Determination of Terrestrial Salamander Abundance Relative to Edge Habitats and Sampling Type on Conserved Properties in Northwestern Pennsylvania

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Pledge

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Abstract

Amphibians are going through global species declines because of human impacts such as forest fragmentation and other habitat disruptions. Monitoring species declines is important to gather information and conserve species. Salamanders, which are a group of amphibians, are easy to monitor and are essential to habitats because of their roles as keystone and indicator species. As an indicator species, salamanders are sensitive to microhabitat changes in edge habitat areas, which can be created by human interference. Monitoring populations can detect species declines caused by microhabitat changes, but can vary in effectiveness. The objective of this study is to monitor terrestrial salamander abundance in edge and core habitat in a mixed deciduous forest and to determine the best location and sampling method for salamander monitoring. I conducted my study on a property owned by the French Creek Valley Conservancy (FCVC), a local land trust in Northwestern Pennsylvania (PA) from April 2022 to October 2022. I found no significant difference in the number of salamanders between edge and core or sample type. However, my results suggest artificial cover boards are the most effective sampling method, and salamander research should be conducted during the fall. With this information, I hope FCVC can conduct more efficient, accurate, and inexpensive studies on local salamander populations. Monitoring by conservancy organizations like FCVC is important to determine biodiversity on private lands and determine long-term trends in species. Private lands conserved by land trusts like FCVC are important for amphibian conservation as habitat fragmentation continues to threaten amphibian numbers.

Introduction

We are in the age of mass species extinction caused by human impacts (Ceballos et al., 2020; Díaz et al., 2019). Over the past 50 years, because of biodiversity loss, nature's ability to support human quality of life has declined (Díaz et al., 2019). Understanding biodiversity loss is essential because of the ecosystem services provided by high biodiversity that are beneficial to humans and the connectedness of species to one another (Reaka-Kudla et al., 1997). In addition to biodiversity's importance to people, many species rely on each other for resources, and the extinction of one species can cause cascading effects, making biodiversity important to sustain people and ecosystems (Ceballos et al., 2020).

Amphibians are one of the most affected vertebrate groups of this human-caused decline, with 40% of amphibian species declining worldwide (Allentoft & O'Brien, 2010). Amphibians are hypothesized to be declining because of the introduction of non-native species, over-exploitation, habitat reduction, climate change, ultraviolet (UV) radiation, contaminants, and emerging infectious diseases (Hussain & Pandit, 2012). Habitat loss and fragmentation are some of the most significant threats to amphibians.

Many amphibians are vulnerable to the loss and fragmentation of upland habitats which are typically described as a forested system that is near water. Fragmentation occurs when a habitat is split apart into smaller unconnected patches. Connectivity of upland habitats can provide amphibians with refuge around critical habitats such as breeding ponds. Habitat connectivity is crucial to the regional success of amphibians because of the importance of their dispersal in preventing local extinction (Cushman, 2006). Further, amphibians' species richness is positively related to habitat patch size, thus showing the negative effects fragmentation can have on species richness (Amburgey et al., 2021; Delaney et al., 2021; Wright et al., 2020). In addition, forest fragmentation creates edge habitats with a sharp transition from forest to human disturbances. Edge habitats face more variability in microhabitats and become hotter and drier without protection from trees (Hofmeister et al., 2019). Roads are one form of fragmentation that have large ecological impacts from the sharp transition from road to habitat. They cause microclimate changes and restrict animal movement (Coffin, 2007). One direction for future research to slow amphibian decline is developing efficient and effective monitoring programs that can detect salamander abundance in varying environments (Hussain & Pandit, 2012).

One way to increase knowledge about biodiversity loss is by monitoring populations for declines (Pereira & Cooper, 2006). Monitoring creates biodiversity data that can be used to inform conservation policy (Chiarucci et al., 2011; Pereira & Cooper, 2006). On a global scale, this can create a globally coordinated approach to understanding the overall trends of biodiversity (Pereira & Cooper, 2006). Understanding these trends is important in informing global leaders and creating large-scale action. In addition, local monitoring has the potential to be more cost-effective, create reliable results, and prompt local management decisions (Danielsen et al., 2005). Local management allows for the efficient protection of local species.

