Salamander Habitats in an Urban Context within Allegheny County

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Citation: Flynn, S. P. (2023). Salamander Habitats in an Urban Context within Allegheny County. *Earth Envi Scie Res & Rev, 6*(4), 636-655.

Abstract
Human population growth has led to urbanization. Ecosystems produce habitats for many species in both local and national areas. Salamanders are crucial for ecosystems and urbanization affects them by having habitats being destroyed. Several tools along with a comparison between the Simpson and McIntosh Biodiversity Index, allows the results to show similar scores between the diversity indexes and while the scores are great considering the landscape of Allegheny County, more research needs to be done regarding observations and how the ever-changing environment affects salamanders throughout the life cycle.

Keywords: Biodiversity, GIS, Wetlands, Urban Ecology, Wetland Mitigation, Ecosystems, Land use, Policy

1.0 Introduction

Since the industrial revolution of the 1700s, along with the improvement of science and technology, urban populations have increased, urban land has expanded, production and life has increased [1]. These improvements have brought numerous problems to the environment which includes degradation, soil erosion, desertification, wetlands that are replaced by lawns, and finally impervious land became expanded [1]. In the 1900s, the urban population increased to 50 percent of the total distribution of the population, and urbanization resulted in 58 percent of wetland loss. Looking at the relationship between both wetland loss and pressure from development is crucial for both wetland conservation and wetland programs, which allows for understanding and planning for the future effects within the realm of urban growth within the context of wetland environments [2]. The expansion of urban areas is negatively impacting the localized ecosystems within regions of North America based on fragmentation and isolated naturalized land covers [3].

Urbanization is a threat to ecological communities and is a cause of species extinction [4]. The progressive development of areas can alter both abiotic and biotic characteristics within habitats. Furthermore, the connectivity across the landscape can be altered, and there have been numerous studies that have shown the loss of species that are native to the land, which shows that species reduction is influenced by urbanization and that urban areas bring in invasive species that has a contribution to biodiversity loss [4].

Urbanization is occurring at a global scale and risks the biodiversity of natural areas [5]. The cities of the world support more than 50 percent of the population and are projected to increase in the future, and cities threaten biodiversity based on altering development of the natural habitat that supports various species [5]. Also, urbanized areas are home to species of conservation concern and could possibly be at risk of destruction from the ongoing human development, which is based on continuous improvement from roads and buildings, which creates habitat fragmentation, nutrient cycling alterations, and water distribution [5]. When urbanized areas expand, the efforts for conservation are more important, and co-existence becomes the goal [5]. The opportunity for conserving biodiversity within urban areas by use of green spaces and other beneficial green technology that includes urban cooling and air purification systems [5].

The urban landscapes are part of the global population at 51 percent, with 80 percent of both European and United States citizens and 90 percent of Latin Americans [6]. The ever-continuous increase in the number of cities, along with transforming the landscape, creates numerous challenges for the reduction of biodiversity loss and the associated ecosystem functions and, finally, human welfare [6]. Different species are the key to ecosystems and the services these ecosystems provide [6]. The idea of ecosystem services is the means of assessing, managing, or designing the environments to fulfill the processes that support the well-being of humans, and the functions include nutrient processing and the removal of nutrients,

habitats for species, carbon sequestration, and other functions [7].

Globally, complex urban systems are further expanding into valuable lands, specifically agriculture, and forest production, and intruding on both the health and resiliency of social-ecological systems [8]. The ever-changing land use does produce benefits while the cost of destroying options for the future in regard to ecosystem economics. Furthermore, the growth of population forces the growth of urban systems and the objectives with land management [8]. Another major threat is fringing urban areas. The urban fringe regions are being developed very fast and covers more area than the cities within the United States and threatens the natural areas of conservation that are considered high value and will create more problems with ecological impacts than

urban areas that are compacted together [9]. The government-led protection with aquatic ecosystems within the United States falls under Section 404 of the Clean Water Act. Both public and private developers within the context of projects that will impact marine ecosystems need to apply for permits under the guidance of the United States Army Corps of Engineers [10].

2.0 Methods
2.1 Site Description
The Ohio River Basin has an area of roughly 204,000 square miles that covers fourteen different states and covers major cities that includes Pittsburgh, Columbus, Cincinnati, Louisville, Indianapolis, and Nashville (Figure #1).

Figure #1: Map of the Ohio River Basin that includes the boundary which is red along with the various dams and locks in which there are nineteen. Image taken from [11].

2.2 Study Area
The area for the study will be within the boundaries of Allegheny County, Pennsylvania, and will include local watersheds [11].

2.3 Datasets
The datasets are opensource and the datasets are Allegheny County Boundary, The National Land Cover Database, Soils, Wetlands, Jefferson Salamander, Spotted Salamander, Northern Dusky Salamander. Seal Salamander, and Northern Ravine Salamander (Table #1).

Name:	Owner:	Publication Year:	Links to Datasets:
Allegheny County Boundary	ESRI	2015	https://www.arcgis.com/home/item.html?id=12d17d63e67d4b22b833b5733abf2f7e.
The National Land Cover Database	USGS	2011	https://www.usgs.gov/centers/eros/science/national-land-cover-database#data.
Soils	Natural Resources Conservation Service	2018	https://www.nrcs.usda.gov/resources/data-and-reports/web-soil-survey.
Wetlands	U.S. Fish and Wildlife Service	N/A	https://www.fws.gov/program/national-wetlands-inventory/wetlands-mapper.
Jefferson Salamander	USGS	2018	https://doi.org/10.5066/F7XK8CT6.
Spotted Salamander	USGS	2018	https://doi.org/10.5066/F72R3PZS.
Northern Dusky Salamander	USGS	2018	https://doi.org/10.5066/F7NZ85XC.
Seal Salamander	USGS	2018	https://doi.org/10.5066/F7F47MDH.
Northern Ravine Salamander	USGS	2018	https://doi.org/10.5066/F7N014SV.

Table #1 Datasets with Name, Owner, Publication Year, and links associated with the datasets.

2.4 Data Analysis

The Allegheny County Boundary outlines the area of focus [12]. The National Land Cover Database allows for land cover and land cover change with a 30-meter resolution and also uses spatial reference and descriptive data for urban areas, agriculture, and forest, along with the percentage of tree canopy cover. The dataset that will be used is from the year 2011 [13]. The web soil survey provides various entities for relevant soil that is used for land use and other management determinations and the data's publication date in 2018 [14]. The wetlands mapper creates easy map views of wetland resources. The wetlands mapper creates digital maps to show the current information on the status, characteristics, and functions of wetlands and other types of habitats [15]. The Gap Analysis Project provides common species and plant species with identification purposes within conservation lands, and the species dataset is from the year 2001 [16]. The data sets look at the habitat maps for the Jefferson Salamander (Ambystoma jeffersonianum), Spotted Salamander (Ambystoma maculatum), Northern Dusky Salamander (Desmognathus fuscus), Seal Salamander (Desmognathus monticola), and Northern Ravine Salamander (Plethodon electromorphus) within the United States based on the ground conditions from the year 2001 [17].

2.5 Computer Software

ArcGIS Pro v3.1 is a desktop GIS application that is made by ESRI and there are many different applications that can be used within ArcGIS including creating maps, analyzing data, and sharing work online [18].

2.6 Tools

The first tool that was used is summarize within. Summarize within overlaps polygon layers with another layer to calculate the number of points, line length, or area within another polygon and then calculates field statistics about the various features that are found within the polygon [19].

The second tool that was used is clip. The clip tool is part of the extract toolbox and will extract the features that overlap within the clip features. The tool is used to cut out pieces of a dataset with the goal of creating a new dataset, and the perimeters include values of points, lines, and polygons. Each of the parameters is unique based on the input features or the dataset type [20].

