Logging Effects on Amphibian Larvae Populations In Ottawa National Forest

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Abstract

Studies have shown worldwide declines in amphibian population, and habitat disturbance has been cited as a chief factor. In continuation of longitudinal research, seven vernal ponds in Gogebic County, Michigan were sampled for tadpole populations. Four of the vernal ponds reside in areas of the Ottawa National Forest scheduled for timber harvesting, while the other three ponds are located on protected property of the University of Notre Dame. The experiment is designed to compare species richness and density in the vernal ponds both before and after the logging in order to determine if timber harvesting affects amphibian populations. This paper includes the research conducted in the fourth year during the pre-logging stage. Each pond was sampled three times over a period of three months. Species richness and tadpole density was tabulated in each pond for each of the three sampling periods. Amphibian densities were compared against pond characteristics such as air and water temperatures, pH, dissolved oxygen, conductivity, and perimeter to find correlations. Four species, *Rana sylvatica*, *Pseudacris crucifer*, *Ambystoma maculatum*, and *Ambystoma laterale* were collected. R. sylvatica was most abundance and was the only amphibian found during the first sampling period. Negative correlations were found between number of species and water temperature in the month of May ($p= 0.031$), and between amphibian density and pH in July ($p= 0.050$). Data obtained from the research can be implemented by the forest service to understand amphibian interactions with environmental characteristics in order to improve management and care of the forest.

Introduction

Researching how logging impacts amphibian populations is needed to understand the effect the timber industry has on the environment. Monitoring amphibian abundance is a good marker of ecological influences because amphibians require both aquatic and terrestrial habitats to complete their life cycle. If either land or water is affected by the logging, an alteration in amphibian populations should detect the change because amphibians are dependent on each environment to survive. Because of their dual habitat dependence, they are sensitive to environmental changes, and this characteristic is convenient to evaluate how the timber industry affects the environment. In addition, amphibians are a critical element within the food web, as they serve as both predator and prey to other organisms in the biome. Any influence that timber harvesting has on amphibian populations could have noticeable effects as the state of Michigan removes approximately 120 million board feet of timber from its three national forests each year (USDA Forest Service, 2001).

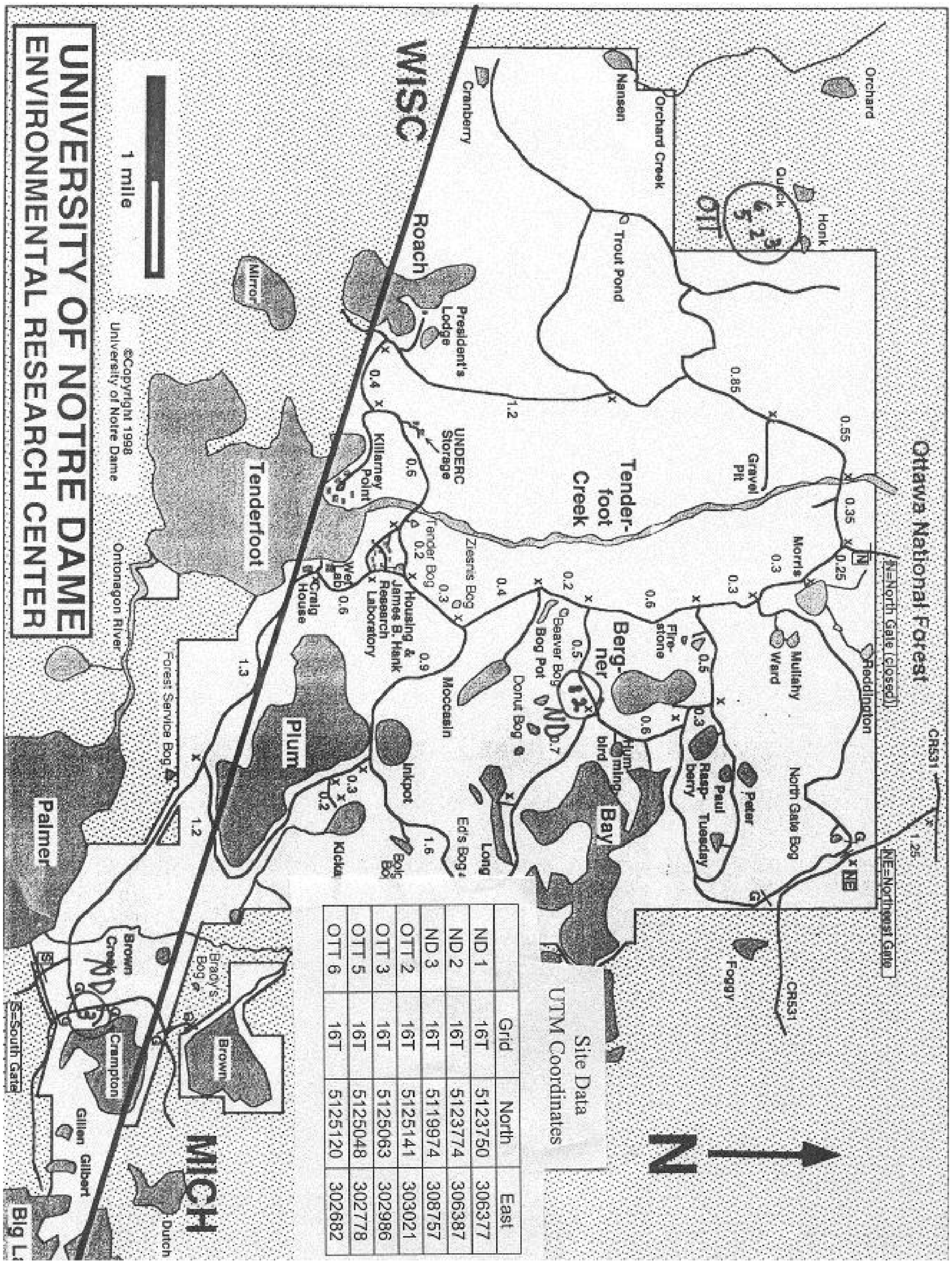
Looking exclusively at amphibians, recent research shows that amphibian populations are declining, including cases of local extinctions (Green, 2003). A study that started in 1989 has discovered that by 1993 over 500 populations of amphibians spanning the globe had decreased in number (Alford, 1999). Habitat destruction and climate change are two primary factors for population reduction (Green, 2003). The logging will certainly change the environmental features of the area, but it is unknown how the alteration will affect the amphibians. Deforestation could eliminate vital terrestrial habitats and reduce abundance, or the logging could produce open, low-lying areas that are conducive for vernal pond formation, a suitable breeding site for most amphibians that may increase local populations. Four amphibian larvae species were observed during the sampling: Wood Frog (*Rana sylvatica*), Spring Peeper (*Pseudacris crucifer*), Spotted Salamander (*Ambystoma maculatum*), and Blue-spotted Salamander (*Ambystoma laterale*). Among these four species of amphibians, the spotted salamander is most likely to be affected adversely by the logging as this species of salamander relies on dense forests with full canopies (Harding, 1997).

The importance of amphibians extends beyond basic wildlife conservation. Amphibian decline is of interest to humans because of the medicinal potential that they possess, particularly the chemistry of their skin secretions. Already skin compounds have displayed promise in psychotic treatment for schizophrenia and Parkinson disease as well as other neural disorders and eating disorders such as bulimia and anorexia nervosa (Cohen Jr., 2001). The decline in amphibian populations may limit the medical discoveries and retard cures to illness plaguing the human race.

Vernal ponds are ideal breeding areas for amphibians due to the absence of predators associated with permanent bodies of water, such as fish. In continuation of previous research (Chormanski, 2001), a survey of amphibian larvae was conducted in seven ponds located in Gogebic County of Michigan's Upper Peninsula. Amphibian larvae was collected to estimate amphibian abundance because the larvae is limited to standing water, and they are easier to locate and catch than the adults that are dispersed across the forests and surrounding areas of the ponds. Three ponds with adjacent areas that will remain undisturbed were surveyed as controls, while four ponds within the scheduled logging area were sampled to determine if logging influences amphibian populations.

Materials and Methods

Site Location: The vernal ponds sampled during the experiment were determined from previous years. The ponds were originally chosen to include ponds located within the Ottawa National Forest zoned for future logging and ponds situated on the Notre Dame property which will be undisturbed by logging activity. Global positioning coordinates were recorded from charts from previous research (Slavick, 2002)(Figure 1).



	Grid	North	East
ND 1	16T	5123750	306377
ND 2	16T	5123774	306387
ND 3	16T	5119974	308757
OTT 2	16T	5125141	303021
OTT 3	16T	5125063	302986
OTT 5	16T	5125048	302778
OTT 6	16T	5125120	302682

Figure 1: Map of Vernal Pond Sites with GPS coordinates. OTT sites indicate ponds in the Ottawa National Forest. ND sites are located on Notre Dame property.

Chemical, Physical, and Geometric Characteristics: In order to collect data for dissolved oxygen, air and water temperature, conductivity, pH, and maximum depth specialized instrumentation was employed. A YSI-55 dissolved oxygen meter recorded both oxygen readings as well as water temperature. Conductivity was measured with Hanna instruments HI-9033 conductivity meter, and Hanna Instruments pH meter assessed the acidity levels of the ponds. Maximum depth was determined using a pole that had metric units inscribed on it. A common thermometer was used to calculate air temperature. A tape measure was utilized to obtain measurements of the length, width, and perimeter of the vernal ponds. Length and width were evaluated by measuring the farthest reaching areas of the pond, forming a rectangle. Perimeter was quantified by circling the ponds and staking the bank of the ponds every ten meters. All measurements were recorded in meters. The readings were taken at each vernal pond location during all three of the sampling periods.

