Characterization of Amphibian Populations Prior to Logging Practices

Kathleen Kochanowicz

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Advisor: Dr. Yurewicz
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Abstract

A survey of seven ponds was conducted from late May through late July 2003 to compile baseline data on pre-logging amphibian populations of ponds in the Ottawa National Forest, which will be subject to logging in the future, and control vernal ponds at the University of Notre Dame Environmental Research Center (UNDERC), which will not be logged. The ponds sampled contained five amphibian species, 244 larvae were collected. Species richness peaked in June for most ponds. Population density increased at each sampling period for most ponds. Significant correlations were found between the amount of dissolved oxygen and amphibian size; open canapy and species richness; canopy cover and amphibian size; air temperature and salamander density; water temperature and amphibian density; maximum depth and size, density, and biomass. A comparison of densities from 2002 and 2003 show that population densities were higher in the summer of 2003.

Introduction

The healthiness of a local amphibian population can indicate the condition of the environment (Blaustein and Wake, 1995). Because of the biphasic amphibian life cycle, larvae inhabit aquatic environments whereas adults are able to exploit terrestrial environments as well. A wide variety of aquatic environments support embryonic and larval development. Permanent ponds usually have inhabitants of a single species of tadpole, whereas temporary ponds have been known to contain as many as six species (Skelly, 1997). This reflects the interplay between competition and predation; some species, those that inhabit temporary ponds, are specialized in competitive ability, but others, such as those that inhabit permanent ponds, are better specialized to reduce susceptibility to predators (Skelly, 1997). Amphibian eggs can be directly exposed to the soil, water, and sunlight of their environment, and because of their diffusible gelatinous capsules, the uptake of environmental contaminants can occur (Blaustein and Wake, 1995; Gibbons et al., 2000). Concern exists about the apparent decline of amphibian populations worldwide (Blaustein, 1998). Possible causes of the population decline may include habitat destruction, pathogens in the environment, introduction of exotic species, pollution, increased ultra-violet radiation (Blaustein, 1998), acid precipitation, pesticides, and heavy metals in the environment (Grant and Licht, 1995).

Anurans play important roles in both aquatic and terrestrial environments, so it is important to understand if and why their populations may be declining. In the larval stage, anurans are herbivores, although adults are carnivores. As crucial components of their ecosystem, larvae are food for aquatic insects, fish, mammals, and birds. The seasonal fluctuations in tadpole biomass cause shifts in nutrient cycling and primary production of their environment (Seale, 1980). The tadpoles depend on suspension feeding which reduces the concentration of phytoplankton (Seale, 1980). The increase of tadpole biomass accompanies a decrease in nitrogen in its particulate form and increase in dissolved nitrogen (Seale, 1980). This means that tadpoles act as regulatory consumers, thus causing an increase in the nitrogen uptake by phytoplankton (Seale, 1980). Tadpole feeding reduces the primary productions rates, causing a decrease in the standing crop of blue-green algae, and thus reduces the amount of chlorophyll present in the environment (Seale, 1980). Adult amphibians are predators that primarily hunt insects and other arthropods (Blaustein and Wake, 1995).

Amphibians are important to humans because they are monitors for local conditions (Blaustein and Wake, 1995). The same things that affect amphibians may also affect humans. In addition, amphibian skin secretions may have great pharmaceutical value in painkillers, treatment of burns and heart attacks, and antibacterial and antiviral properties. The extinction of a species may lead to a loss of possible remedies to human maladies (Blaustein and Wake, 1995). Thus, continued monitoring of the health of local amphibian populations under various conditions is important because of its implications for human well being.