Amphibian decline is important to slow because declines cause changes in primary production, organic matter, aquatic and terrestrial predators, and reduced energy transfer between aquatic and terrestrial environments (Hallidy, 2008). Salamanders regulate food webs through top-down and bottom-up controls as a mid-level predator of macroinvertebrates and as an abundant prey item in terrestrial and aquatic systems (Keitzer & Goforth, 2013; Davic & Welsh, 2004). In addition, salamanders are relatively easy to monitor because of their small territory size and low sampling cost (Welsh & Droege, 2001). Indicator species change presence with variation in the environment and are valuable to study, with salamanders acting as an indicator species of healthy habitats (Caro & Doherty, 1999; Welsh & Droege, 2001). Terrestrial salamander densities are highest in older moist forests and lower in more degraded habitats (Meshaka et al., 2019; Welsh & Lind, 1991). Plethodontid (lungless) salamanders can be used as environmental monitoring indicators because of their response to microhabitat change (Cushman, 2006; Welsh & Droege, 2001). For example, *Plethodon cinereus*, red-backed salamanders, have lower densities in areas with historical agriculture use (Cushman, 2006) and near gravel roads (Marsh & Beckman, 2004). Salamanders' sensitivity to changes in microhabitats makes them vulnerable to forest fragmentation, especially from roads.

Prior to starting monitoring programs in a new area, it is important to test for reliable sampling methods for that region's habitats and salamander species. Methods vary in effectiveness across microhabitats and species because salamanders have varying life histories (Hyde & Simmons, 2001). Both cover boards (DeGraaf & Yamasaki, 1992) and area-constrained searches of natural cover objects (Smith & Petranka, 2000) are effective methods for terrestrial salamanders. Overall, natural cover flipping has been more effective than cover boards in assessing salamander abundance (Houze & Chandler, 2002). In addition, the cover boards allow for sampling in the daylight and do not degrade the natural habitat that occurs with flipping natural cover (DeGraaf & Yamasaki, 1992). While the artificial cover is an effective way to sample for red backed salamanders, the artificial cover is used more by salamanders when there is less natural cover (Monti et al., 2000). A study found a difference in the sizes of red-backed salamanders under artificial and natural cover (Marsh & Goicochea, 2003). However, there have been other studies that contradict this finding (Monti et al., 2000). Different types of cover boards can be more effective than others, such as wood is better than plastic (MacNeil & Williams, 2013). Creating an effective protocol for salamander monitoring allows for accurate results that can be done with effort restrictions.

French Creek Valley Conservancy (FCVC) in Meadville, Pennsylvania (PA), is a non-profit land trust committed to protecting and increasing habitat within the French Creek Watershed. French Creek Valley Conservancy has 6,000 acres protecting French Creek, which is a hotspot for the biodiversity of mussels, darters, and other fish, birds, plants, and aquatic salamanders (*French Creek Valley Conservancy,* 2022). However, FCVC knows less about the terrestrial biodiversity on their lands than they do of their aquatic biodiversity and would benefit from this knowledge to make future conservation decisions regarding the property. To do this, they require methods that are low in cost and time effort. Monitoring salamandering species abundance will allow the conservancy to monitor a terrestrial animal that indicates the ecosystem's healthiness, plays a crucial role in ecosystems, and is easy to monitor. I expect to find mostly red-backed salamanders on their properties because of their high densities in this area.

The primary objective of this project is to determine how terrestrial salamander abundance varies based on the distance to the edge habitat in a mixed deciduous forest created by a road at Mammoth Run, an FCVC property. The second objective is to compare sampling methods between artificial and natural cover objects. As a result, I will put forth a protocol for salamander sampling that can help FCVC sample in the most diverse habitat types. I hypothesize that I will recommend sampling the core habitat with cover boards as the core will have the highest diversity and density, and cover boards will be the less time-intensive and effective method.

Methods

Study Area

The field study took place at Mammoth Run, an FCVC owned property since 2017 in Meadville, Pa. The land within Mammoth Run was farmland from 1939 to about 1993 when it began to revert to a forest (L. Brooks, personal communication, February 15, 2023; Pennsylvania Geological Survey, 2023). Mammoth Run is 0.348 square kilometers (eighty-six acres), containing a small tributary, hydric soils, mature timber, and vernal pools (*Our Properties*, 2022, Fig. 1). The property is mainly hardwoods (cherry and maple) with some areas of dense understory with thorn bushes. Mammoth Run is surrounded by human development with roads, agricultural fields, and a neighborhood.

