larger **adult** salamanders have distinctive bright red coloration and require larger coverage to keep them from exposure.
- Model suggests SVL decreases in salamander observations found along the wetted edge, potentially having to do with slightly less vulnerability to brook trout along these shallow regions.

[1] Hebron, D. 2022. "Gyrinophilus porphyriticus" (On-line), Animal Diversity Web. Accessed November 10, 2022 at https://animaldiversity.org/accounts/Gyrinophilus_porphyriticus/

[2] Knoward, Thamus. "Terraforming - [Geomorphology 101] 1. Fluvial Processes." *WesterosCraft Forums*, WesterosCraft Forums, 15 Apr. 2020, https://forum.westeroscraft.com/threads/geomorphology-101-1-fluvial-processes.284/.

[3] "Identification and Delineation of Bed Features - Vermont." *Appendix M*, VT Agency of Natural Resources, Apr. 2004, https://dec.vermont.gov/sites/dec/files/wsm/rivers/docs/assessment-protocol-appendices/M-Appendix-M-04-Delineation-of-Bed-Features.pdf.

[4] Jennings, Greg, and Will Harman. "Natural Stream Processes: NC State Extension Publications." Natural Stream Processes | NC State Extension Publications, NC State Extension, 1 June 1999, https://content.ces.ncsu.edu/natural-stream-processes.

[5] Margenau, Eric L., et al. "Modified Salamander Stick to Facilitate Accurate Measurement of Small Individuals." Herpetological Review, vol. 49, no. 2, 2018, pp. 243–246., https://www.fs.usda.gov/nrs/pubs/jrnl/2018/nrs_2018_margenau_001.pdf. Accessed 10 Nov. 2022.