Habitat modifications may affect amphibian populations because amphibian skin allows for respiration (Blaustein and Wake, 1995), and therefore adult amphibians are required to remain in moist areas to survive. The highly permeable, glandular skin of amphibians promotes vulnerability and increased sensitivity to aquatic and terrestrial toxins (Gibbons et al., 2000). Because few amphibians travel more than a few hundred meters in a lifetime, they are defenseless against drastic changes in their environment (Gibbons et al., 2000). Amphibians breed in discrete sites (Hecnar and M'Closky, 1996). Species that prefer to be associated with woodlands have smaller populations in wooded areas that have been modified by human populations because of dependence on the forest habitat for foraging and hibernation (Hecnar and M'Closky, 1996). An inverse association has been found between human population density and amphibian species richness in wooded areas (Hecnar and M'Closky, 1996).

Studies in Maryland, on adult amphibians, show that logging and prescribed burning, while changing vegetation composition and structure, also alter the abundance and occurrence of amphibian populations (McLeod and Gates, 1998). When large trees are cut, the opening in the canopy causes greater environmental fluctuations. The fluctuations of air and soil temperatures, humidity, light intensity, and wind speed have detrimental effects on amphibians especially through desiccation. The microhabitat of leaf litter and coarse woody debris is also reduced or removed causing harm to amphibian populations. Young amphibians are at risk of dehydration and death when dispersing through dry, open areas during the summer. Forests are important areas for travel during the time that amphibians disperse from breeding pools (McLeod and Gates, 1998).

In nature, forests do go through periods of destruction even without human interference (McLeod and Gates, 1998). Windstorms, fires, and beaver activity are among natural causes of forest disruption. However, although diversity may be decreased in a particular patch, the mix of disturbed and undisturbed patches increase species diversity on a broad scale. Some amphibian species have poor dispersal ability and thus maintenance of old-growth hardwoods and associated wetlands and ponds are vital to the survival of amphibians (McLeod and Gates, 1998).

Canopy cover is a factor that influences the distribution of amphibian larvae. In 1997, Skelly et al. conducted a survey in Connecticut to evaluate the effect of forest canopy cover on two species of larval amphibians, wood frogs, *Rana sylvatica*, and spring peepers, *Pseudacris crucifer*. This study found that canopy cover has significant effects on wood frog growth. In open canopy ponds, wood frogs grew 90% faster than their counterparts in closed canopy ponds. However, wood frogs had better survival in closed canopy ponds. Spring peepers grew 87% faster in open versus closed canopy ponds. Canopy development has been associated with the absence of spring peeper populations, however, wood frog populations may still persist. For many species, local species extinction has been associated with forest canopy overgrowth (Skelly, 2002).

This study will be done to compile data to investigate the impact of logging practices on amphibian populations. I will gather data on pre-logging amphibian populations of vernal ponds in the Ottawa National Forest, which will be subject to logging in the future, and control vernal ponds at the University of Notre Dame Environmental Research Center (UNDERC), which will not be logged; both areas are located in northern Wisconsin and Michigan's Upper Peninsula. Data collected in 2003

in conjunction with data collected in 2002 and 2001 will be used as a baseline of pre-logging amphibian populations, against which to compare post-logging populations and environments. Data will be collected regarding amphibian diversity, population numbers, and natural rates of population growth and decline.

Materials and Methods

This study was conducted from late May 2003 through late July 2003. Similar studies were carried out in 2001 and 2002 as well. Studies carried out over multiple years will provide data with a more accurate representation of amphibian populations. By compiling data over a greater period of time the representation for baseline data will yield more precise information for future comparisons.

Vernal Pond Characterization

Four ponds at the Ottawa National Forest and three ponds at University of Notre Dame Environmental Research Center (UNDERC) were characterized through multiple tests and measurements, at each research period. The circumference, length, width, and maximum depth of each pond was be measured in order to create a numbered grid sectioning the perimeter of each pond into one meter square plots at a distance of zero and one meter from the shoreline. We placed wooden stakes at a distance of ten meters apart around the perimeter of each pond to be used as reference points during sampling. Qualitative observations of watercolor, water turbidity, primary substrate, and the presence of fish were taken. Observations regarding weather, distance from the shoreline

to the forest edge, percent margin of emergent vegetation, and species of emergent and surrounding vegetation were compiled as well.