Tadpole Collection: Each pond was surveyed once during the months of May, June, and July. One meter plots were surveyed by randomly selecting between one fourth and one third of the measured perimeter of each pond. The perimeter was reestablished each experimental period to ensure an accurate perimeter as the ponds shrink as the summer progresses. Random plots for each pond were established using a random number generator program from a Texas Instruments graphing calculator, model TI-83 plus. Both location along the perimeter and whether the plot was situated adjacent to the shoreline or one meter into the water were determined by the random number generator. Between one-fourth and one-third of the total perimeter was assigned a plot and sampled. A 0.88 x 0.51 x 0.43 cubic meter plastic bin with its bottom removed was placed into the water to enclose the allotted plot, while aquarium nets were swept through the bin to collect the tadpoles. The tadpoles were stored in plastic sandwich bags for transportation.

Tadpole Measurement and Identification: After capture, the tadpoles were relocated to the laboratory for measurements. A hand caliper recorded the snout-vent length as well as tail length in millimeters of each specimen. The species of the tadpoles were identified by examining eye position, gill structure, tailfin patterns, body coloration, and head shape. The tadpoles were released to their native ponds upon completion of the measurements and identification.

Data Analysis: Although results related to the logging effects cannot be analyzed until the areas have been logged, the data will be examined for correlations between current and previous years' research. The data was graphed in Microsoft Excel using bar charts to examine possible trends among the ponds and sampling periods. Scatter plots and linear regression formulas were implemented to determine correlations between tadpole and pond characteristics. Linear regression tests from SYSTAT generated p values for the relationships between the data. A Shannon-Weiner Index, which measures species diversity, was calculated.

Results

Bar graphs were compiled to look for trends occurring across the vernal ponds and through the sampling periods. The most noticeable tendency appeared in relationships between time and various measurements of amphibian population. With each sampling period the general trend was an increase in populations. The number of species increased in five of the vernal pond sites (Figure 2), and the number of tadpoles increased over time at all ponds (Figure 3). A similar trend appears between tadpole density and the sampling periods; the density of each pond increases with each month of sampling (Figure 4). These relationships indicate that as the summer progresses, more amphibians as well as more species have traveled to the ponds to deposit their eggs. Biomass increases at all vernal ponds as the summer progresses (Figure 5) as a result of tadpole growth and the addition of species laying eggs in the later months of the summer.

Four species of tadpoles totaling 386 specimens were collected during the experiment. The Wood Frog was the most common tadpole species collected (Figure 7). This species was captured in six of the seven vernal ponds, and was the sole species to inhabit the ponds during the May sampling period (Figure 6). Tadpole data and physical pond characteristics were analyzed to find possible correlations between tadpole density or species richness and air temperature,

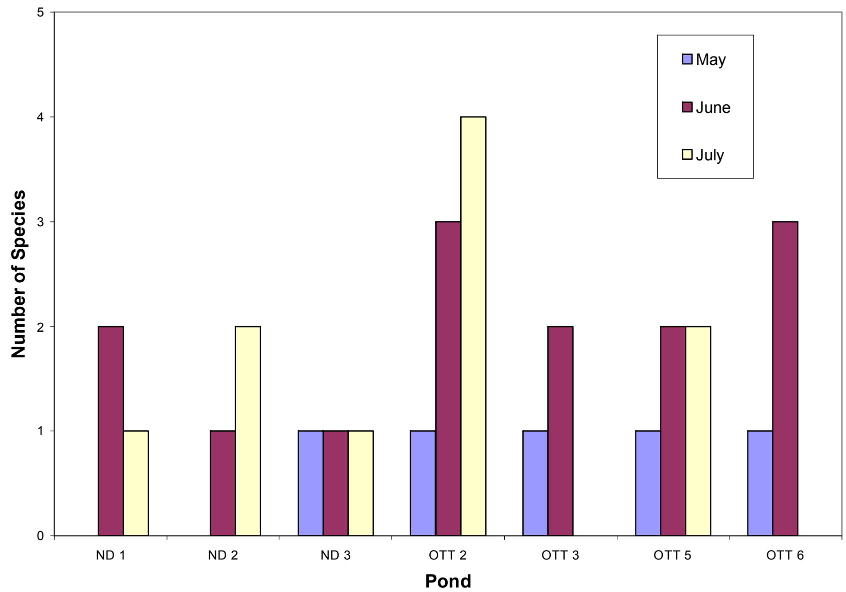


Figure 2: Species Richness. Number of amphibian tadpole species in each pond by month.

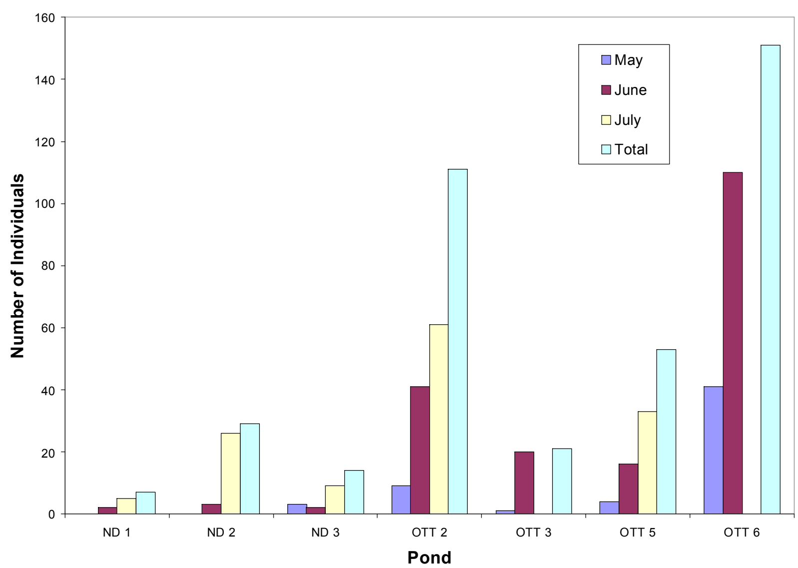


Figure 3: Tadpole Count. Number of tadpoles collected in each pond by month.

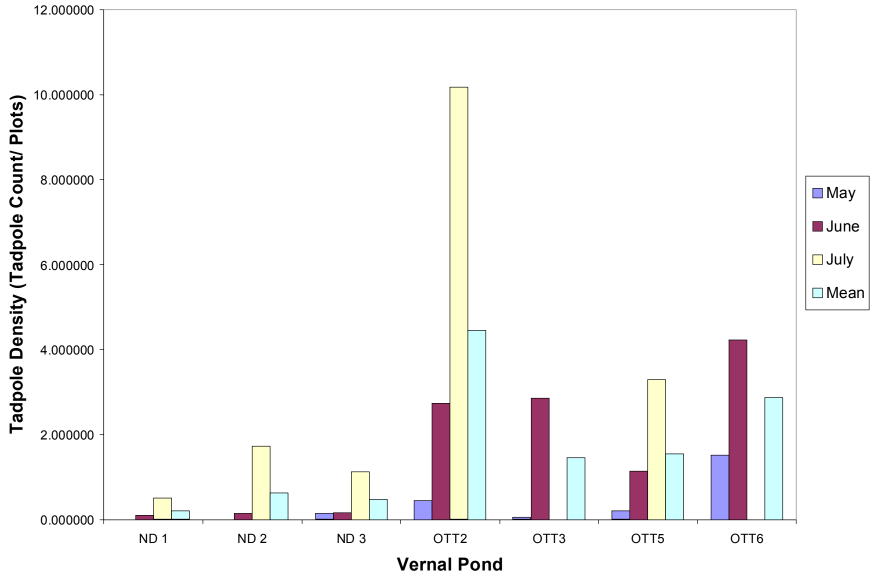


Figure 4: Tadpole Density. Each pond by month. Calculated by dividing number of tadpoles collected by number of plots sampled in each pond.

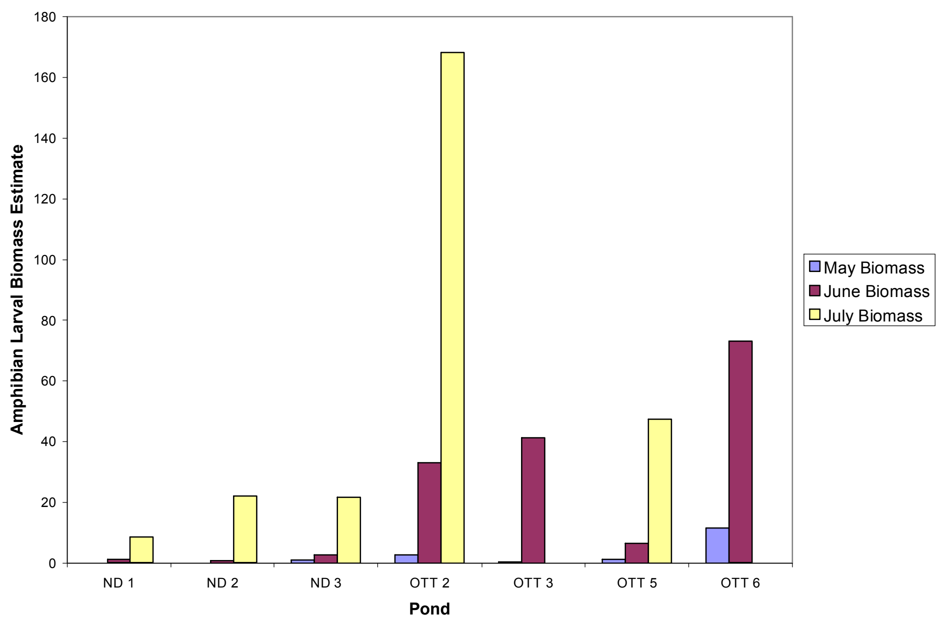
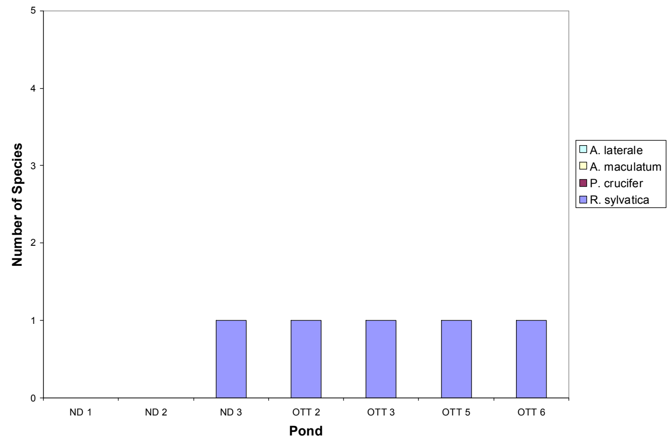
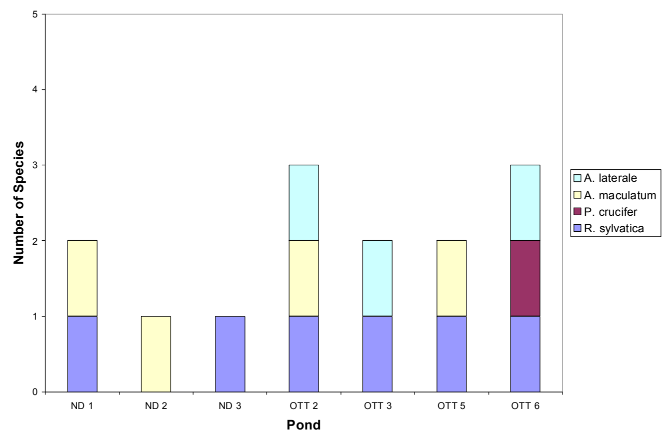