Figure 1

The study site, Mammoth Run

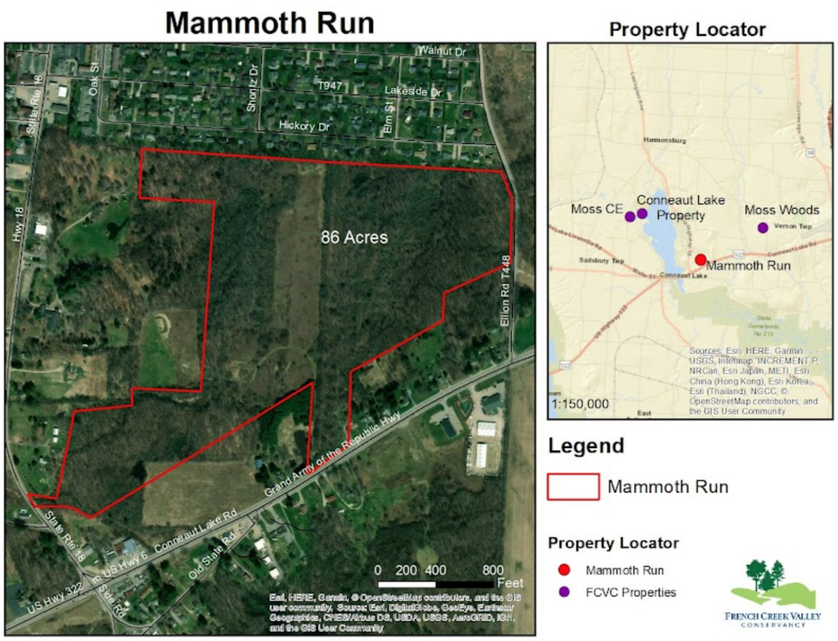

Figure 1. Mammoth Run, a French Creek Valley Conservancy's properties (*Our Properties,* 2022) where sampling took place for terrestrial salamanders.

Field Methods

I had five transects, each fifty meters long, starting at a road edge and going into the core of the property (Fig. 2 and Fig. 3). The edge was characterized by a sharp transition from forest to road, while the core was located in the forest center. The transects started 1.524 meters (five feet) from the road to prevent being disturbed by cars and were checked approximately every other week from April 14th through October 16, 2022, when terrestrial salamanders are typically active in Northwest PA. At each sampling date, the days since the last precipitation and current air temperature are recorded. I used an IMKO Soil Moisture Probe P2 to measure soil moisture at the edge and core of each transect to test for differences between the edge and core (Fig. 3). The soil temperature was recorded at the beginning of each artificial box (Fig. 3), but the sampling location wasn't consistent throughout the sampling period due to different field crews.

Figure 2

Five Transects at Mammoth Run

Figure 2. The five transects ran from Elion Rd. to core forest at Mammoth Run to study the edge effect and sampling methods on terrestrial salamander richness from April to October 2022. Figure created with the help of C. Shaffer, GIS Manager

Each transect contained a natural cover section and a cover board section that were parallel (Hyde & Simons, 2001). Both sections were separated into five boxes, each ten meters apart. The natural cover section was fifty meters long by three meters wide (Fig. 3) and was sampled by the observer walking through the box and overturning (then replacing) all the natural cover (logs, sticks, and rocks). The number of cover objects overturned was recorded (Bailey et al., 2004; Hyde & Simons, 2001) in addition to the time spent in each box.

Figure 3

Sampling Methods

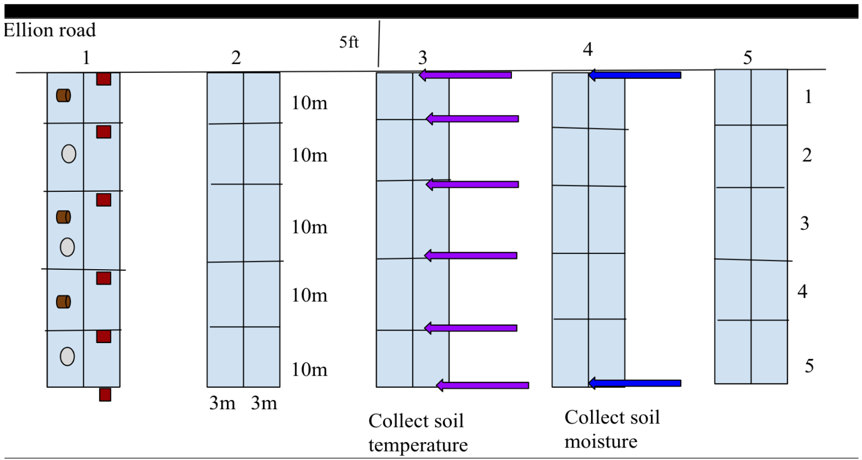

Figure 3. The five transects are split into a natural cover section (left section) and a cover board section (right section). Soil moisture is collected at the edge and core of each transect, shown in transect four, while soil temperature is taken multiple times, as shown in transect three.