Data was also collected to estimate the percentage of forest canopy cover shading each pond using a spherical densiometer. Observations were taken at the north, south, west, east, and center of each pond. At each point, I determined the percent of open canopy by taking counts facing north, south, east, and west. An average of these counts was then calculated for each pond.

Ambient air and water temperatures were measured using a standard alcohol thermometer. Dissolved oxygen (DO) was measured using a YSI 55 dissolved oxygen meter. Conductivity was measured using a Hanna Instruments HI 9033 multi-range conductivity meter. Water pH was measured with at Hanna Instruments pHep 3 meter.

Larval Amphibian Sampling

About one-fourth of the plots of each vernal pond were sampled. Each plot around the pond was designated a number, the plots 0-1 m from the shore will be assigned "A" and the plots 1-2 m from the shore will be assigned "B." We used a random number table to determine the plot numbers to be sampled and "A" or "B" was sampled at a given plot. During every sampling, the pond perimeters and square plots were re-determined due to vernal pond desiccation throughout the summer. Sampling of ponds occurred once in May, June, and July, 2003.

We placed a 31-gallon Rubbermaid bin with the bottom removed, measuring 0.876 m long, 0.508 m wide, and 0.425 m deep, into the determined plot and held it securely to the bottom of the pond to prevent any larval amphibians from escaping. The

bin was swept thoroughly with a small fish net and the contents were placed into a bucket for analysis. All larval amphibians captured were placed in labeled buckets filled with pond water and were identified and measured in the laboratory. Adult amphibians captured were identified and promptly returned to the pond.

Larval Amphibian Analysis

All captured larval amphibians were taken to the lab for quantitative analysis. Larval salamander species were identified by the differentiation of body coloration and lateral stripes. We used head shape, coloration, body size, and knowledge of phenology to assess tadpole identity. Each larval amphibian was measured to the nearest 0.1mm using general calipers. For Anurans, tail length, snout-vent length, and total length were recorded. For Caudata, snout-vent length and total length were recorded. Following identification and measurement, larval amphibians were returned to their original vernal pond.

Analysis

The primary data collected for the number of species and individuals of each species in each sampling plot will be used to determine the mean size and standard deviation across ponds at each date. The larval amphibian density will be determined by dividing the total number of individuals captured at each vernal pond by the number of plots sampled.

Bar graphs were created using Microsoft Excel. Systat was used to create regression scatter plot graphs. Graphs compare percentage of forest canopy cover; air

temperature; water temperature; amount of dissolved oxygen; water conductivity; water pH; and species richness with the larval amphibian population density. Correlation of data and statistics for all vernal ponds was examined.

The data collected is expected to show a correlation between larval amphibian population density and percentage of forest canopy cover; air temperature; water temperature; amount of dissolved oxygen; water conductivity; water pH; and species richness (German and Slavick 2002).

Results

The ponds sampled contained five amphibian species (Table1.), 244 larvae were collected. *Rana sylvatica* had the highest incidence, found in six of the seven ponds, whereas *Hyla versicolor* was present only in ND2. All species were found in ND2. Only *R. sylvatica* was present in ND3.

Species richness (Fig. 1) for the summer of 2003 peaked, in most ponds, in June with three species. However, ND2 reached peak richness in July with five species collected. Larval amphibians were not found in OTT3 during the May sampling and the pond was completely desiccated in June. All of the other ponds had one species at the May sampling. OTT6 was totally desiccated for the July sampling. Species richness dropped off for most ponds in July; ND1, ND3, and OTT5; each had only one species.

The Shannon-Wiener Index, calculated for the June (Fig. 2) and July (Fig. 3) samplings, indicates that overall the ponds had a higher level of diversity in June. OTT2 has the highest June index of 1. However, in July, ND2 has a higher index. More ponds

were diverse in June than in July, but the most diversity found in a single pond, was found in July.