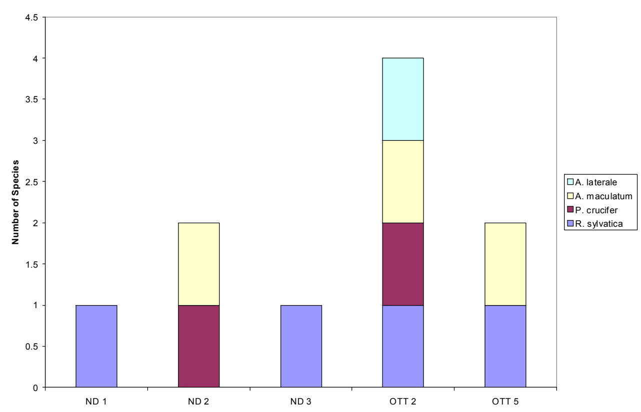
Figure 5: Tadpole Biomass in each pond by month.



a.

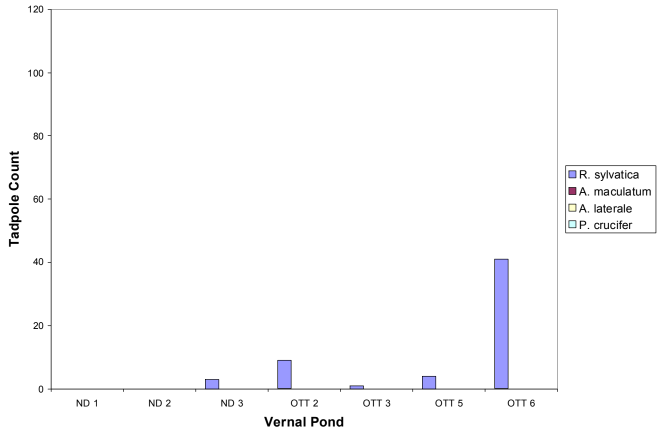


b.

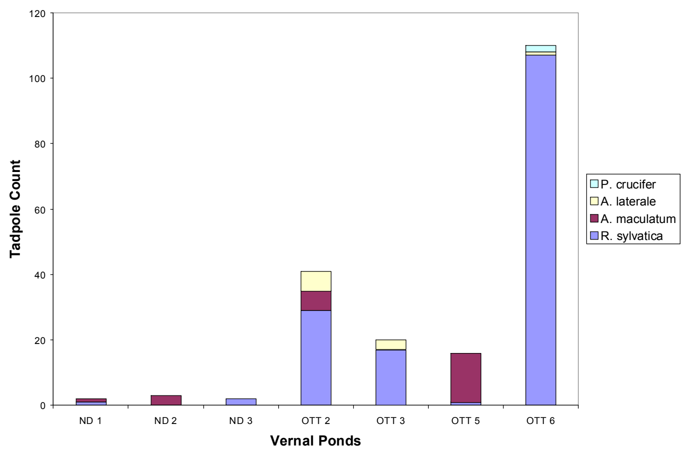


c.

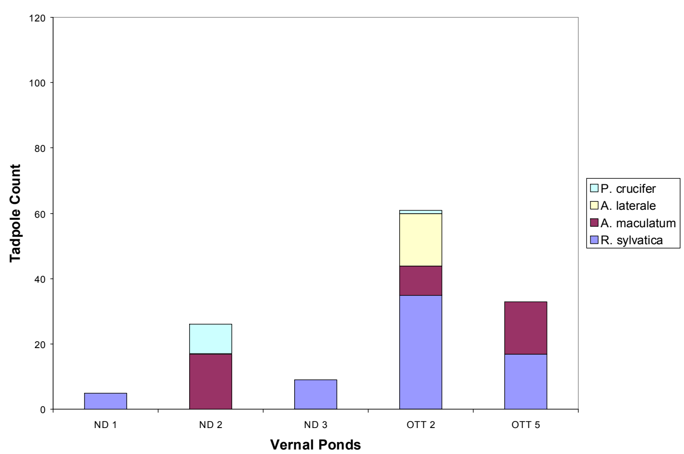
Figure 6: Species type found in each pond.
a.) May sampling b.) June sampling c.) July sampling



a.



b.

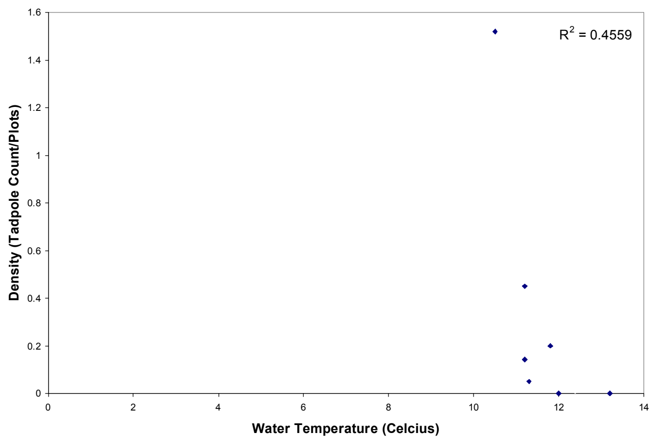


c.

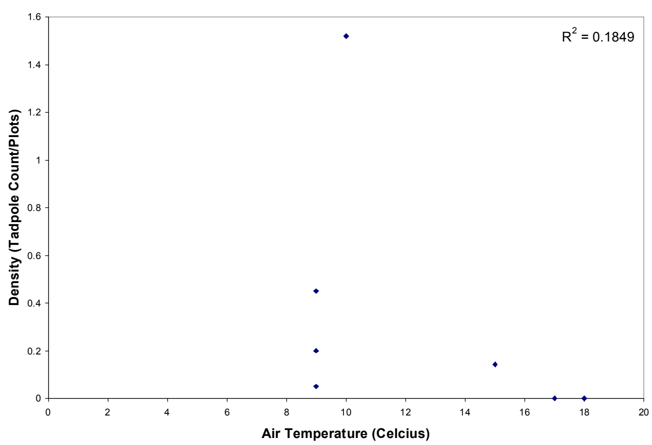
Figure 7: Tadpole count by species in each pond
a.) May sampling b.) June sampling c.) July sampling

water temperature, dissolved oxygen, water conductivity, pH, and maximum depth. In the May sampling, the number of species present and water temperature had a significant ($p<0.05$) negative correlation (Figure 8). No significant correlations were found in the June sampling results (Figure 9). Tadpole density and water pH during the July sampling was the only other significant relationship and the two factors had a negative correlation. (Figure 10). An appendix with p values from all linear regressions including categories not explored in this paper has been incorporated as a resource for the longitudinal aspects of the experiment.

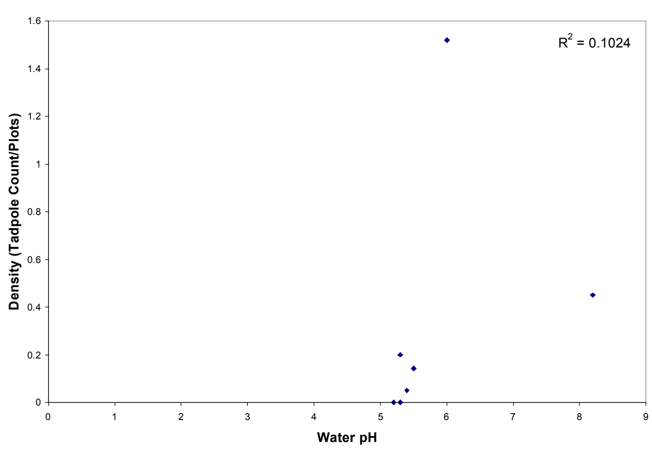
Data from 2004 was compared with the three previous years of study. The number of species present at the ponds was the same or lower than the previous years for UNDERC ponds, but the Ottawa ponds had either the same or a greater number of species than in previous years (Figure 11). Except for UNDERC Vernal Pond 2, which has decreased each year, amphibian density varied extensively over the years (Figure 12). UNDERC Vernal Pond 3 had a Shannon-Weiner value of zero each year, indicating continually low species diversity. Ottawa Vernal Pond 3 had a Shannon-Weiner value of 0.41, the first time that it was greater than zero at that site (Figure 13).