The third tool that was used is Summary Statistics and is part of the analysis toolbox. The created output table will show the results from the performed statistical operation. The operations that can be used include sum, mean, standard deviation, variance, and unique operation [21].

The fourth tool that was used is Raster to Polygon which is a conversion tool. The input ratser needs to have a valid integer and can be any size. The perimeters allow for choosing the attribute with the inout of a raster dataset and will create a feautre class based on the output and the gridcode becomes the attribute table for the output class of features [22].
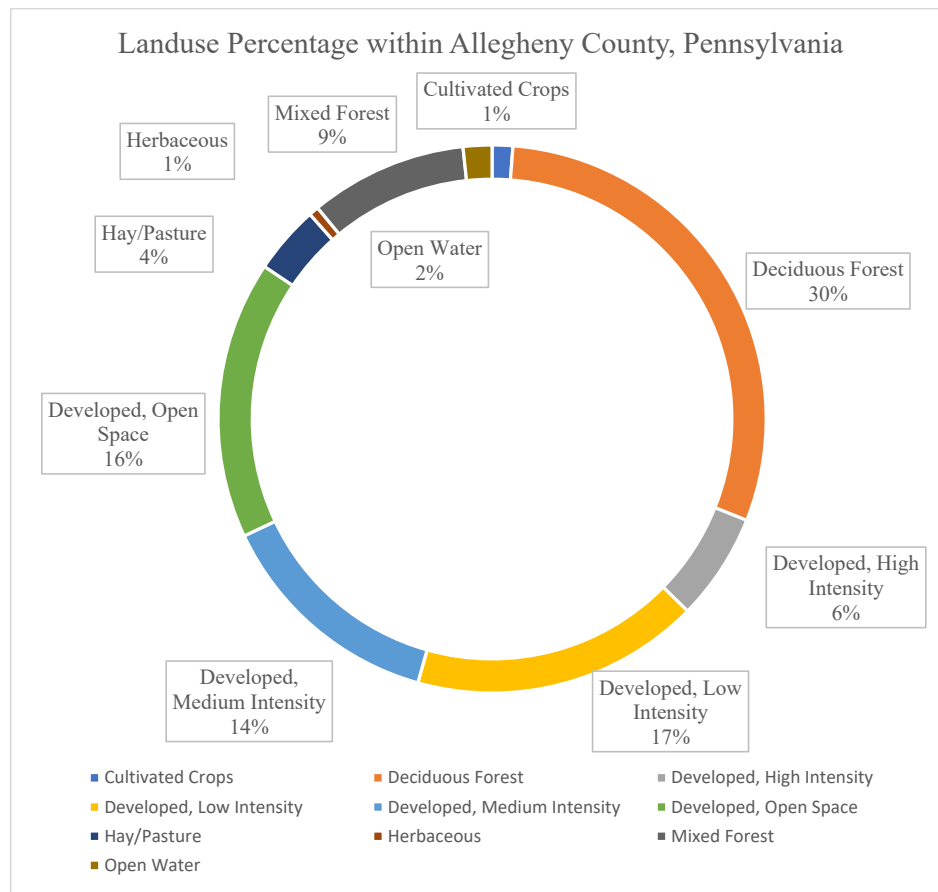
The final tool that was used is Optimized Outlier Analysis which is a spatial tool. The optimized outlier analysis creates a map of significant hotspots and outliers using Moran's I statistics. This evaluates the characteristics of feature classes to create remarkable results [23].

2.6.1 Statistical Analysis

The analysis that was performed is a comparison between the McIntosh Diversity Index and Simpsons Diversity Index. The Simpsons Diversity Index measures diversity and is used to look at the biodiversity of a given habitat. The index looks at the number of species that are present and the abundance of the given species [24]. The McIntosh Diversity Index looks at the diversity of a sample in terms of geometry. The description of the sample looks at the point of an S-dimension and uses distance from the point of origin [25].

3.0 Results

Land use within Allegheny County, Pennsylvania

Landuse Percentage within Allegheny County, Pennsylvania

- Cultivated Crops 1%
- Mixed Forest 9%
- Herbaceous 1%
- Hay/Pasture 4%
- Open Water 2%
- Deciduous Forest 30%
- Developed, Open Space 16%
- Developed, High Intensity 6%
- Developed, Medium Intensity 14%
- Developed, Low Intensity 17%

Legend:
- ■ Cultivated Crops
- ■ Deciduous Forest
- ■ Developed, High Intensity
- ■ Developed, Low Intensity
- ■ Developed, Medium Intensity
- ■ Developed, Open Space
- ■ Hay/Pasture
- ■ Herbaceous
- ■ Mixed Forest
- ■ Open Water

Figure #2: Breakdown of Allegheny County, Pennsylvania land-use by percentage

3.1 Simpson Index

Observations of Different Salamanders within Allegheny County using Simpson's Index					
Common Name	Latin Name	Number of Observations (F)	F^2	Percent (P)	P^2
Spotted Salamander	*Ambystoma maculatum*	152	23104	14.7%	0.021609
Jefferson Salamander	*Ambystoma jeffersonianum*	29	841	2.8%	0.000784
Northern Dusky Salamander	*Desmognathus fuscus*	746	556516	71.9%	0.516961
Seal Salamander	*Desmognathus monticola*	8	64	1%	0.0001
Northern Ravine Salamander	*Plethodon electromorphus*	102	10404	9.8%	0.009604
	Totals ∑	**1037**	**590929**	**100%**	**0.549058**

Table #2 The number of observations shown above is derived from [26].

Test #1 for Simpsons Index using observations according to Guajardo, [27].

$$D = 1 - \frac{\sum F^2}{F^2}$$

$$D = 1 - \frac{0.549058^2}{1037^2}$$

$$D = 1 - \frac{590929}{1075396}$$

$$D = 1 - 0.451$$

$$D = 0.549$$

Test #2 for Simpsons Index using percentages according to Guajardo, [27].

$$D = 1 - \sum P^2$$

$$D = 1 - 0.451$$

$$D = 0.549$$

3.2 McIntosh Index

Observations of Different Salamanders within Allegheny County using McIntosh Index				
Common Name	Number of Observations	Observations ^2	Percent (P)	Percent^2
Spotted Salamander	152	23104	14.7%	0.021609
Jefferson Salamander	29	841	2.8%	0.000784
Northern Dusky Salamander	746	556516	71.9%	0.516961
Seal Salamander	8	64	1%	0.0001
Northern Ravine Salamander	102	10404	9.8%	0.009604
Totals $\sum$	**1037**	**590929**	**100.0%**	**0.549058**
S = 5				
Square Root of 5 = 2.23				

Table #3. The number of observations shown above is derived from (Allegheny County, n.d.).