Population density (Fig. 4) increased at each sampling period for most ponds. OTT5 slightly decreased from June to July and ND3 decreased from May to June. In May (Fig. 5), the amphibian population was most dense in OTT2. The pattern for June (Fig. 6) was much the same as May. In July however (Fig. 7), the population density of ND2 sharply increased. From June to July (Fig. 8) an increase and shift is seen from tadpoles to salamanders. Figure 9 and figure 10 show a shift from primarily *Rana sylvatica* to other species of tadpoles and salamanders.

Analysis of the biomass shows a strong shift as the summer progresses. The biomass in May (Fig. 11) is made up entirely of tadpoles. In June (Fig. 12), salamanders make up some of the biomass. Finally, by July (Fig. 13), there is a dramatic shift in the biomass of OTT5 from primarily tadpoles in June to only salamanders in July.

Canopy cover (Fig. 14) was observed during the June sampling. The percentage of open canopy cover ranged from .312% at ND3 through 7.794% at ND2. It is interesting to note that although ND2 had the most open canopy, it did not become completely desiccated.

Few significant correlations can be noted from the first sampling, however, some trends did occur. The May sampling (Table 2.) shows a correlation between air and water temperature (P=.046). There is a trend observed between air temperature and pH (P=.059); water temperature and dissolved oxygen (P=.094); and water temperature and average snout-vent length (P=.089).

Correlations run on the June sampling data yielded more significant correlations (Table 3.). The amount of dissolved oxygen and the snout-vent length of *A. maculatum* (Fig. 15) have a significant correlation(P=.01), as dissolved oxygen increases *A. maculatum* snout-vent length increases as well. A positive correlation (P=.046) also exists between the percentage of open canopy and the species richness of a pond (Fig. 16). Finally, the percentage of open canopy has a positive correlation (P=.032) with *P. crucifer* snout-vent length (Fig 17). A positive trend exists between the water temperature of a pond and the number of species found in the pond (P=.063)(Fig. 18) as well as with *A. maculatum* snout-vent length (P=.064)(Fig. 19). The amount of dissolved oxygen has a positive trend with *A. laterale* density (P=.091)(Fig. 20); *A. laterale* biomass (P=.069)(Fig. 21); *A. maculatum* biomass (P=.07)(Fig. 22); and salamander biomass (P=.068)(Fig. 23).

The final sampling, in July, produced several significant correlations (Table 4). Significant correlations were found once again with air and water temperature (P=.048). Air temperature also has significant correlations with salamander density (P=.008), *R. sylvatica* biomass(P=.052), *A. laterale* biomass(P=.008), and total salamander biomass(P=.006). Water temperature has significant correlations with amphibian density (P=.023) and *R. sylvatica* biomass(P=.027). Maximum depth has a positive correlation with the snout-vent length(P=.025), the density(P=.025), and the biomass(P=.025) of *H. versicolor* and *P. crucifer*. Dissolved oxygen concentration has a positive correlation with *A. laterale* snout-vent length(P=.003).

In comparing the density data from 2002 with the data collected this year, in May(Fig. 24), four of the seven ponds sampled had a higher population density than last

year. June density values (Fig. 25) were higher this year than last in five ponds. Five ponds had higher densities in 2003 for July (Fig. 26) as well.

Discussion

Amphibians are not equally suited for survival and success in all environments. Different species are better adapted to tolerate different conditions. These adaptations are demonstrated by species preferences for different temperatures and varying amounts of canopy cover as is illustrated by breeding cycles and habits. Species richness was at its peak for most ponds in June due to the staggered metamorphic cycles of species. *R. sylvatica* larvae, which hatched early in the season were still present in June as well as *P. crucifer*, *A. laterale*, and *A. maculatum* which had hatched since the May sampling and accounted for the increase in species richness.

The amount of dissolved oxygen present in a pond has trends showing a promotion of amphibian size, density, and biomass. A more open canopy has been found to significantly correlate with increased species richness as well as having a positive correlation with *P. crucifer* snout-vent length. In comparing observations from last year with this year's observations, data indicates that population density has increased in most of the ponds sampled.