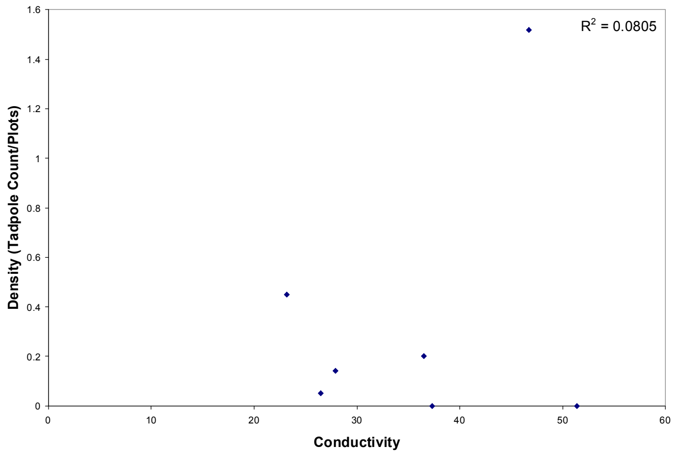
Density (Tadpole Count/Plots)
Water Temperature (Celcius)
R2 = 0.4559



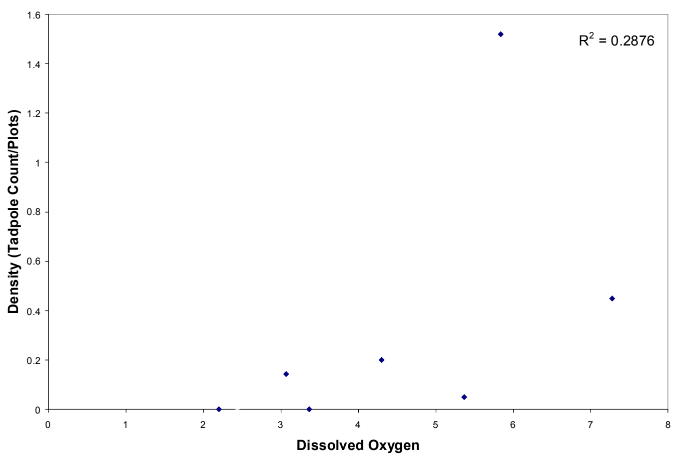
Density (Tadpole Count/Plots)
Air Temperature (Celcius)
R2 = 0.1849



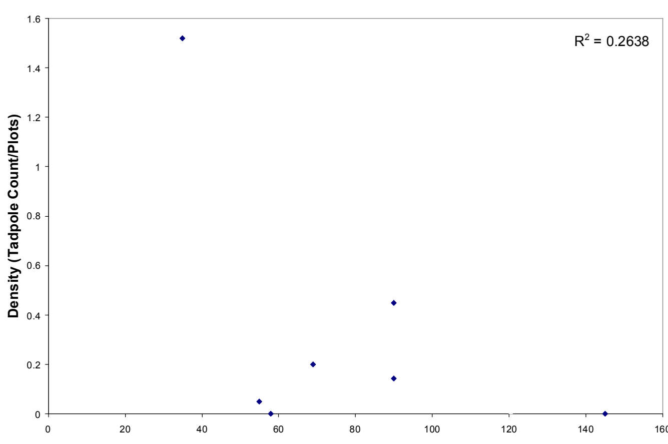
Density (Tadpole Count/Plots)
Water pH
R2 = 0.1024



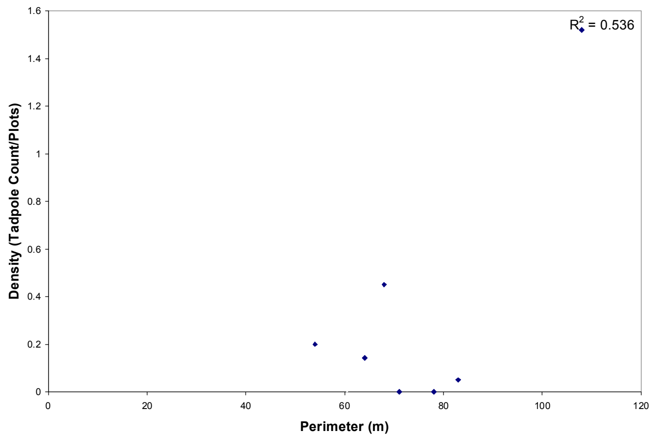
R^2 = 0.0805
Density (Tadpole Count/Plots)
Conductivity

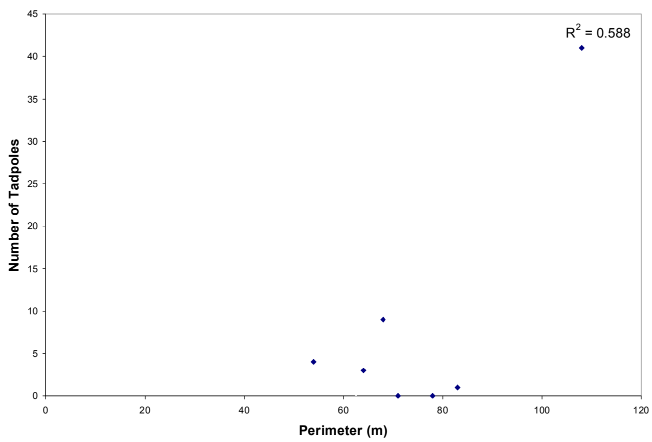


R^2 = 0.2876
Density (Tadpole Count/Plots)
Dissolved Oxygen



R^2 = 0.2638
Density (Tadpole Count/Plots)
Maximum Depth (cm)





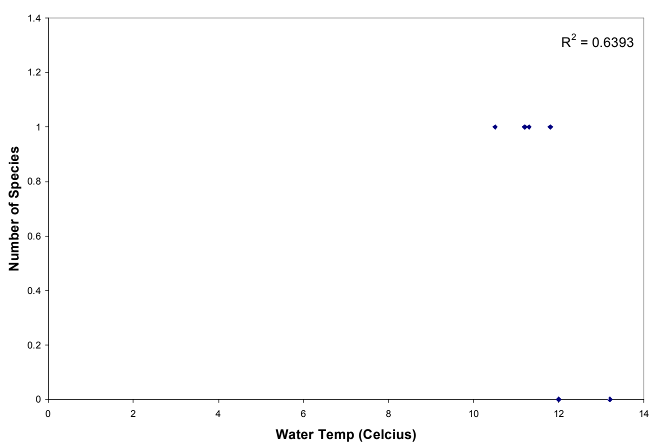
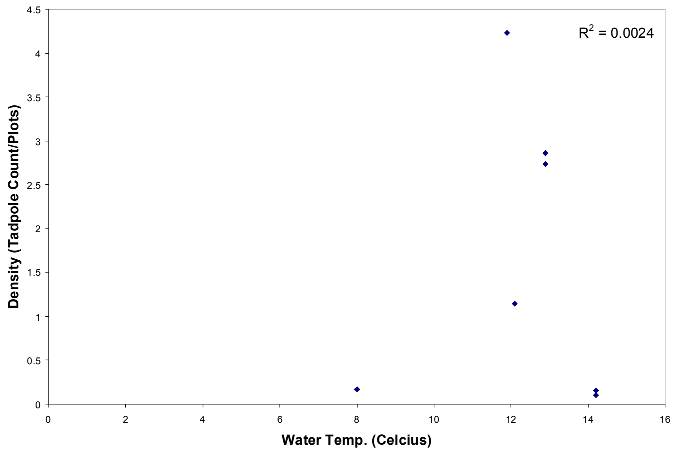
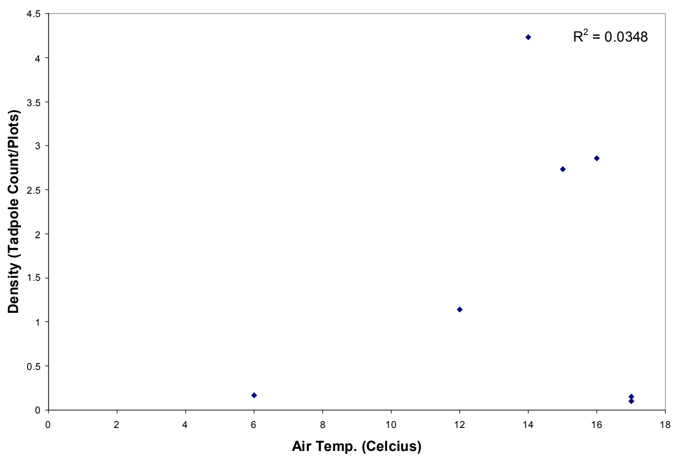


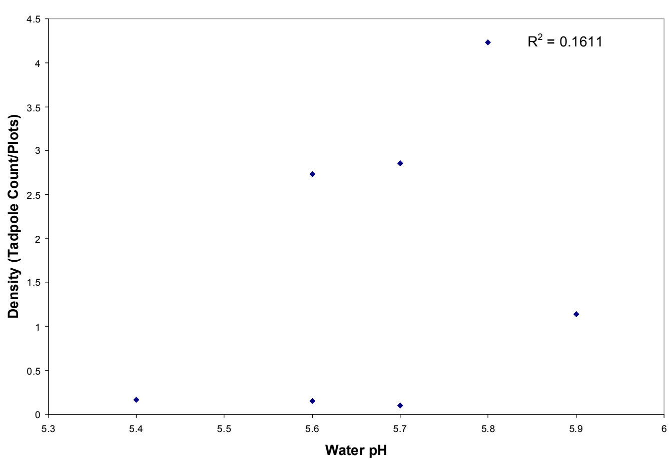
Figure 8: Tadpole Densities, Species, and Count vs. Pond Characteristics (May)