The cover board section was sampled by overturning a 20.32 by 20.32 centimeter (eight inches by eight inches) ceramic tile within each box (Fig. 2). Due to the high cost of plywood, ceramic tiles were used as an alternative. Every salamander observed was identified as species and returned to where it was found (Bailey et al., 2004; Hyde & Simons, 2001).

Statistical analysis

I used Excel to complete all statistics (Microsoft Excel Version 16.661). I ran a one-way ANOVA to test the effect of distance to edge (1 = edge and 6 = core) on the number of salamanders. In addition, I ran a one-way ANOVA to test the temperature difference between the boxes (1 = edge and 6 = core). I ran a two-tailed t-test assuming equal variance on soil moisture in the edge and core of the property.

I ran a two-tailed t-test assuming equal variance to test the effect of the sampling method, natural or artificial, on the number of salamanders. For this test, the salamanders found in the natural cover section were standardized by dividing the number of salamanders by the number of cover objects flipped in that section (Marsh, 2007).

Results

A total of nine sampling days occurred from April 14, 2022, to October 16, 2022, and I detected nine salamanders total across the sampling days. Seven eastern red-backed salamanders were detected in addition to two red-spotted newts. Throughout the sampling period, I detected one salamander on September 4, 2022, four on October 2, 2022, and four on October 26, 2022 (Fig. 4).

Figure 4

Total Salamanders Detected by Sampling Date

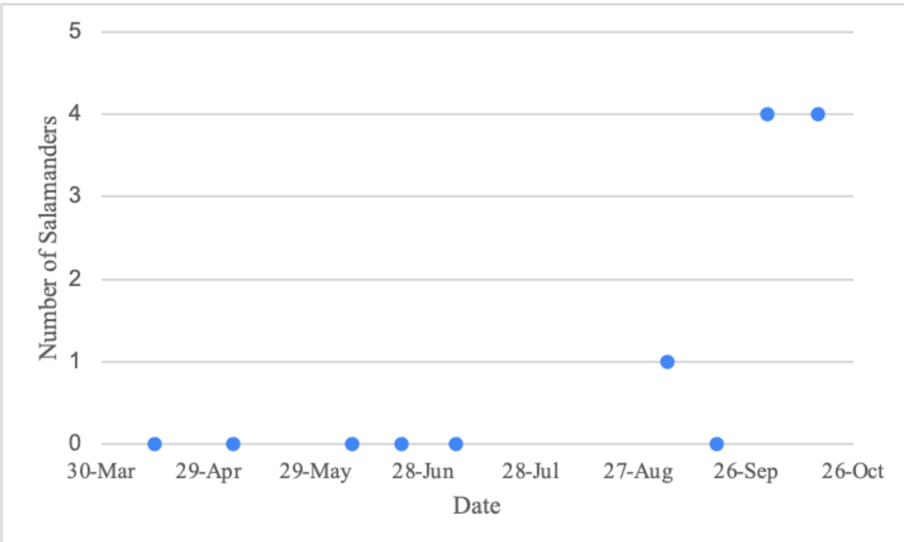

Figure 4. Total salamanders detected by sampling date. The study was conducted from April 14, 2022, to October 26, 2022, at Mammoth Run, a conserved property in Meadville, PA.

Altogether, box two had the most salamanders, with three detected, and box five had the least detected, with zero (Fig. 5). There was no significant difference between the number of salamanders detected in each box (1 = edge and 6 = core)($p = 0.81$). In addition, the temperature was not significantly different between the boxes ($p = 0.99$). The temperature test had lots of blanks due to sampling errors. However, soil moisture was significantly lower at the edge than at the core ($p = 0.005$). I only had data for four sampling dates for soil moisture because the probe stopped working.