Acknowledgements

I thank Dr. Kerry Yurewicz for sharing her expertise and for her guidance throughout this project. I express my great appreciation to Dave Choate for helping me with my SYSTAT woes. Lauren Kinsman, my tadpole buddy, made our sampling an absolute pleasure. Mary Pendergast guided us through our first sampling, so to her I am grateful. I also am forever indebted to Mike McReynolds, Christine Mingione, and Amblyn Allen, without them my final research week would have been impossible. Finally, I must express my gratitude to the entire UNDERC 2003 class for making the trek out to Ottawa National Forest, the bellowing echoes of "TADPOLE!" will never be forgotten.

Literature Cited

Blaustein, A.R. 1998. Effects of ultraviolet radiation on amphibians: field experiments. *American Zoologist* **38:** 799-812.

_____, and D.B. Wake. 1995. The puzzle of declining amphibian populations. *Scientific American* **272(4):** 56-61.

German, C., and J. Slavick. 2002. Characterization of vernal pond amphibian populations in the Ottawa National Forest prior to clear cutting and selective thinning. UNDERC Student Paper, University of Notre Dame, Notre Dame, 25 pp.

Gibbons, J.W., D.E. Scott, T.J. Ryan, K.A. Buhlmann, T.D. Tuberville, B.S. Metts, et al. 2000. The global decline of reptiles, déjá vu amphibians. *BioScience* **50:** 653-666.

Grant, K.P., and L.E. Licht. 1995. Effects of ultraviolet radiation on life-history stages of anurans from Ontario, Canada. *Canadian Journal of Zoology* **73:** 2292-2301.

Hecnar, S.J., and R.T. M'Closky. 1996. Regional dynamics and the status of amphibians. *Ecology* **77:** 2091-2097.

Heyer, W.R., M.A. Donnelly, R.W. McDiarmid, L.C. Hayek, and M.S. Foster, editors. 1994. Measuring and monitoring biological diversity: standard methods for amphibians. Smithsonian Institutional Press, Washington, D.C.

McLeod, R.F., and J.E. Gates. 1998. Response of herpetofaunal communities to forest cutting and burning at Chesapeake Farms, Maryland. *The American Midland Naturalist* **139:** 164-177.

Seale, D.B. 1980. Influence of amphibian larvae on primary production, nutrient flux, and competition in a pond ecosystem. *Ecology* **61:** 1531-1550.

Skelly, D.K. 1997. Tadpole communities. *American Scientist* **85:** 36-45.

Skelly, D.K., L.K. Freidenburg, and J.M. Kiesecker. 2002. Forest canopy and the performance of larval amphibians. *Ecology* **83:** 983-992.