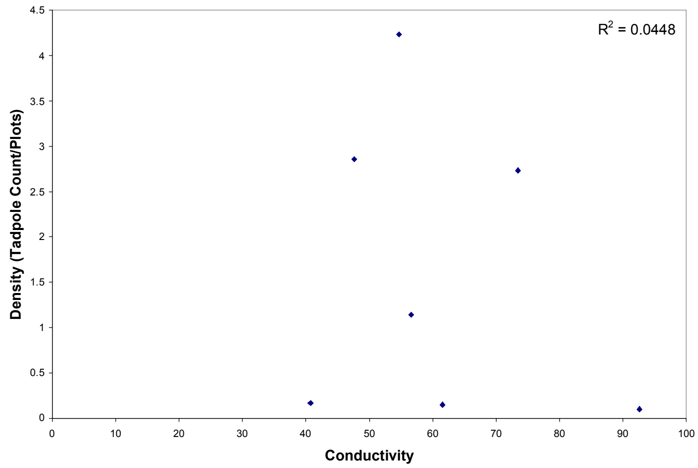
$R^2 = 0.0024$
Density (Tadpole Count/Plots)
Water Temp. (Celcius)



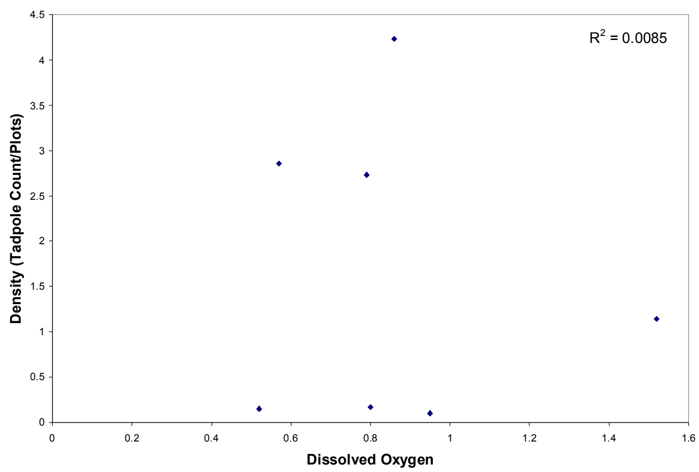
$R^2 = 0.0348$
Density (Tadpole Count/Plots)
Air Temp. (Celcius)



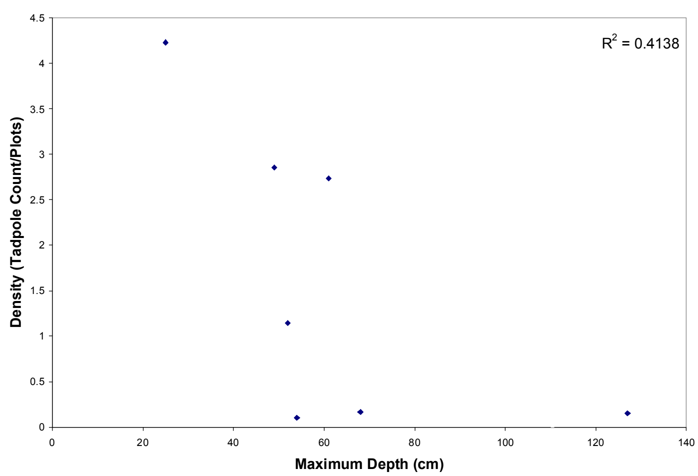
$R^2 = 0.1611$
Density (Tadpole Count/Plots)
Water pH



$R^2 = 0.0448$
Density (Tadpole Count/Plots)
Conductivity



$R^2 = 0.0085$
Density (Tadpole Count/Plots)
Dissolved Oxygen



$R^2 = 0.4138$
Density (Tadpole Count/Plots)
Maximum Depth (cm)

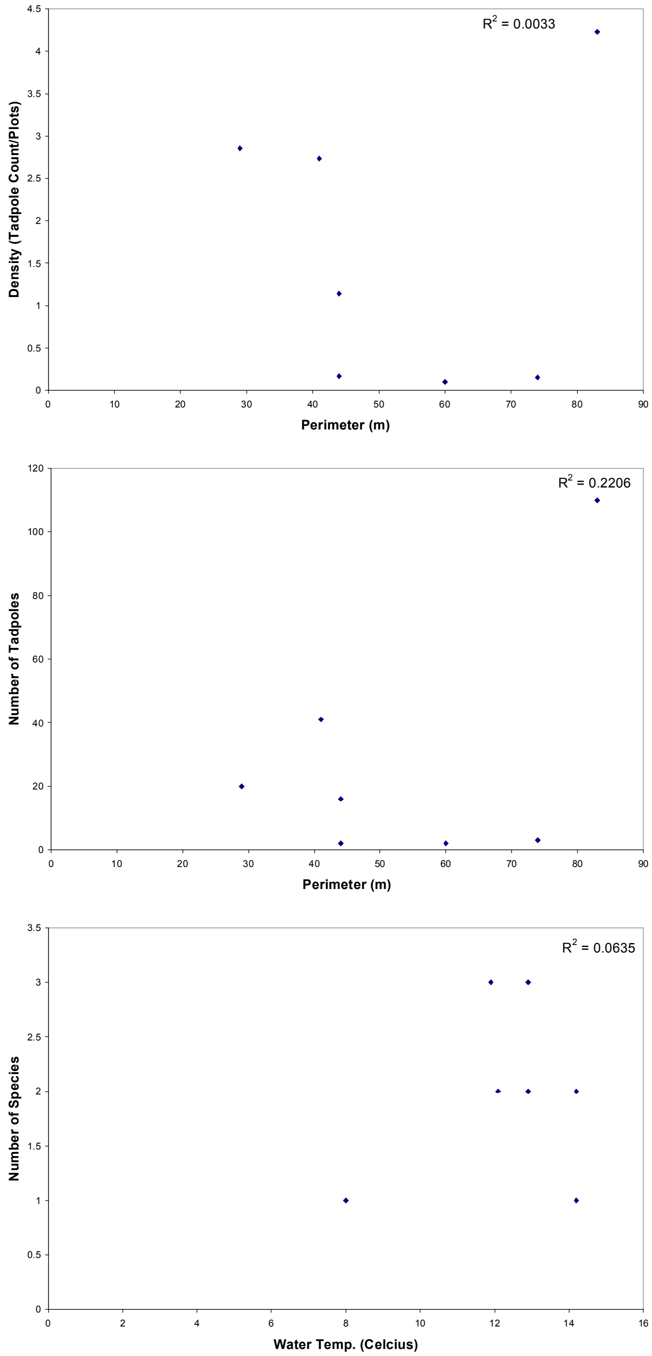
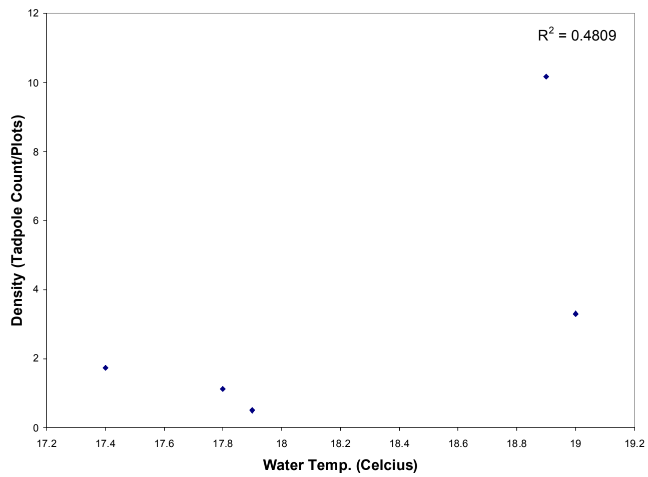
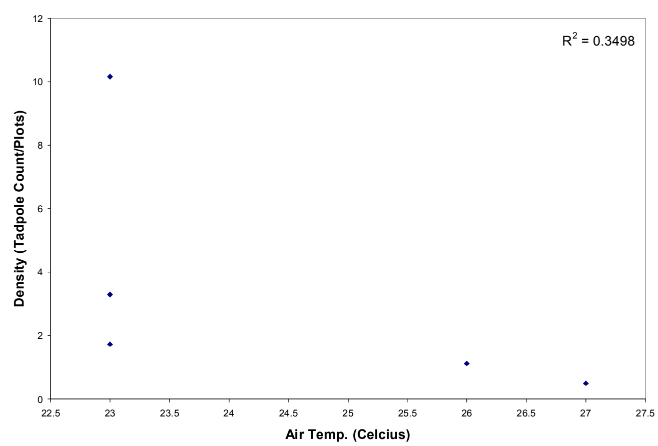


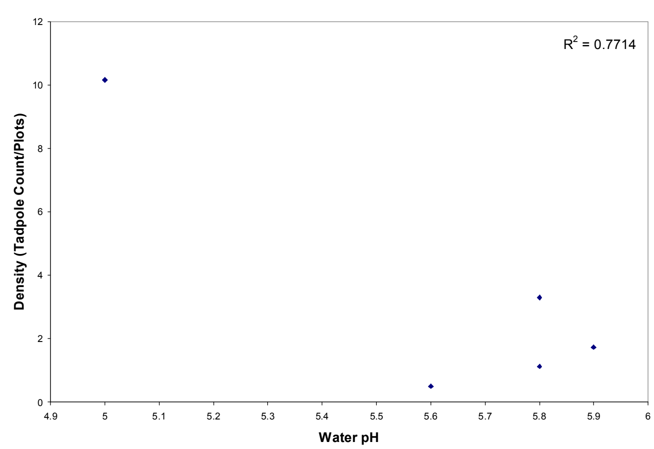
Figure 9: Tadpole Densities, Species, and Count vs. Pond Characteristics (June)