Test #1 using McIntosh Index observations according to Guajardo, [27].

$$D_E = \frac{N - \sqrt{(\sum n^2)}}{N - N/\sqrt{S}}$$

$$D_E \frac{1037 - 768.71}{1037 - 1037/2.23}$$

$$D_E = 0.469$$

Test #2 using McIntosh Index percentages according to, (2015).

$$D = \frac{P - \sqrt{(\sum P^2)}}{P - P/\sqrt{S}}$$

$$D = \frac{1 - 0.7409}{1 - 1/2.23}$$

$$D = 0.469$$

Guidelines for Interpreting Index Scores	
Simpson Score	Interpretation
0	Absence of diversity (homogeneity)
0.01–0.40	A low degree of diversity/heterogeneity
0.41–0.60	A moderate degree of diversity/heterogeneity
0.61–0.80	A moderately high degree of diversity/heterogeneity
0.81–0.99	A high degree of diversity/heterogeneity
1	Absolute (perfect) diversity/heterogeneity

Table #4 The guidelines for Simpson Diversity Index Scores according to Guajardo, [27].
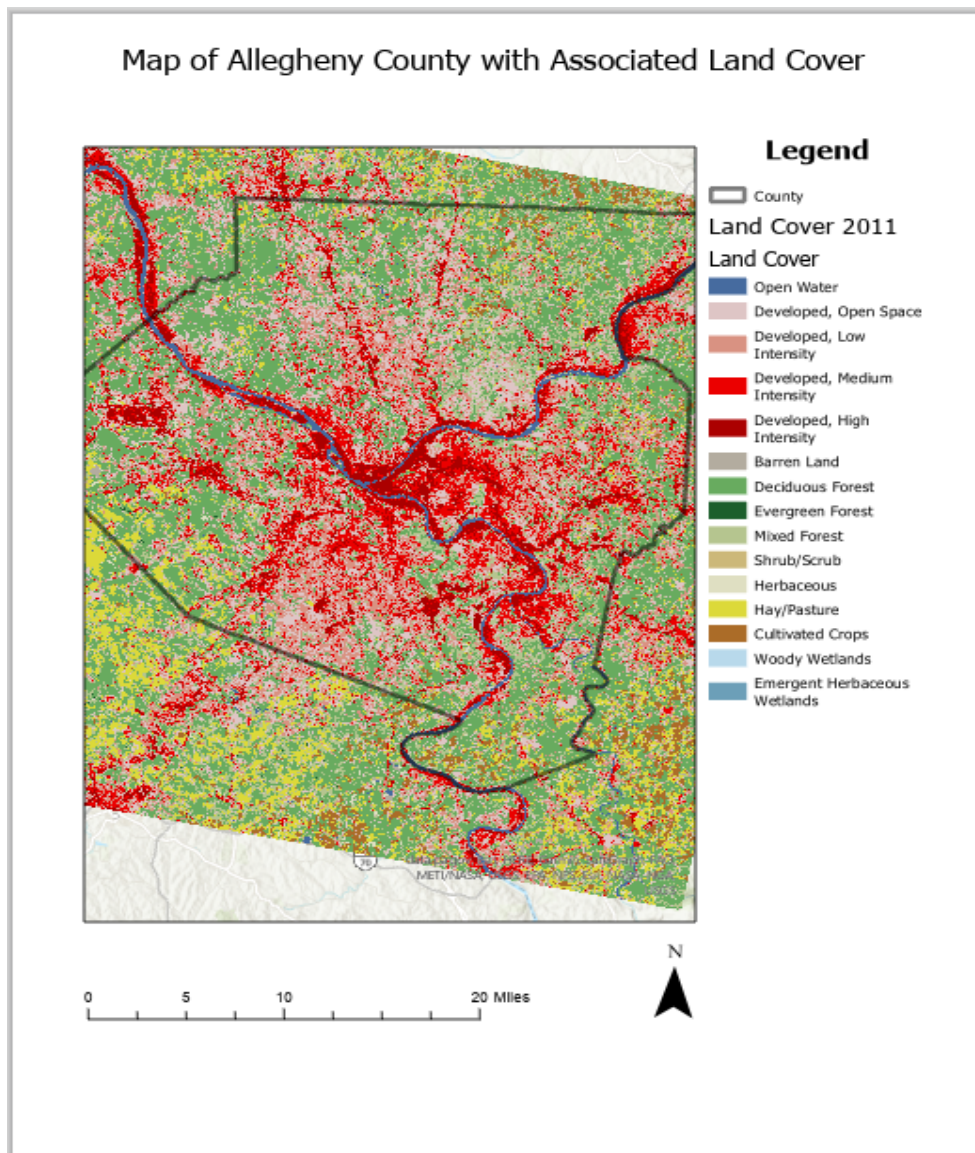
Figure #3 Shows the land use within Allegheny County, Pennsylvania and shows the fifteen different land covers from the year 2011.
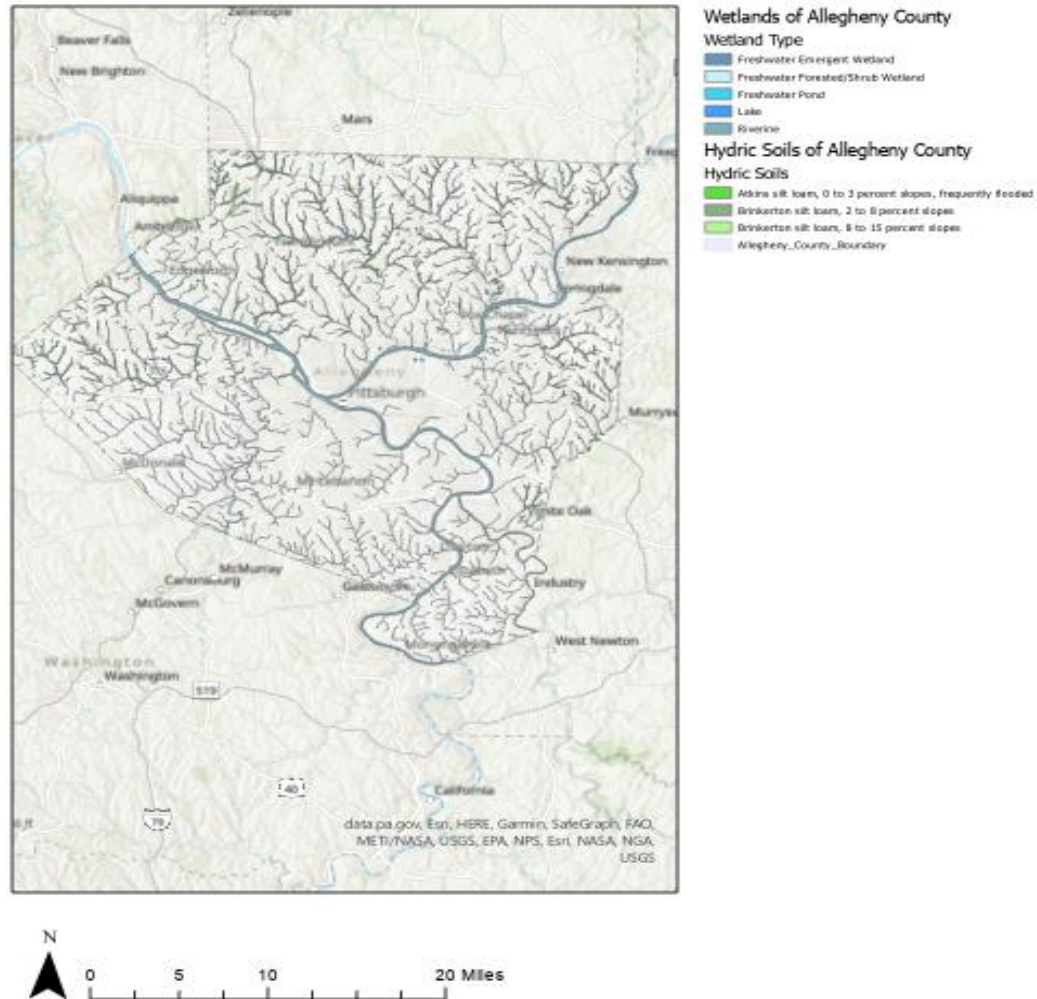
Figure #4 Local wetlands that can be found in Allegheny County, Pennsylvania and where hydric soil can be found.