Figure 1. Species Richness 2003

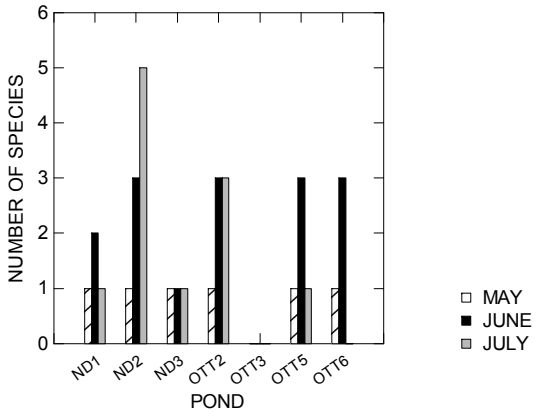

Figure 2. June Shannon Index

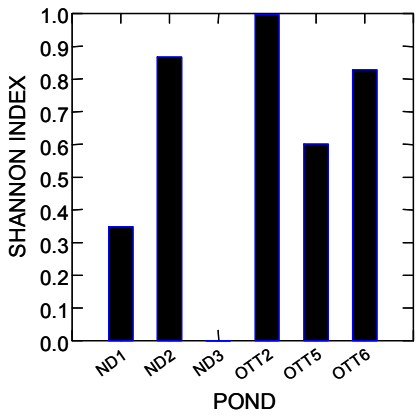

Figure 3. July Shannon Index

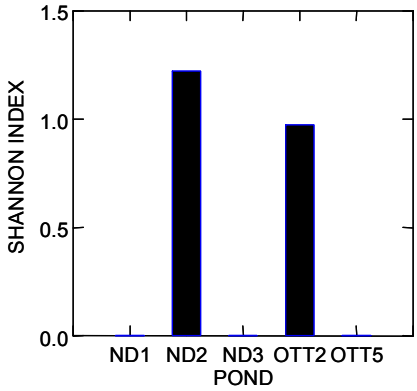

Figure 4. Population Density

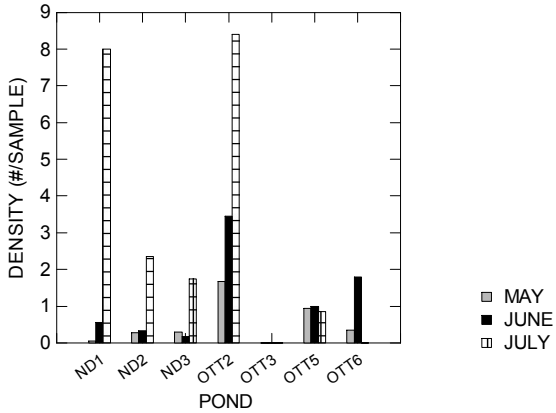

Figure 5. May Population Density

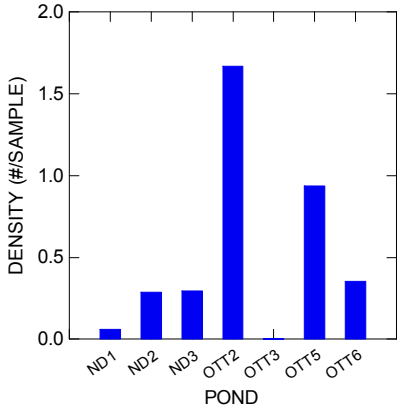

Figure 6. June Population Density

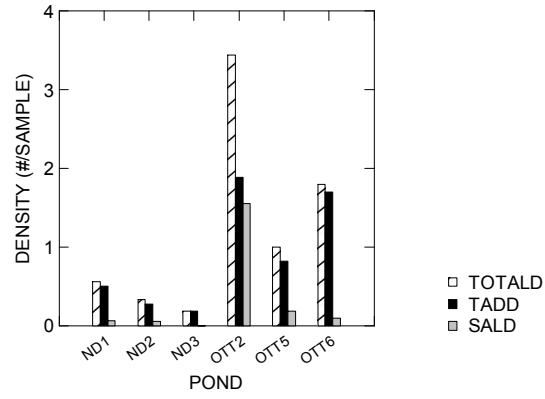