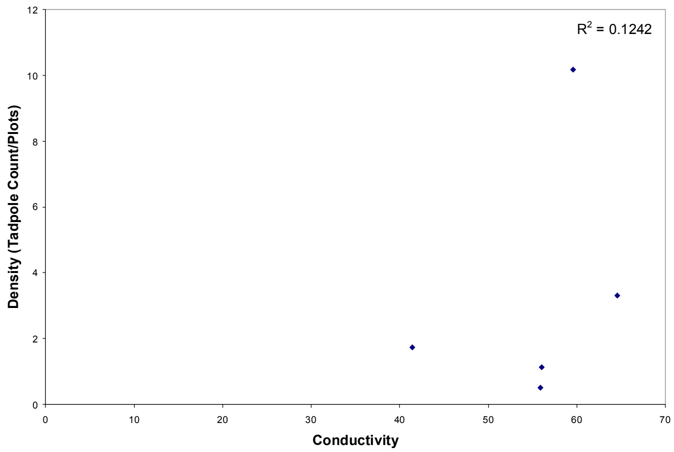
$R^2 = 0.4809$
Density (Tadpole Count/Plots)
Water Temp. (Celcius)



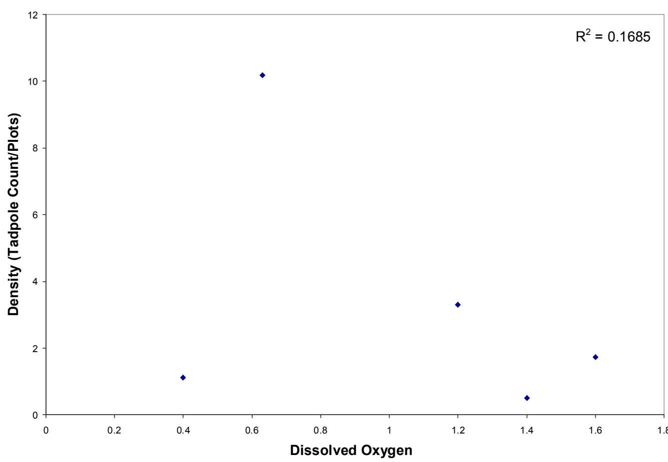
$R^2 = 0.3498$
Density (Tadpole Count/Plots)
Air Temp. (Celcius)



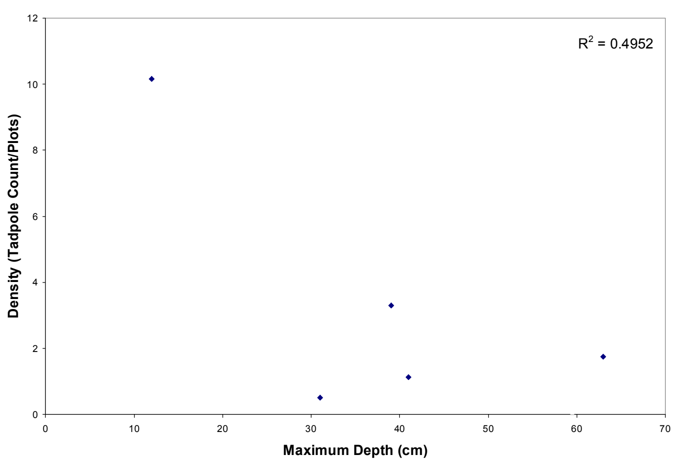
$R^2 = 0.7714$
Density (Tadpole Count/Plots)
Water pH



R^2 = 0.1242
Density (Tadpole Count/Plots)
Conductivity



R^2 = 0.1685
Density (Tadpole Count/Plots)
Dissolved Oxygen



R^2 = 0.4952
Density (Tadpole Count/Plots)
Maximum Depth (cm)

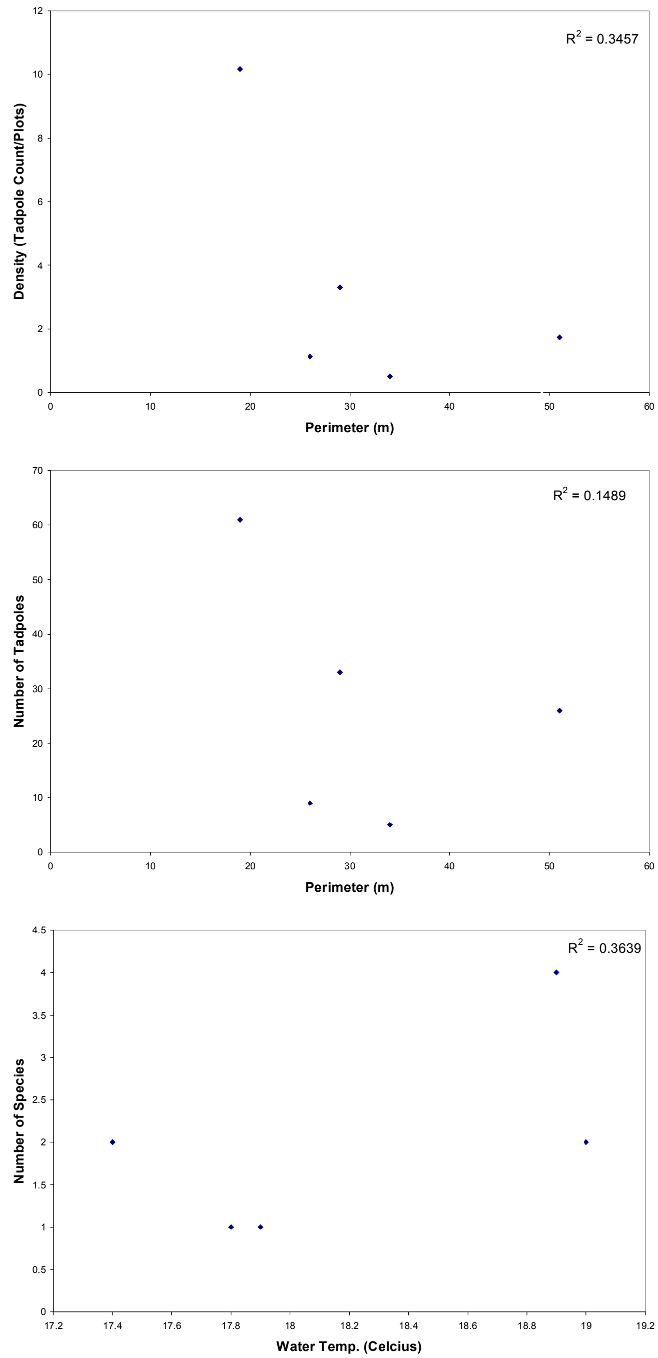


Figure 10: Tadpole Densities, Species, and Count vs. Pond Characteristics (July)

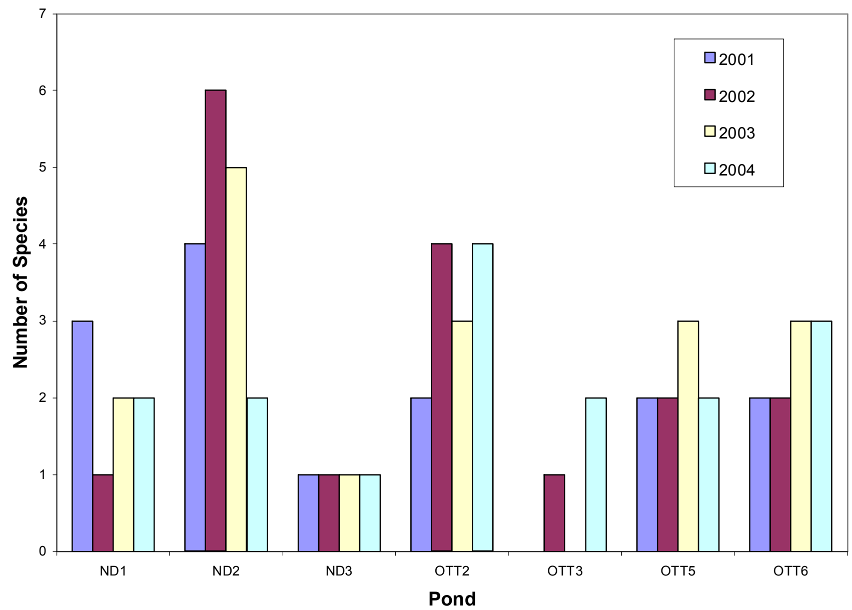


Figure 11: Species richness across 4 years in each pond.

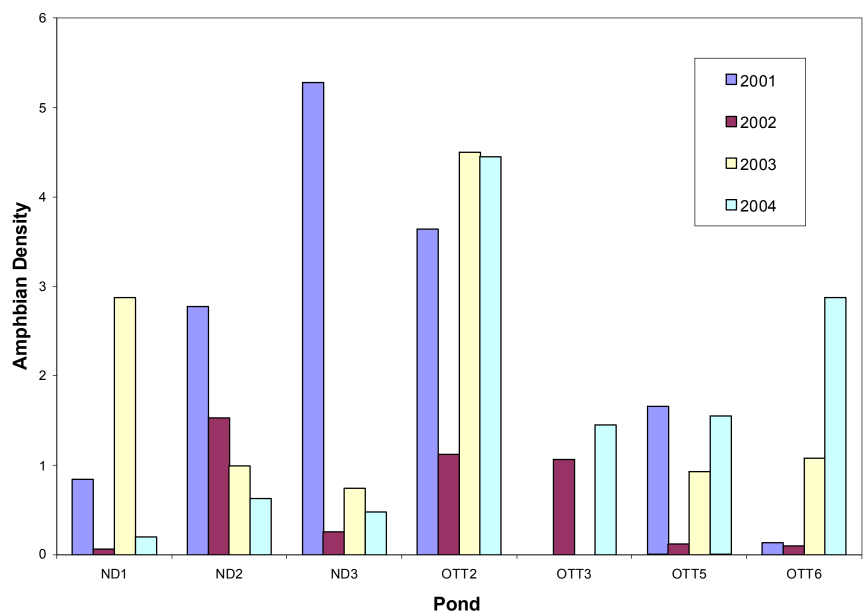


Figure 12: Amphibian density across 4 years in each pond.

