Introduction

Figure 1: Ambystoma opacum

The Appalachian Mountains are home to the greatest number of Plethodontidae salamander species in the world. It is estimated that 77 different salamander species inhabit the Appalachian Mountains (Binkovitz, 2013). Despite this fact, salamanders and their habitats remain largely understudied. Many ecological features that create the ideal habitat for salamanders are often changed or destroyed due to landscape-altering activities associated with human development e.g., golf courses, road construction, mining, and logging. Fewer salamanders (larval, metamorph, juvenile, and adult) were found in sections of a stream located on the golf course in comparison to locations up or downstream from the course (Mackey et al., 2014). In this study, I aim to determine what ecological variables are most important to salamander abundance and improve our conservation methods accordingly.

Materials and Methods

I surveyed two locations owned by Union College throughout this project: Indian Creek Springs Golf Course and Turner Outdoor Center. I placed 12 sites at each location and checked each one4 times across the research period (June 2022 to September 2022). Each site contained one cover board, one 1m x 1m plot, and a 3m transect. The locations and their sites can be seen in the following figures.

Figure 2: Turner Outdoor Center (left) and Indian Springs Country Club (right)

Each site was composed of 1/2" plywood that I turned over once upon each visit. I also placed a 4m transect at each site and walked it once per visit. I also checked 1m x 1m plot each visit by turning over the leaf litter a few leaves at a time. If a salamander was found, I captured it using proper handling techniques and placed it in a plastic bag. Then, I measured its Snout-Vent-Length and identified the salamander to the species level. I also took pictures of the salamanders that were uploaded to iNaturalist for future reference and documentation. During each visit, I recorded temperature, time, and soil moisture. At the end of the research period, I recorded site-level variables. I measured the canopy cover of each site using a Forest Supplier's densitometer. I measured the aspect using an orienteering tool. I obtained elevation data via a Garmin GPS that automatically recorded to elevation and the specific location of each site. I also took soil samples from each site using a soil probe and tested them for the following elements using Lamonte soil testing kits: Nitrogen, Phosphorus, Potassium, lead, and Ph. I then obtained leaf litter samples from each site to check for arthropod density using Berlese funnels. I then counted the arthropods using a dissecting microscope.

I then imported all data into the open-source statistical analysis program "R" to build occupancy models (R Development Core Team, 2008). Occupancy modeling accounts for imperfect detection and helps estimate real occupancy (Wenger & Freeman, 2008). Occupancy models are built using two categories of variables: detection and occupancy. In this study specifically, detection variables include temperature, moisture, time, and precipitation while occupancy includes all site variables. I built the models using all combinations of detection and observation variables. It is important to note that since some variables showed no variance between site and location, they were not included in any occupancy models. I then compared each model using AIC values. AIC values serve as a gauge of fitness for occupancy models where a lower AIC value is more desirable.

Results and discussion

Using the aforementioned methodology, a total of 22 salamanders representing 5 species were found during the survey period from June 6th, 2022, to September 9th, 2022. The species found included *Pseudotriton ruber, Pseudotriton Montanus, Pleurodelinae, Ambystoma opacum, and Eurycea longicauda.* The data from the best occupancy models can be seen in the following figure.

Model (obsvars, sitevars)	AIC	ΔAIC	Estimate	SE	p
temp+ precip, lead + arthropods	36.34	0	29.19	32.09	0.363
temp + precip, canopy + arthropods	36.97	0.63	13.42	5.94	0.024
precip , athropods	41.19	4.85	59.91	103.71	0.563
temp + temp, Aspect	47.37	11.03	-0.767	89.2	0.933
precip, lead	51.35	15.01	6.879	15.61	0.659
moisture + temp, canopy + arthropods	66.64	30.3	-62.79	79.5	0.43

Figure 3: AIC Comparison Table

Of the four observation-level measured (time of arrival, temperature, moisture, and rainfall), temperature and rainfall were most significantly associated with salamander abundance. Out of the ecological variables studied, canopy cover and arthropod counts were most significantly associated with salamander abundance. Previous studies had similar results that reveal a correlation between both canopy cover and moisture with salamander abundance (Baecher & Richter, 2013). My results also show that the measure of lead in soil and arthropod counts are correlated with salamander abundance. Across the two locations, lead levels varied from 400ppm at Indian Springs Country Club and 100ppm at Turner Outdoor Center (all site lead measures at each respective location were equivalent). Despite the first assumptions, arthropod counts were higher in locations with lead levels of 400ppm than those with 100ppm. The cause for this difference in lead count across locations is likely due to Indian Springs Country Club being built on a former coal mine. To account for this difference, I ran an additional model using location as a variable to distinguish between the lead counts of the two locations, but the results were not of significant value. The link between higher lead counts and arthropod density directly is not known. For salamander abundance and arthropod abundance, past studies found that salamanders act as top-down regulators of arthropod densities; this means that in sites occupied by salamanders, it is expected that the density of arthropods would be less than those that are unoccupied. Though this does help me to form a hypothesis, it does not definitively confirm the link since the study focused only on one species of arthropod (Walton, 2013).

Conclusion and Final Thoughts

In conclusion canopy cover, arthropod density, and lead presence are clearly associated with salamander abundance in the Appalachian Mountains of Southeast Kentucky. Though the research period was short, my study found results that, with more research, can increase our knowledge of the ecological variables that affect salamander abundance. As temperatures continue to rise due to climate change, finding salamanders will become increasingly more difficult. Throughout the summer, this is an issue I encountered personally. Continuing research on the salamander populations of the Appalachian Mountains to improve our conservation methods will help ensure that the vast diversity is protected. This research allowed me to learn many important skills while exploring potential career options. I gained experience in coding in R and field biology. I learned to perform soil test in the field and in the lab. Thanks to the Appalachian College Association and Ledford’s scholar for giving me this opportunity.

References

Binkovitz, L. 2013. The surprisingly colorful salamanders of Appalachia. *Smithsonian Magazine.com*.

Maigret, TA. 2013. Effects of streamside management zone timber harvest on salamander communities in Robinson Forest. [unpublished master's thesis]. *University of Kentucky*.

Wenger S J & M C Freeman. 2008. Estimating species occurrence, abundance, and detection probability using zero-inflated distributions. *Ecology* 89(10): 2953-2959.

Baecher A & Richter S. 2018. Environmental gradients in old-growth Appalachian forest predict fine-scale distribution, co-occurrence, and density of woodland salamanders. *Ecology and Evolution* 8: 12940-12952

Walton, B. 2013. Top Down Regulation of Litter Invertebrates by a Terrestrial Salamander. *Herpetologica* 69(2) : 127-146