Figure 5

Total Salamanders Detected by Box

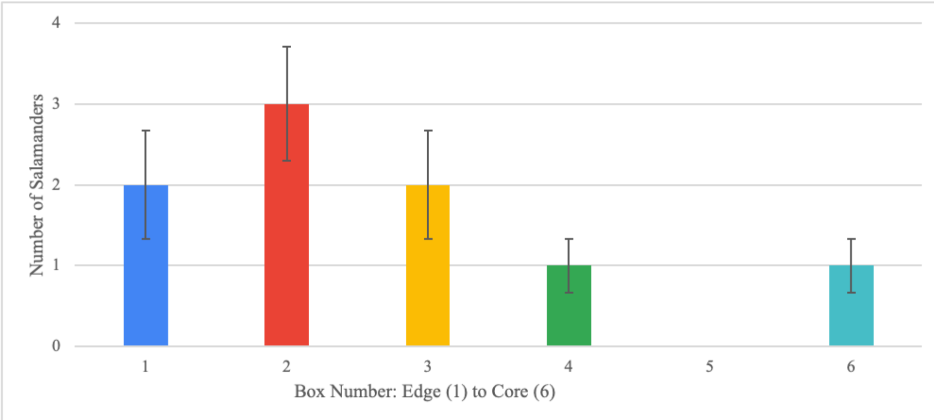

Figure 5. Total salamanders detected by box (1 = edge and 6 = core)($p = 0.81$). The study was conducted from April 14, 2022, to October 26, 2022, at Mammoth Run, a conserved property in Meadville, PA.

I detected three salamanders under natural cover objects and six under artificial cover. The standardization led to 0.67 salamanders per object under natural cover and six salamanders per object under artificial cover (Fig. 6). There was no significant difference between the sampling methods ($p = 0.23$).

Figure 6

Total Salamanders Detected by Sampling Method

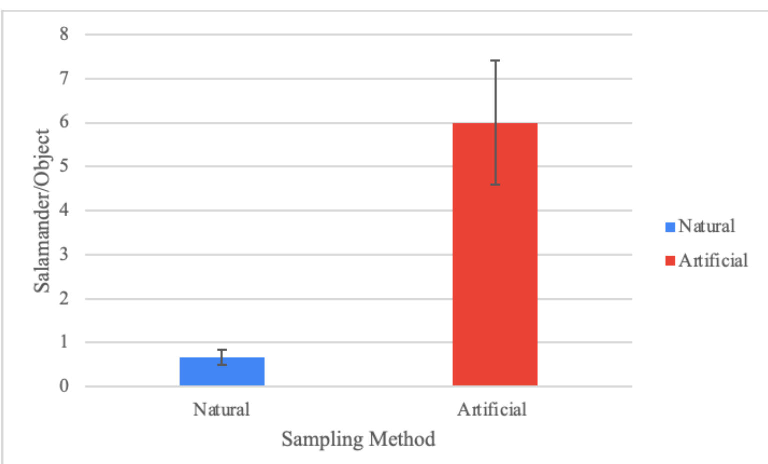

Figure 6. Total salamanders detected by sampling method, natural or artificial ($p = 0.23$). The natural section was standardized by dividing the number of salamanders found by the number of cover objects. The study was conducted from April 14, 2022, to October 26, 2022, at Mammoth Run, a conserved property in Meadville, PA.

Discussion

Edges created by features like roads have large impacts on abiotic components and can create edge effect zones. Edge habitats tend to be hotter and drier than core habitats (Hofmeister et al., 2019; Coffin, 2007). However, I found no significant difference in temperature between the edge and core ($p = 0.99$), but the soil moisture was significantly lower at the edge ($p = 0.005$). Similarly, Marsh and Beckman (2004) found that soil temperature was not significant between edge and core, but soil moisture was when studying gravel roads' impact on terrestrial salamanders. Soil moisture is vital in determining the effect of the edge zone on species like red-backed salamanders (Marsh & Beckman, 2004). However, it is hard to determine how large the edge effect zone is due to many abiotic and biotic factors (Coffin, 2007). In one study on forested gravel roads, the abundance of salamanders was reduced 20 m into the core and 80 m during a very dry period (Marsh & Beckman, 2004). Yet, another study found that the edge effect persisted 100 m into the core for macroinvertebrates, an important food source for salamanders (Haskell, 2000). However, I found no significant difference between the number of salamanders found in each box, showing no difference between the edge and core (Fig. 5, $p = 0.81$). This result may be because my study only went 50 m into the core by a paved road and went through an abnormally dry period. In Northwest Pennsylvania, June, July, and August, on average, have about 5 inches of precipitation per day. However, in the summer of 2022, June, July, and August averaged 0.13, 0.13, and 0.11 inches of precipitation per day (*Erie, PA, Weather History* 2022). In addition, my study had a small sample size, with only nine salamanders detected.