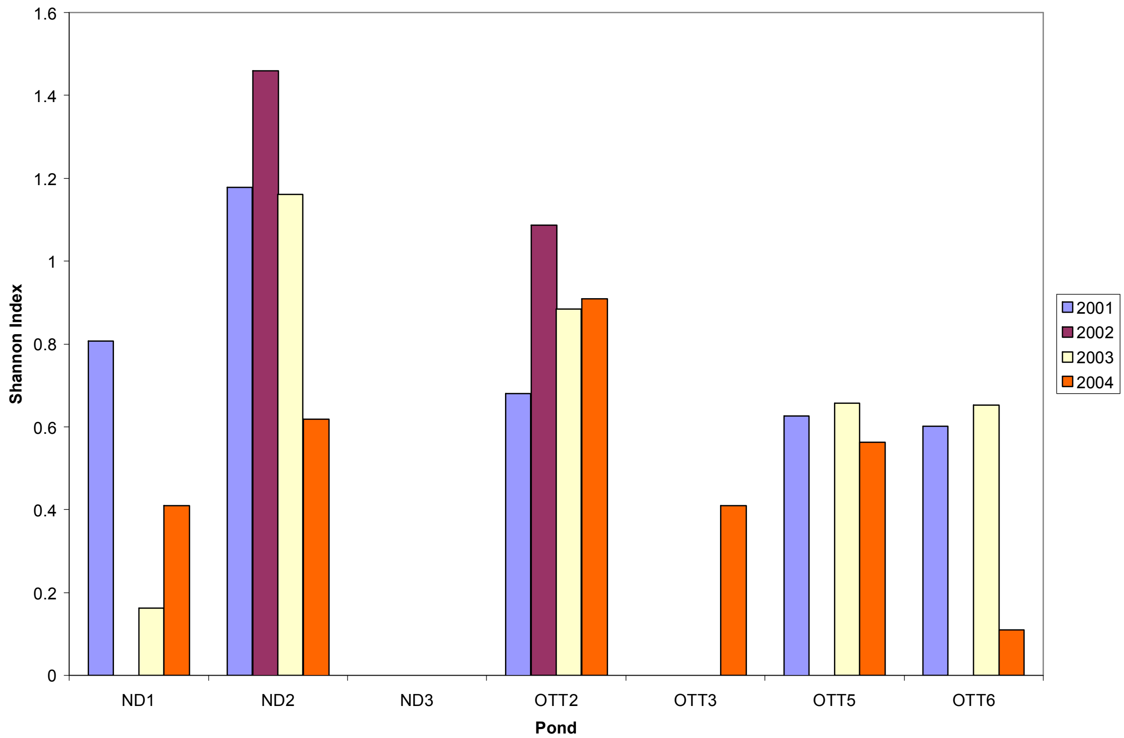


Figure 13: Shannon-Weiner Index across 4 years in each pond.

Discussion

Tadpole densities and biomass per pond increased as the summer sampling progressed. A logical explanation for this occurrence is that some amphibian species lay their eggs in the ponds later in the summer so that tadpole counts grow as time passes. Biomass would also be influenced by additional species entering the ponds as well as tadpole growth. Wood Frog was the most abundant tadpole collected. This could be attributed to habitats conducive to either the tadpole or the adult. The fact that Wood Frog was the only tadpole captured during the May samplings might contribute to its abundance. By residing in the ponds before other species, Wood Frog has the opportunity to grow without competing against other species for resources. As other tadpoles begin to enter the ponds, Wood Frog has a size advantage and out competes the incoming species.

Most correlations between tadpole densities and pond characteristics were insignificant, probably due to the lack of variability among the pond traits. However, if logging alters pond characteristics by changing the forest structure, an increasing number of significant correlations could appear as the new environment affects the amphibian life cycle. The negative correlation between species and water temperature in May is counter-intuitive. It would seem logical that species would be present at higher water temperatures in the cool month of May. Further experimentation may be needed to truly understand the correlation.

Looking at the study on a larger scale, the potential for changes caused by logging are great. Absence of trees could influence water temperature by altering available sunlight, conductivity by changing the amount of organic matter that collects in the vernal ponds, or pH if the logging process deposits foreign residues to the area. Also heavy equipment used to harvest the timber has the potential to alter the terrain; modifications to the landscape could change how water flows and collects at the surface and change the size, shape, and location of the vernal ponds. Loss or alteration to small temporary water sources less than four hectares can be extremely detrimental to amphibians water (Semlitsch, 2000). Without vernal ponds amphibians would have difficulty inhabiting forested areas because they rely on the ponds as breeding grounds. If logging disturbs the ponds, amphibian populations could diminish in the areas that surround these vernal pools.

Data obtained from the research can be implemented by the forest service to understand amphibian interactions with environmental characteristics in order to improve management and care of the forest. The Ottawa National Forest should be able to utilize the information to harvest timber in a manner that retains amphibian welfare.

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Appendix

Pearson's Correlation Table

May 2004

	Water Temp.	Air Temp.	pH	Conductivity	DO	Max Depth
Water Temp.	0.000					
Air Temp.	0.092	0.000				
pH	0.716	0.296	0.000			
Conductivity	0.305	0.296	0.305	0.000		
DO	0.197	0.024	0.033	0.455	0.000	
Max Depth	0.658	0.303	0.033	0.488	0.250	0.000
Plots	0.042	0.419	0.830	0.651	0.459	0.371
Species	0.031	0.015	0.403	0.189	0.110	0.298
Count	0.112	0.391	0.584	0.465	0.270	0.231
SVL-R sylvatica	0.021	0.028	0.545	0.232	0.146	0.240
Density- R sylvatica	0.096	0.336	0.484	0.538	0.215	0.238
Biomass- R sylvatica	0.103	0.374	0.563	0.491	0.256	0.230

	Plots	Species	Count	SVL-R sylvatica	Density- R sylvatica	Biomass- R sylvatica
Water Temp.						
Air Temp.						
pH						
Conductivity						
DO						
Max Depth						
Plots	0.000					
Species	0.318	0.000				
Count	0.001	0.396	0.000			
SVL-R sylvatica	0.243	0.738	0.346	0.000		
Density- R sylvatica	0.002	0.343	0.203	0.310	0.000	
Biomass- R sylvatica	0.001	0.372	0.065	0.326	0.308	0.000

June 2004

	Water Temp.	Air Temp.	pH	Conductivity	DO	Max Depth
Water Temp.	0.000					
Air Temp.	0.001	0.000				
pH	0.281	0.349	0.000			
Conductivity	0.087	0.133	0.671	0.000		
DO	0.772	0.526	0.153	0.803	0.000	
Max Depth	0.623	0.735	0.303	0.950	0.353	0.000
Plots	0.530	0.538	0.574	0.366	0.919	0.959
Species	0.586	0.492	0.243	0.506	0.660	0.076
Count	0.957	0.859	0.382	0.791	0.973	0.157
SVL-R sylvatica	0.351	0.405	0.543	0.859	0.263	0.001
SVL- A maculatum	0.116	0.262	0.718	0.043	0.595	0.283
SVL- A laterale	0.751	0.571	0.998	0.911	0.520	0.469
SVL- P crucifer	0.853	0.973	0.437	0.731	0.997	0.230
Density- Total	0.916	0.689	0.372	0.649	0.844	0.119
Density- R sylvatica	0.983	0.702	0.545	0.637	0.595	0.140
Density- P crucifer	0.853	0.973	0.437	0.731	0.997	0.230
Density- A maculatum	0.870	0.834	0.205	0.922	0.026	0.949
Density- A laterale	0.689	0.518	0.899	0.915	0.396	0.663
Density- Anuran	0.985	0.706	0.541	0.638	0.600	0.139
Density- Salamander	0.734	0.918	0.276	0.968	0.175	0.792
Biomass- R sylvatica	0.991	0.731	0.506	0.608	0.629	0.135
Biomass- Pcrucifer	0.853	0.973	0.437	0.731	0.997	0.230
Biomass- A maculatum	0.837	0.867	0.222	0.883	0.032	0.986
Biomass- A laterale	0.698	0.575	0.788	0.837	0.396	0.762
Biomass- Anuran	0.990	0.732	0.506	0.608	0.600	0.135
Biomass- Salamander	0.688	0.822	0.489	0.809	0.370	0.837
Biomass- Total	0.980	0.715	0.461	0.624	0.691	0.126

	Plots	Species	Count	SVL-R sylvatica	SVL- A maculatum	SVL- A laterale	SVL- P crucifer
Water Temp.							
Air Temp.							
pH							
Conductivity							
DO							
Max Depth							
Plots	0.000						
Species	0.521	0.000					
Count	0.199	0.045	0.000				

SVL-R sylvatica	0.689	0.239	0.446	0.000			
SVL- A maculatum	0.621	0.966	0.367	0.289	0.000		
SVL- A laterale	0.732	0.058	0.277	0.648	0.806	0.000	
SVL- P crucifer	0.088	0.211	0.002	0.540	0.289	0.733	0.000

	Plots	Species	Count	SVL-R sylvatica	SVL- A maculatum	SVL- A laterale	SVL- P crucifer
Density- Total	0.765	0.024	0.009	0.352	0.284	0.055	0.083
Density- R sylvatica	0.611	0.055	0.006	0.399	0.180	0.099	0.038
Density- P crucifer	0.088	0.211	0.002	0.540	0.289	0.733	
Density- A maculatum	0.748	0.782	0.776	0.857	0.289	0.864	0.563
Density- A laterale	0.198	0.311	0.812	0.729	0.740	0.010	0.685
Density- Anuran	0.597	0.056	0.005	0.399	0.180	0.103	0.035
Density- Salamander	0.374	0.467	0.879	0.740	0.423	0.462	0.459
Biomass- R sylvatica	0.531	0.072	0.004	0.398	0.157	0.159	0.020
Biomass- Pcrucifer	0.088	0.211	0.002	0.540	0.289	0.733	
Biomass- A maculatum	0.758	0.765	0.772	0.897	0.257	0.908	0.544
Biomass- A laterale	0.337	0.225	0.785	0.812	0.934	0.002	0.649
Biomass- Anuran	0.527	0.072	0.003	0.398	0.157	0.160	0.020
Biomass- Salamander	0.400	0.325	0.965	0.804	0.378	0.201	0.450
Biomass- Total	0.581	0.049	0.003	0.382	0.191	0.116	0.030