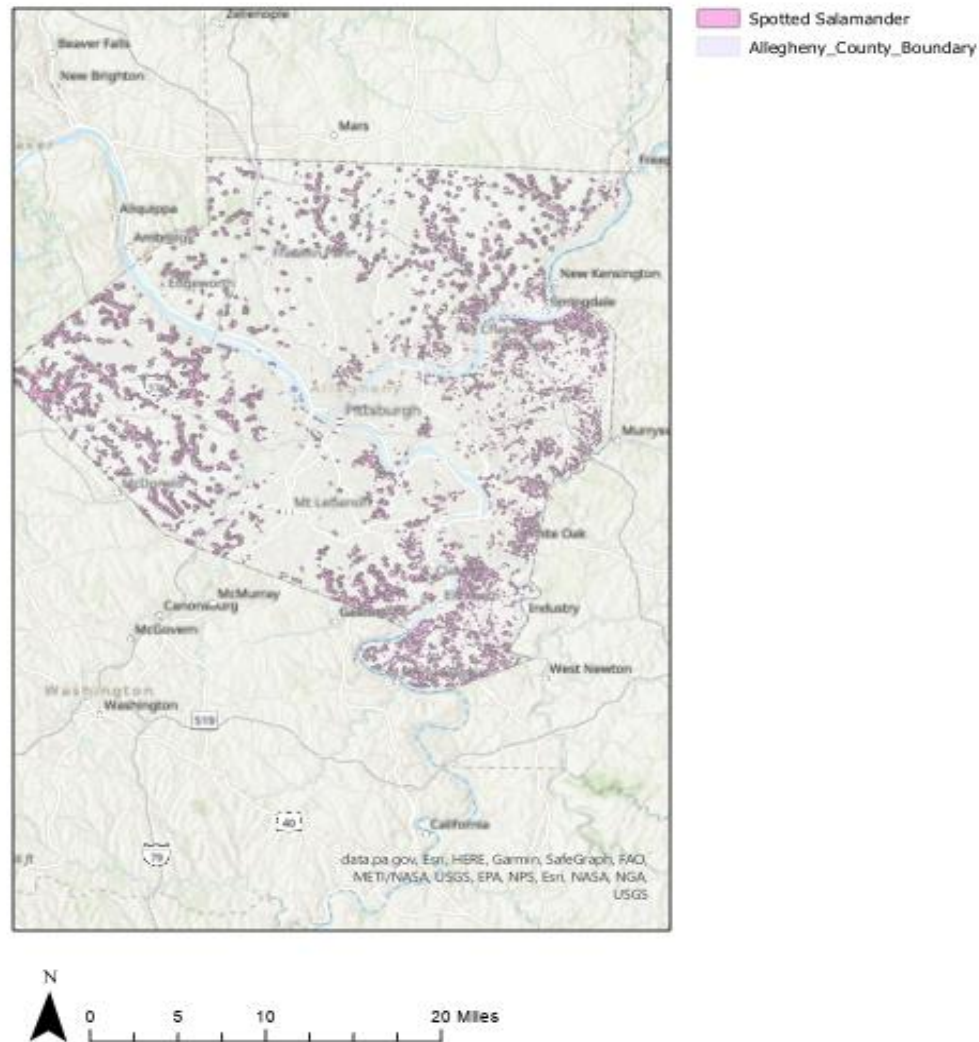
Figure #5 The spotted salamander habitat locations in Allegheny County.
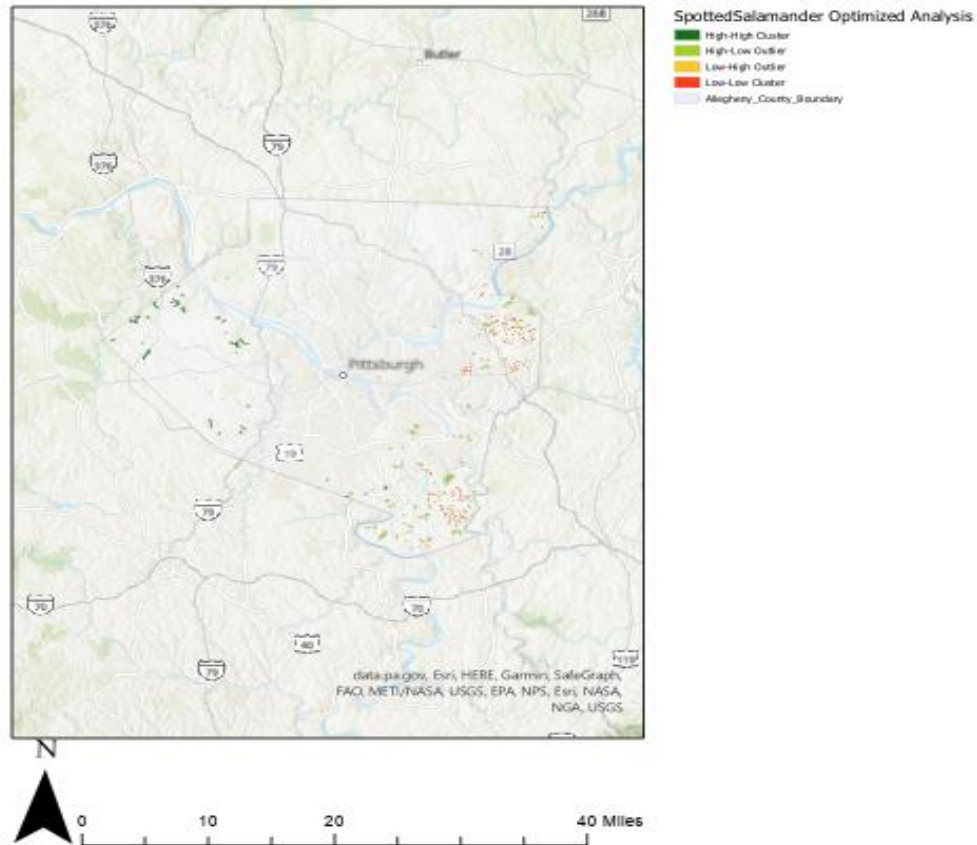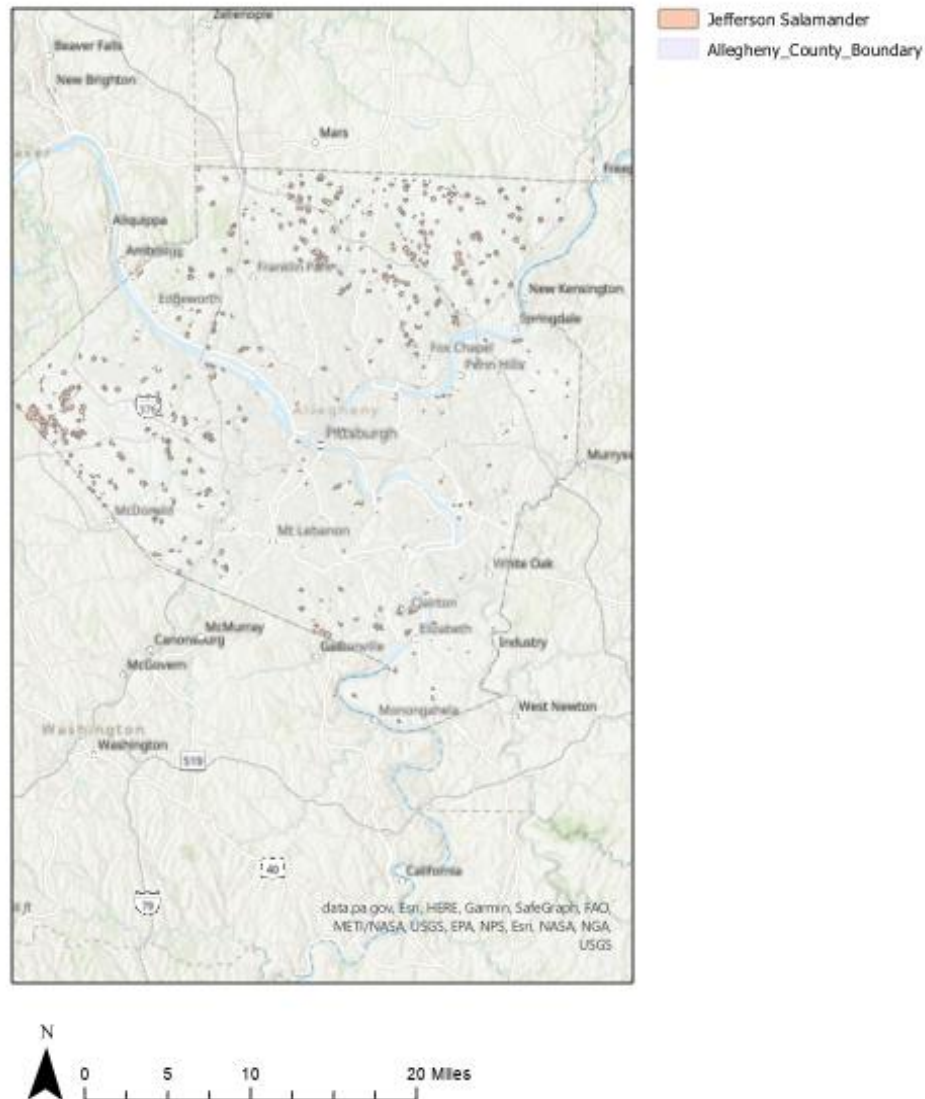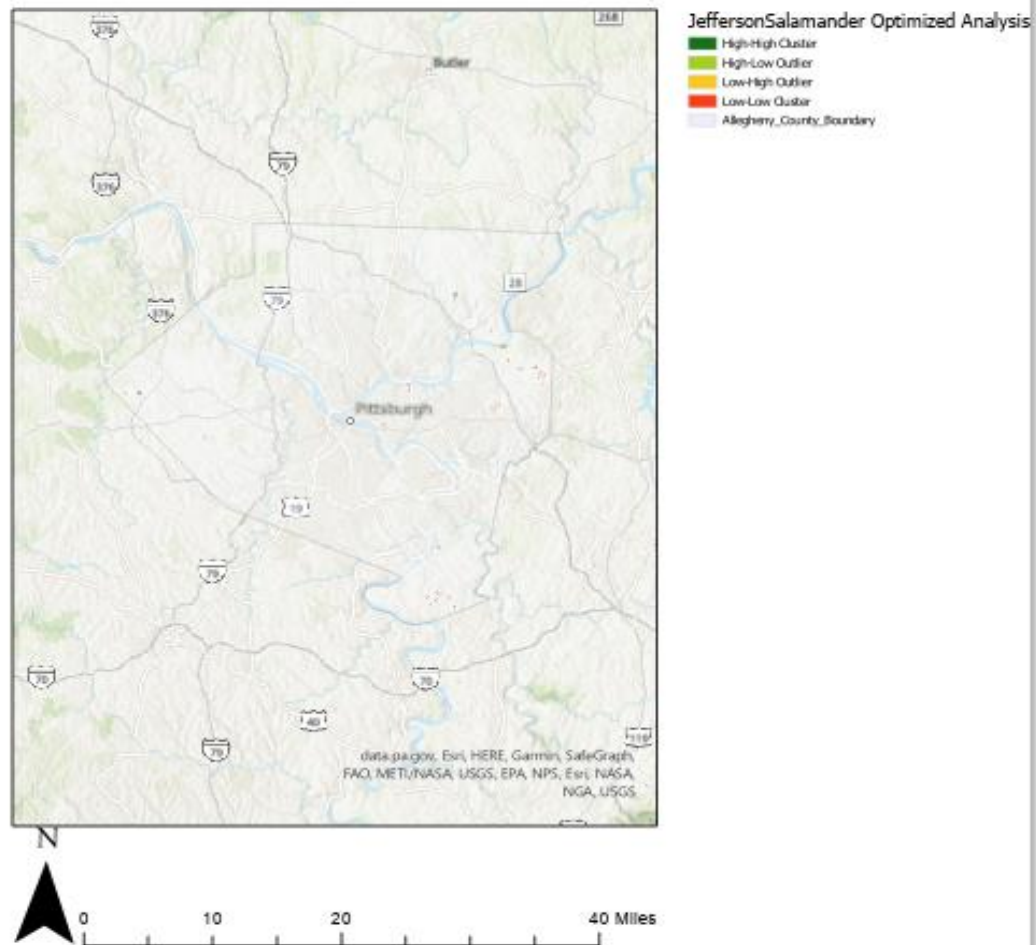
Figure #6 The optimized analysis associated with the Spotted Salamanders habitat have a significant area and is found near the western part of the county.
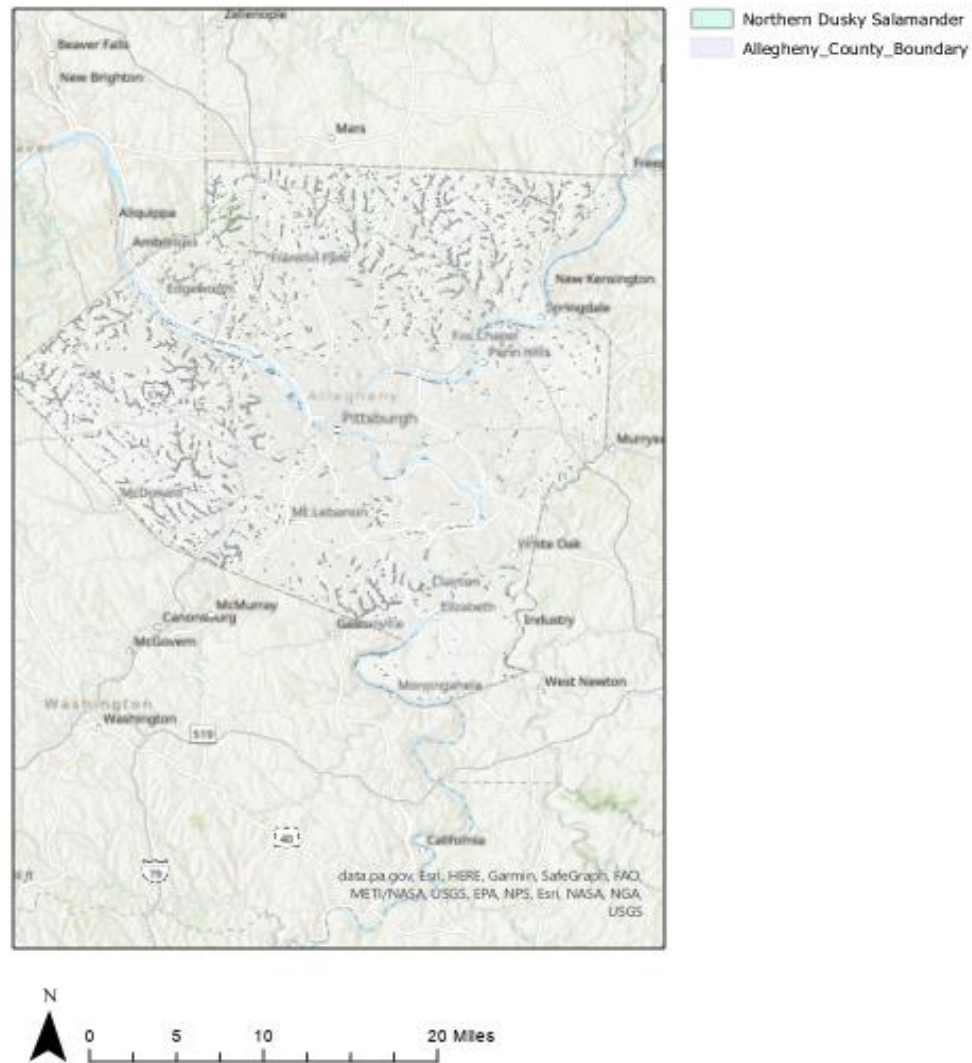
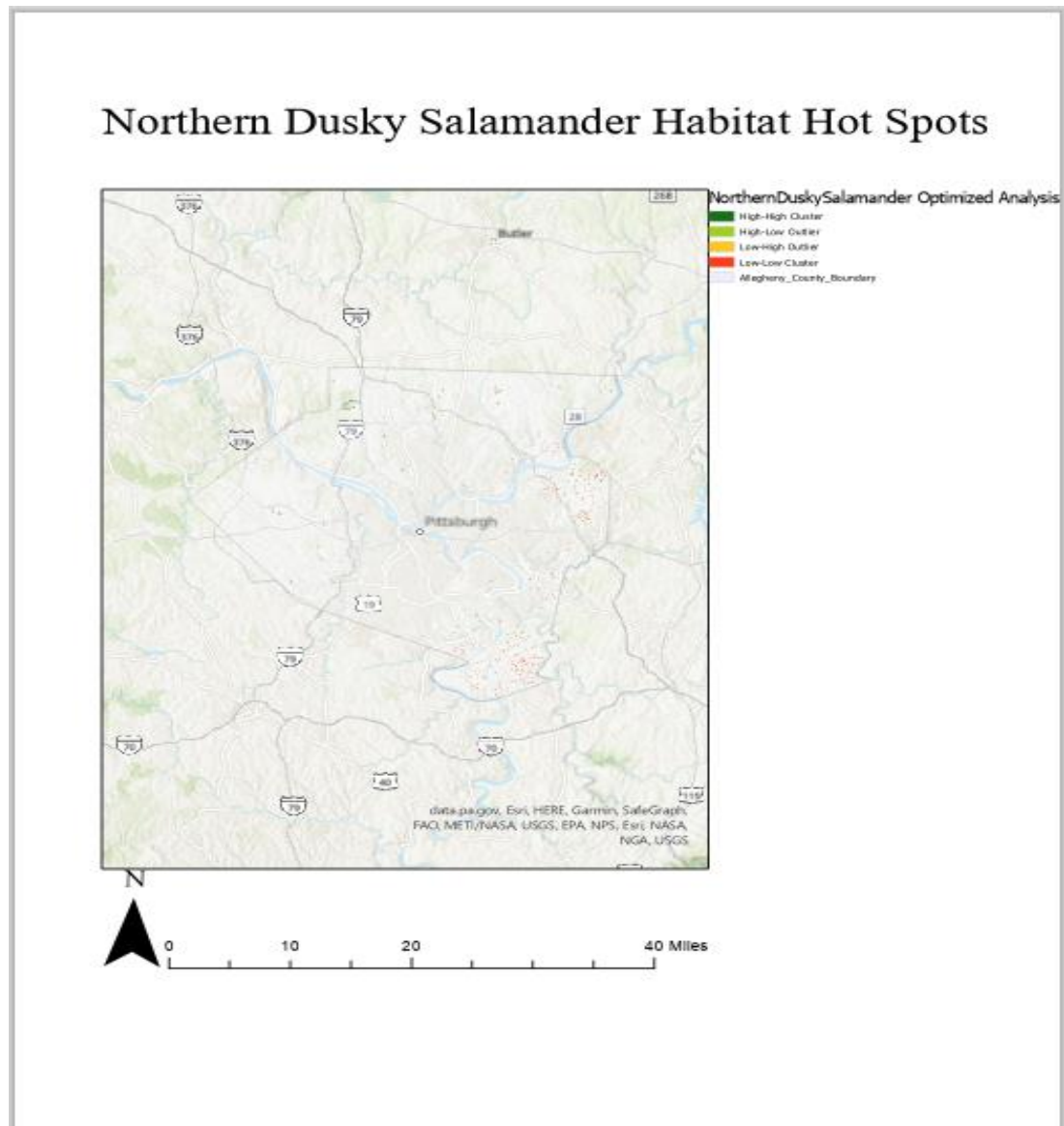**Figure #7** Jefferson salamander habitat locations in Allegheny County.