Figure 7. July Population Density

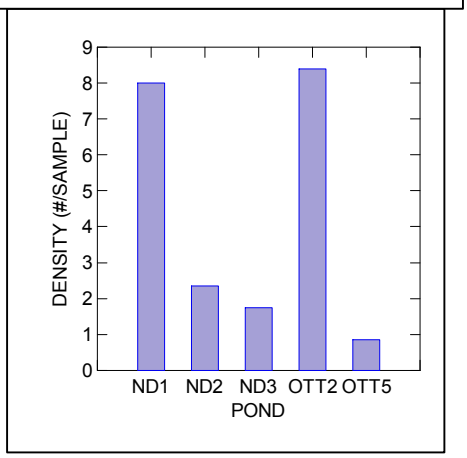

Figure 8. July Tadpole and Salamander Density

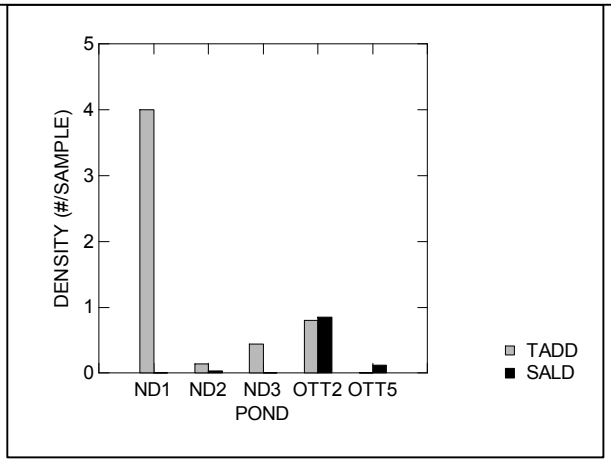

Figure 9. June Species Density

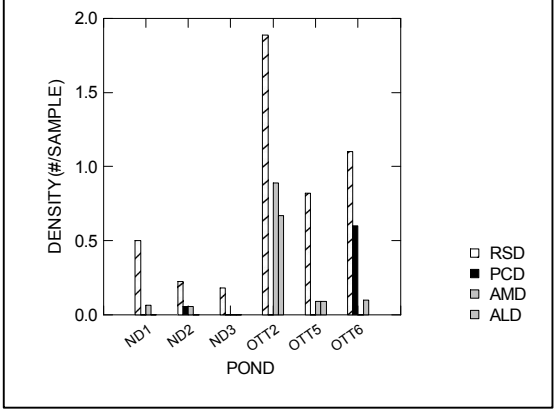

Figure 10. July Species Density

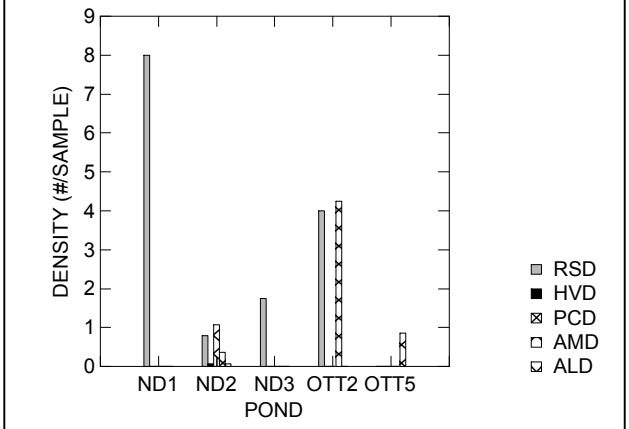

Figure 11. May Biomass

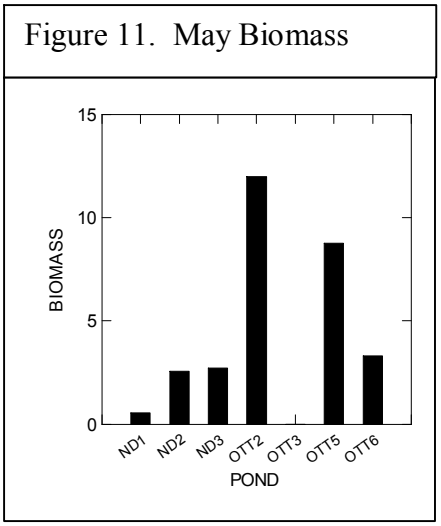

Figure 12. June Tadpole/Salamander Biomass

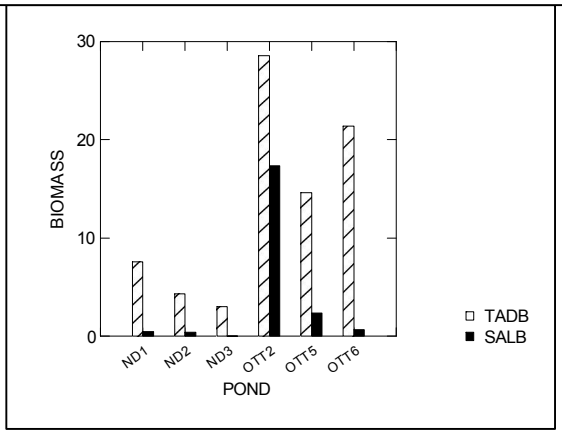