	Density- Total	Density- R sylvatica	Density- P crucifer	Density- A maculatum	Density- A laterale	Density- Anuran	Density- Salamander
Water Temp.							
Air Temp.							
pH							
Conductivity							
DO							
Max Depth							
Plots							
Species							
Count							
SVL-R sylvatica							
SVL- A laterale							

SVL- P crucifer							
Density-Total	0.000						
Density- R sylvatica	0.147	0.000					
Density- P crucifer	0.083	0.038	0.000				
Density- A maculatum	0.839	0.477	0.563	0.000			
Density- A laterale	0.208	0.299	0.685	0.831	0.000		
Density-Anuran	0.145	0.517	0.035	0.477	0.311	0.000	
	Density-Total	Density-R sylvatica	Density-P crucifer	Density- A maculatum	Density-A laterale	Density-Anuran	Density-Salamander
Density-Salamander	0.722	0.854	0.459	0.008	0.405	0.846	0.000
Biomass- R sylvatica	0.001	0.463	0.020	0.459	0.404	0.473	0.769
Biomass-Pcrucifer	0.083	0.038		0.563	0.685	0.035	0.459
Biomass- A maculatum	0.838	0.474	0.544	0.295	0.863	0.473	0.007
Biomass- A laterale	0.266	0.393	0.649	0.986	0.001	0.406	0.309
Biomass-Anuran	0.001	0.459	0.020	0.459	0.408	0.468	0.767
Biomass-Salamander	0.607	1.000	0.450	0.051	0.211	0.989	0.001
Biomass-Total	0.189	0.369	0.030	0.563	0.340	0.295	0.918

	Biomass-Rsylvatica	Biomass-Pcrucifer	Biomass-Amaculatum	Biomass-Alaterale	Biomass-Anuran	Biomass-Salamander	Biomass-Total
Biomass- R sylvatica	0.000						
Biomass-Pcrucifer	0.020	0.000					
Biomass- A maculatum	0.451	0.544	0.000				
Biomass- A laterale	0.525	0.649	0.937	0.000			
Biomass-Anuran	0.456	0.020	0.451	0.529	0.000		
Biomass-Salamander	0.878	0.450	0.042	0.104	0.876	0.000	
Biomass-Total	0.195	0.030	0.557	0.437	0.195	0.964	0.000

July 2004

	Water Temp.	Air Temp.	pH	Conductivity	Max Depth
Water Temp.	0.000				
Air Temp.	0.466	0.000			
pH	0.325	0.794	0.000		
Conductivity	0.062	0.941	0.528	0.000	
Max Depth	0.191	0.881	0.040	0.180	0.000
Plots	0.254	0.777	0.167	0.136	0.037
Species	0.281	0.159	0.115	0.782	0.356
Count	0.207	0.099	0.179	0.690	0.404
SVL-R sylvatica	0.255	0.532	0.524	0.028	0.150
SVL- A maculatum	0.381	0.016	0.974	0.896	0.824
SVL- A laterale	0.336	0.503	0.012	0.666	0.132
SVL- P crucifer	0.336	0.503	0.012	0.666	0.132
Density- Total	0.194	0.293	0.050	0.561	0.185
Density- R sylvatica	0.193	0.368	0.050	0.494	0.153
Density- A maculatum	0.047	0.715	0.308	0.126	0.171
Density- A laterale	0.336	0.503	0.012	0.666	0.132
Density- P crucifer	0.891	0.231	0.617	0.869	0.489
Density- Anuran	0.193	0.443	0.025	0.474	0.107
Density- Salamander	0.109	0.523	0.020	0.344	0.057
Biomass- R sylvatica	0.146	0.468	0.016	0.409	0.075
Biomass- Pcrucifer	0.777	0.174	0.817	0.926	0.645
Biomass- A maculatum	0.055	0.680	0.586	0.108	0.356
Biomass- A laterale	0.336	0.503	0.012	0.666	0.132
Biomass- Anuran	0.265	0.484	0.023	0.551	0.120
Biomass- Salamander	0.084	0.466	0.032	0.321	0.070
Biomass- Total	0.173	0.466	0.016	0.447	0.086
DO	0.605	0.834	0.473	0.425	0.346

	Plots	Species	Count	SVL-R sylvatica	SVL- A maculatum	SVL- A laterale	SVL- P crucifer
Water Temp.							
Air Temp.							
pH							
Conductivity							
Max Depth							
Plots	0.000						
Species	0.545	0.000					
Count	0.562	0.002	0.000				
SVL-R sylvatica	0.057	0.978	0.982	0.000			
SVL- A maculatum	0.669	0.305	0.205	0.617	0.000		
SVL- A laterale	0.250	0.030	0.065	0.720	0.737	0.000	
SVL- P crucifer	0.250	0.030	0.065	0.720	0.737		0.000
Density- Total	0.300	0.007	0.012	0.727	0.463	0.008	0.008
Density- R sylvatica	0.204	0.025	0.032	0.607	0.567	0.009	0.009
Density- A maculatum	0.407	0.412	0.374	0.331	0.528	0.435	0.435
Density- A laterale	0.250	0.030	0.065	0.720	0.737		
Density- P crucifer	0.813	0.735	0.603	0.693	0.340	0.963	
Density- Anuran	0.180	0.030	0.044	0.569	0.636	0.004	0.004
Density- Salamander	0.218	0.062	0.078	0.491	0.598	0.031	0.031
Biomass- R sylvatica	0.186	0.035	0.050	0.528	0.614	0.008	0.008
Biomass- Pcrucifer	0.948	0.553	0.440	0.742	0.309	0.825	0.825
Biomass- A maculatum	0.567	0.599	0.509	0.354	0.424	0.708	0.708
Biomass- A laterale	0.250	0.030	0.065	0.720	0.737		
Biomass- Anuran	0.181	0.037	0.060	0.607	0.716	0.002	0.002
Biomass- Salamander	0.224	0.054	0.062	0.488	0.534	0.036	0.036
Biomass- Total	0.183	0.032	0.048	0.551	0.636	0.004	0.004

DO	0.078	0.728	0.726	0.236	0.602	0.442	0.442

	Density- Total	Density- R sylvatica	Density- A maculatum	Density- A laterale	Density- P crucifer	Density- Anuran
Water Temp.						
Air Temp.						
pH						
Conductivity						
Max Depth						
Plots						
Species Count						
SVL-R sylvatica						
SVL- A maculatum						
SVL- A laterale						
SVL- P crucifer						
Density- Total	0.000					
Density- R sylvatica	0.002	0.000				
Density- A maculatum	0.338	0.387	0.000			
Density- A laterale	0.008	0.009	0.435	0.000		
Density- P crucifer	0.002	0.774	0.574	0.963	0.000	
Density- Anuran	0.002	0.001	0.337	0.004	0.914	0.000
Density- Salamander	0.023	0.035	0.116	0.031	0.774	0.019
Biomass- R sylvatica	0.005	0.006	0.225	0.008	0.952	0.001
Biomass- Pcrucifer	0.622	0.580	0.671	0.825	0.002	0.710
Biomass- A maculatum	0.537	0.590	0.010	0.708	0.731	0.556
Biomass- A laterale	0.008	0.009	0.434		0.963	0.004
Biomass- Anuran	0.005	0.001	0.428	0.002	0.910	0.001
Biomass- Salamander	0.019	0.030	0.109	0.036	0.851	0.018
Biomass- Total	0.003	0.003	0.277	0.004	0.997	0.000

DO	0.492	0.338	0.981	0.442	0.662	0.362

	Density-Salamander	Biomass-R sylvatica	Biomass-Pcrucifer	Biomass-A maculatum	Biomass-A laterale
Water Temp.					
Air Temp.					
pH					
Conductivity					
Max Depth					
Plots					
Species					
Count					
SVL-R sylvatica					
SVL- A maculatum					
SVL- A laterale					
SVL- P crucifer					
Density- Total					
Density- R sylvatica					
Density- A maculatum					
Density- A laterale					
Density- P crucifer					
Density- Anuran					
Density-Salamander	0.000				
Biomass- R sylvatica	0.004	0.000			
Biomass- Pcrucifer	0.968	0.844	0.000		
Biomass- A maculatum	0.279	0.424	0.781	0.000	
Biomass- A laterale	0.031	0.008	0.825	0.708	0.000
Biomass- Anuran	0.034	0.006	0.705	0.674	0.002
Biomass-Salamander	0.000	0.004	0.958	0.256	0.036
Biomass- Total	0.008	0.000	0.797	0.491	0.004
DO	0.611	0.457	0.573	0.867	0.442

	Biomass- Anuran	Biomass- Salamander	Biomass- Total	DO
Water Temp.				
Air Temp.				
pH				
Conductivity				
Max Depth				
Plots				
Species				
Count				
SVL-R sylvatica				
SVL- A maculatum				
SVL- A laterale				
SVL- P crucifer				
Density- Total				
Density- R sylvatica				
Density- A maculatum				
Density- A laterale				
Density- P crucifer				
Density- Anuran				
Density- Salamander				
Biomass- R sylvatica				
Biomass- Pcrucifer				
Biomass- A maculatum				
Biomass- A laterale				
Biomass- Anuran	0.000			
Biomass- Salamander	0.036	0.000		
Biomass- Total	0.002	0.008	0.000	
DO	0.324	0.604	0.415	0.000