Figure #8 The optimized analysis associated with the Jefferson Salamanders habitat has a significant area and can be found near the western part of the county.
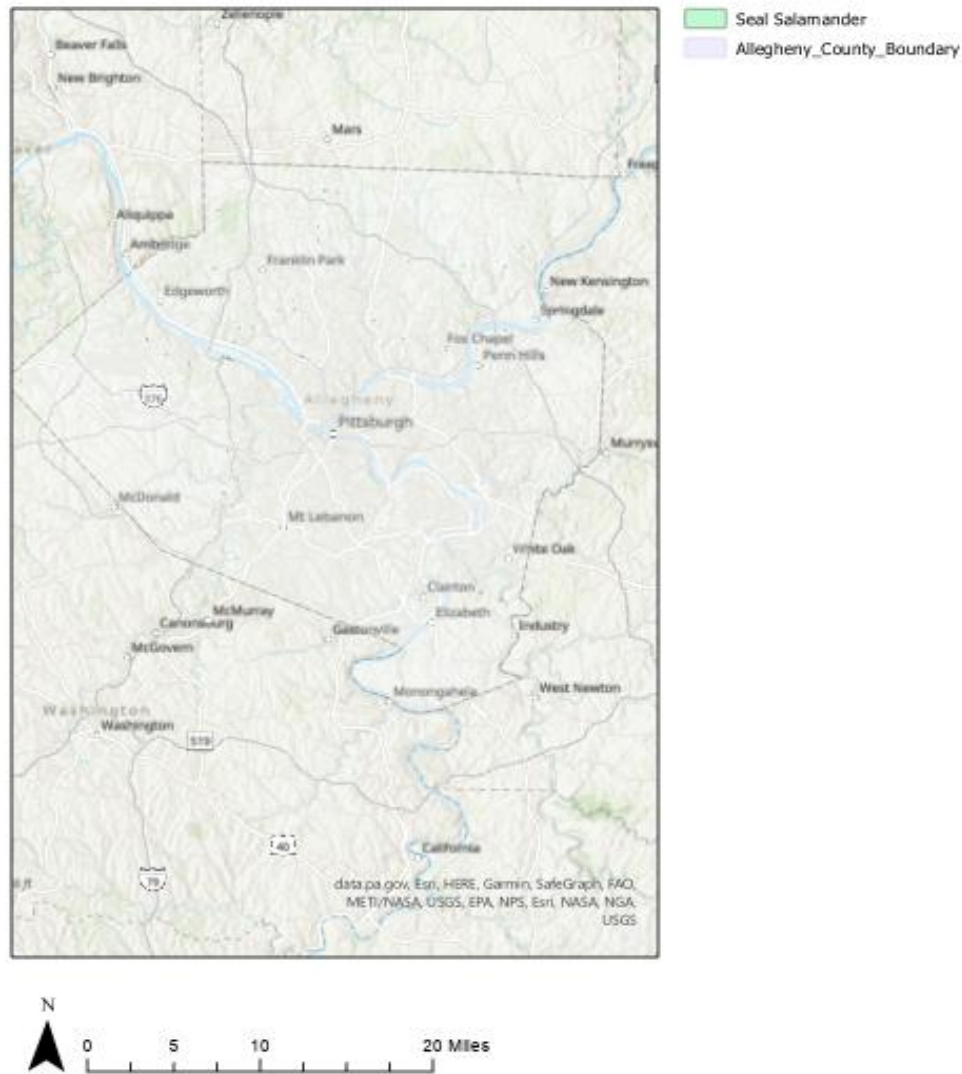
Figure #9 Northern dusky salamander habitat locations within Allegheny County.