Sampling methods vary in effectiveness across habitats and time (Hyde & Simons, 2001). In my study, I found more salamanders under artificial cover than natural cover objects, but there was no significant difference between the sampling methods (Fig. 6, $p = 0.23$). However, Hyde and Simons found that natural cover transects are the most effective method for monitoring long-term trends for terrestrial salamanders. Further, Houze and Chandler (2002) found that overall natural cover searches were more effective except when sites had a less quality natural cover which may have been the case in my study. From my observations, Mammoth Run did not have high-quality natural cover (i.e., large decaying logs). While there may be a disparity between the sampling methods, both artificial cover boards and area-constrained searches of natural cover are effective sampling methods for terrestrial salamanders (DeGraaf & Yamasaki, 1992; Smith & Petranka, 2000).

From my results, research, and personal field experience, I suggest that artificial cover is the most efficient and effective method when monitoring a younger forest with multiple sampling dates for FCVC. French Creek Valley Conservancy requires effective but easy monitoring methods for their properties due to reliance on volunteers. I found through working with student volunteers that flipping artificial objects was the simplest sampling method to teach and the quickest method for volunteers to complete. In addition, Mammoth Run had little high-quality natural cover, and salamanders tend to use artificial cover more when there are fewer natural cover objects (Houze & Chandler, 2002). Further, the artificial cover does not degrade the natural habitat that occurs with flipping natural cover (DeGraaf & Yamasaki, 1992), which parallels FCVC's goals of enhancing natural habitat on their properties (*French Creek Valley Conservancy,* 2022). Due to the high cost of plywood, I used tile as my artificial cover. While I did detect salamanders under tile, I suggest using non-treated plywood as an artificial cover because it simulates a decaying log. In addition, using a cover board made out of native wood may create a microhabitat more similar to a natural cover (Houze & Chandler, 2002; Moore, 2005). While I suggest artificial cover for multiple sampling dates, I suggest flipping the natural cover to reduce setup time if it is one sampling date. In addition, I suggest sampling for terrestrial salamanders from September to November in Northwest Pennsylvania (Fig. 4). Monitoring terrestrial salamanders on FCVC properties will allow the conservancy to learn more about the biodiversity of their lands and create effective management plans.

Overall, I detected a low abundance and diversity of terrestrial salamanders even though I was sampling on a conserved property. Before Mammoth Run was donated to FCVC, it was in agriculture from about 1939 to 1993, when it began to revert to a forest (L. Brooks, personal communication, February 15, 2023; Pennsylvania Geological Survey, 2023). Hyde and Simons (2001) found that salamander diversity and abundance were reduced for 60 years after habitat disturbances such as agriculture. These land use changes may have influenced the low overall numbers of terrestrial salamanders detected at Mammoth Run. Land trust organizations like the FCVC protect land for perpetuity and allow them to "recover" from past land uses. In addition, FCVC has plans to manage and enhance Mammoth Run by thinning the overstocked small trees (i.e, cherry and maple) and potentially planting trees to increase biodiversity (L. Brooks, personal communication, February 15, 2023). Further, Mammoth Run has invasive plant species such as honeysuckle (*Lonicera spp*.) and multiflora rose (*Rosa multiflora*). Invasive plants can have complex impacts on amphibians and should be further studied (Maerz et al., 2005). Despite the need for habitat management, Mammoth Run is an important property to conserve due to its mosaic of habitats, including the hardwood section that was included in this study. Allegheny College and FCVC can continue to collaborate and monitor properties to further inform FCVC.

There has been very little monitoring of conservation easement lands in general, so there is little information about the biodiversity they contain. However, conservation easements allow for private lands to be protected (Rissman et al., 2007), which can contribute to habitat connectivity and potentially increase habitat patch size (Kamal et al., 2015). Amphibians are positively affected by larger habitat connectivity and patch size (Cushman, 2006; Amburgey et al., 2021; Delaney et al., 2021; Wright et al., 2020), and thus their populations could be positively influenced by private land protection, especially ones managed like FCVC. Private lands may help protect amphibians which are very essential to conserve because of their important roles in ecosystems (Hallidy, 2008; Keitzer & Goforth, 2013; Davic & Welsh, 2004). Increasing monitoring of private lands will help determine long-term amphibian trends and if the lands require further management to become better habitats.

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