Figure #10 The optimized analysis associated with Northern Dusky Salamanders shows significance and can be found in the northwest part of Allegheny County.
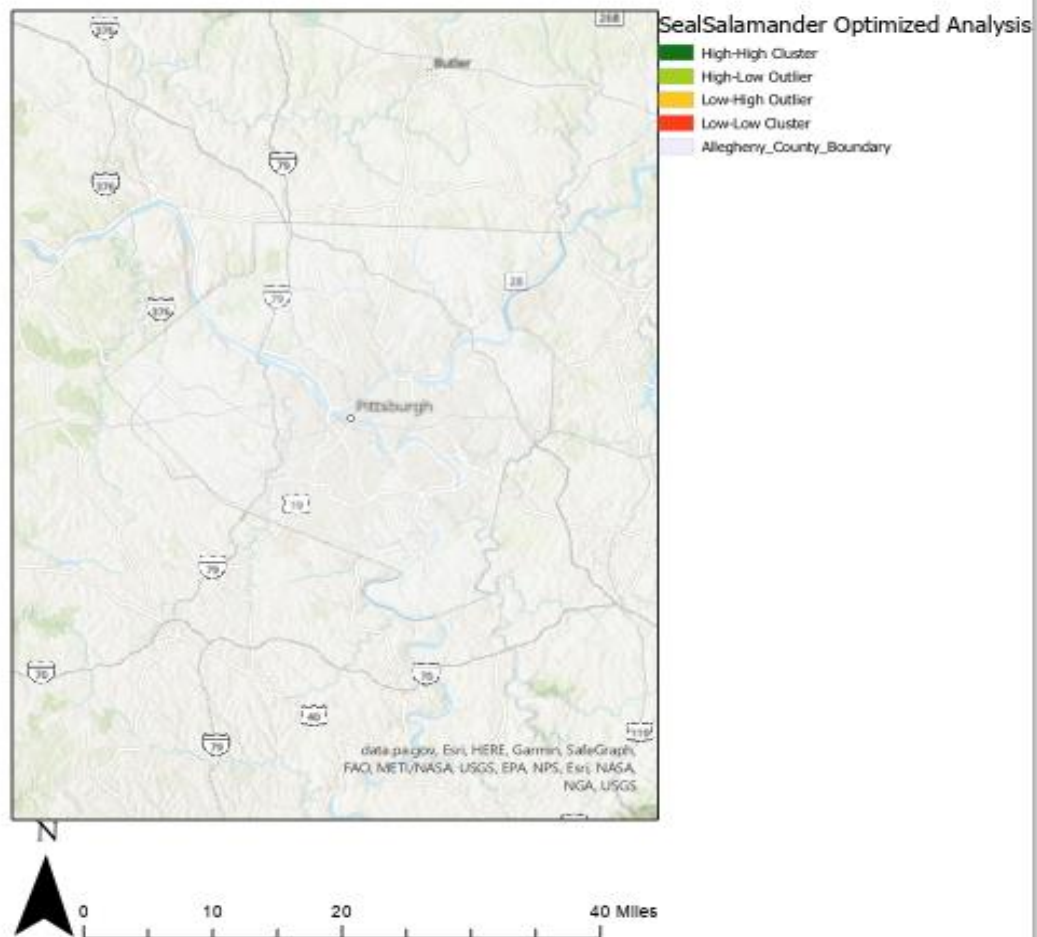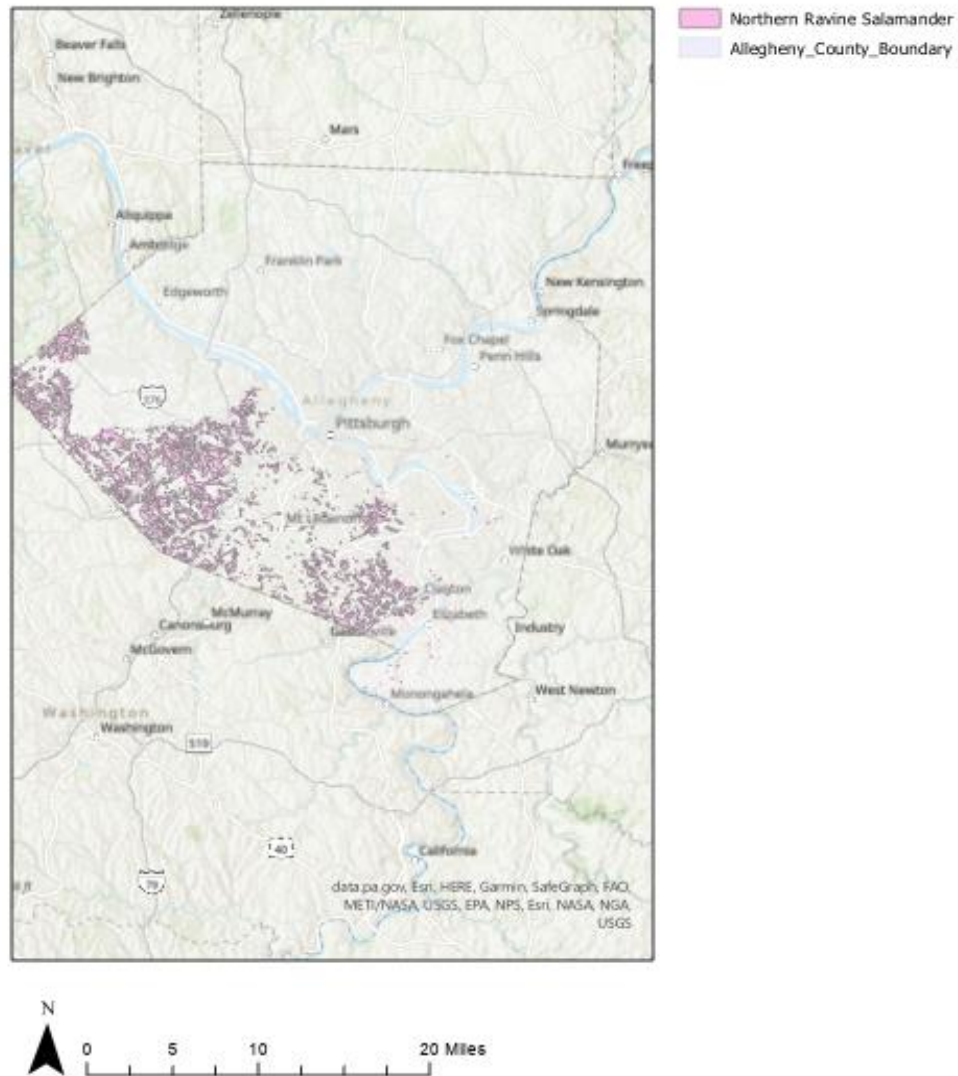
Figure #11 Seal salamander habitat locations within Allegheny County.
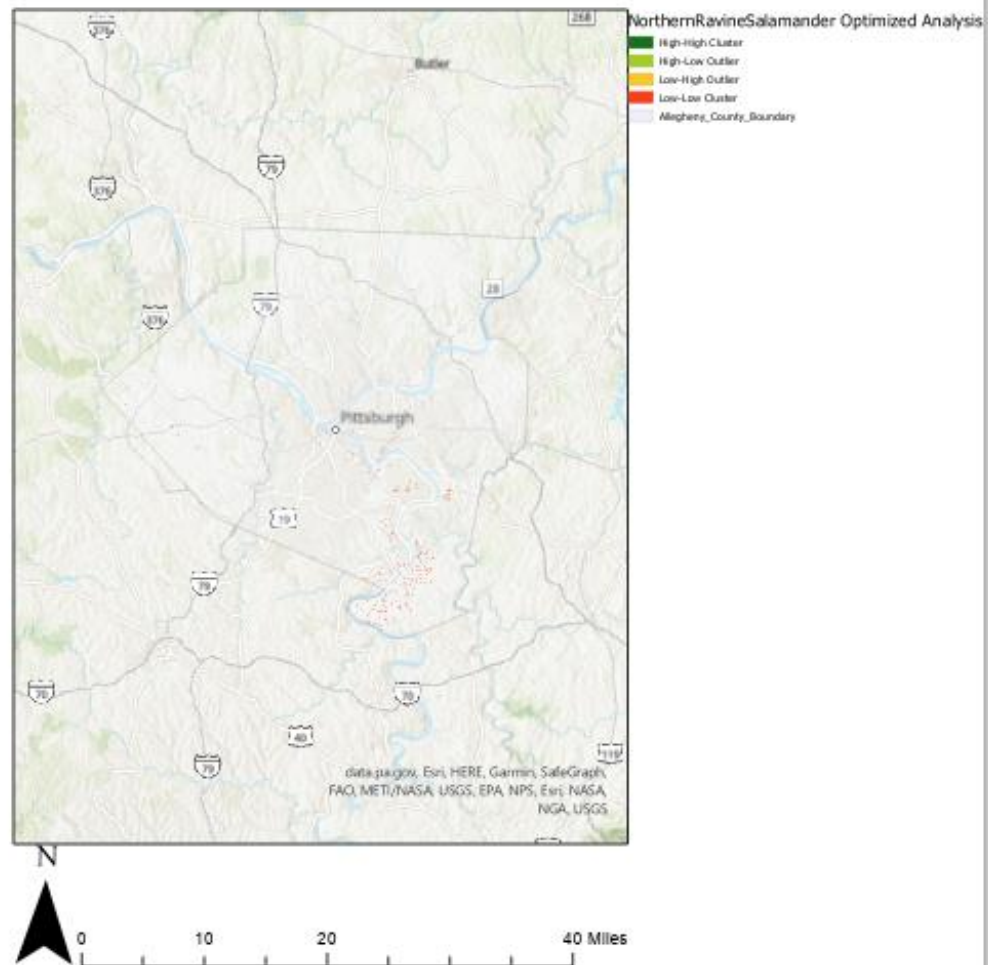
Figure #12 The optimized analysis associated with Seal Salamander shows no significance because there is not enough information.

Figure #13 Northern Ravine Salamanders habitat locations within Allegheny County.

Figure #14 The optimized analysis associated with the Northern Ravine Salamanders shows no significance based on the amount of limited information.

4.0 Discussion

Most of the land use within Allegheny County, Pennsylvania is classified as Deciduous Forest (30%), Developed Low Intensity (17%), Developed Open Space (16%), Developed, High Intensity (6%), Developed, Medium Intensity 14%, Hay/Pasture (4%), Herbaceous (1%), Mixed Forest (9%), and Open Water (2%). Land use describes how humans use land and represents the activities associated with economics and cultural activities that are used within a specific place (Figure #2) [28].

There is an estimated 1.8% of hydric soils that can be found within Allegheny County, Pennsylvania, and the scoring falls between 0% to 100% where 0% is non-hydric and 100% score is predominantly hydric soil. The minority of the soil scores fall between 80 to 85%. Hydric soils are particularly important because the vegetation can grow and regenerate and are habitats for various species (Figure #3) [29]. Allegheny County has an abundant number of wetlands that can be found throughout the county. Wetlands are essential based on the idea that wetlands provide habitats for various species and can aid in flood protection, water quality, recreational purposes, and are beautiful to look at (Figure #3) [30].

The Spotted Salamander habitat encompasses the eastern part of Allegheny County and the southern point of Allegheny County, and the habitat spans 102.24 square miles. The preferred habitats can be found within various habitats that include aquatic, terrestrial, and underground areas but, spotted salamanders have a preference of habitats within forested areas that are near ponds, creeks, and swamps (Figure #5) [31]. The Jefferson Salamander habitat encompasses the northern part of Allegheny County along with the western part of Allegheny County and the habitat spreads 19.68 square miles. The preferred habitats can be found within deciduous forests with a preference for rocky areas that are steep and with rotten logs found within the vicinity (Figure #7) [32]. The Northern Dusky Salamander habitat encompasses most of Allegheny County that is seen outside of Pittsburgh and the habitat spans 28.49 square miles. The preferred habitats can be found by freshwater and has deciduous or coniferous forests with a closed canopy and the aquatic part of the habitat has soft soil (Figure #9) [33].

The Seal Salamander habitat encompasses the northern part of Allegheny County and the western part of Allegheny County with a habitat span of 3.1 square miles. The preferred habitats can be found are found within mountain streams that cut through hardwood forests and are abundant within suitable habitats within a selected habitat range (Figure #11) [34], and finally, the Northern Ravine Salamander habitat encompasses both the southern portion of Allegheny County and the western portion of Allegheny County with a habitat size that spans 45.49 square miles. The preferred habitats can be found within shaded forests and on slopes. Also, they are found along the corridors of streams even though slopes that are rocky are the preferred habitat (Figure #13;, n.d.) [35].

The outlier analysis was configured with 999 permutations with a pseudo value of 0.001, and the other values are multiples to look at significant habitat areas within Allegheny County. HH represents a significant cluster that is significant, and LL is statistically significant for low values. If there is a feature with high levels and is surrounded by low values, the symbol is HL, and the opposite returns an LH. A 95% confidence interval was used (ESRI, n.d.).

The outlier analysis results for the Spotted salamander shows the resulting z score of 5.25 which shows a prominent level of significance (Figure #6). The outlier analysis results for the Jefferson salamander show the resulting z score of 7.76 which shows an elevated level of significance (Figure #8). The outlier analysis results for the spotted salamander show the resulting z score of 8.47 which shows an important level of significance (Figure #10). The outlier analysis results for the seal salamander show no significance (Figure #12), and finally, the outlier analysis results for the Northern ravine salamander show no significance (Figure #14). Salamanders are important because the species eat mosquitos and are food for bigger predatory species and indicate the health of an ecosystem [36].

A lot of the variables used with salamander abundance can be seen with the association of the physical characteristics of streams. This idea shows that the attributes of stream bedrock and shape could be important and other studies show that salamanders who live near streams involve the importance of habitat features that are localized habitat distribution. Another influence is disturbance time and different studies show that the ecological responses in streams within the context of land use changes depend on the stream flow changes compared to the natural flow of the stream. Future studies need to focus on modeling that will create a prediction of stream salamanders for the smaller watersheds. Various studies have claimed that the less tolerant species of salamanders need to survive amongst the salamander species that have a higher tolerance of pollution. In some areas this is true, but within the bounds of the Allegheny County, this is not true. An explanation for this would be distribution of patchy areas with the selected species [37].

Regardless of the results, research is further needed for a better conclusion with the interpretations for salamander habitats. The methods for the research can be improved with the goal of getting better results. Some improvements would be better observational data on salamander species, either within Allegheny County, or other areas, habitat corridors, the role of salamanders in the ever-changing environment, and stream salamander modeling in small watersheds [38, 39].

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