Figure 13. July Tadpole/Salamander Biomass

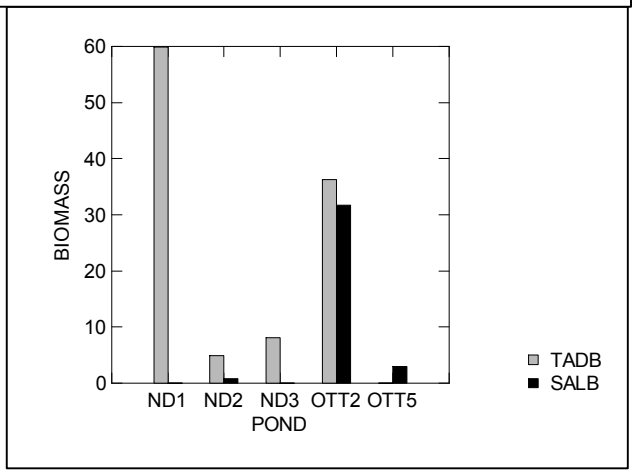

Figure 14. Percentage of Open Canopy Cover

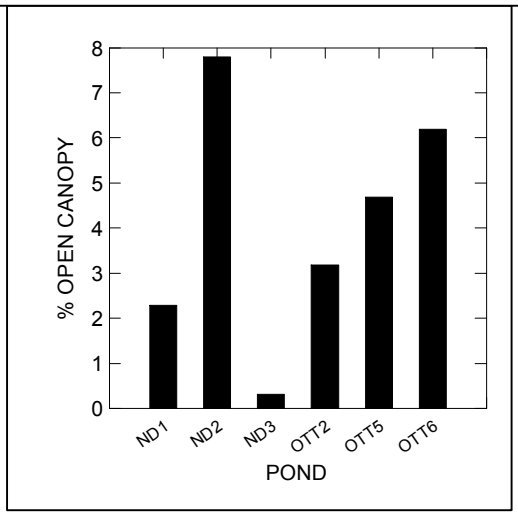

Figure 15. Dissolved Oxygen and *A.maculatum* Snout-vent Length

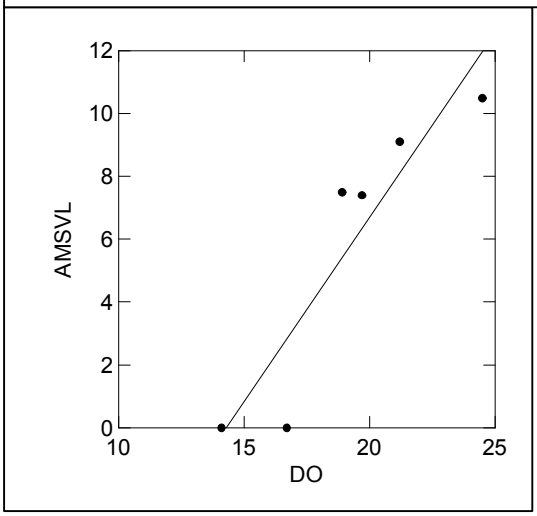

Figure 16. Percent Open Canopy and Species Richness Correlation

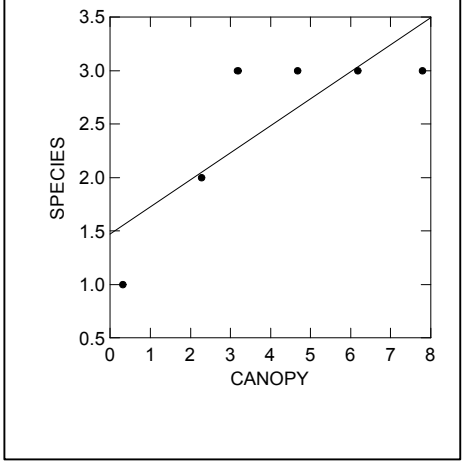

Figure 17. Percent Open Canopy Cover and P.crucifer Snout-Vent Length

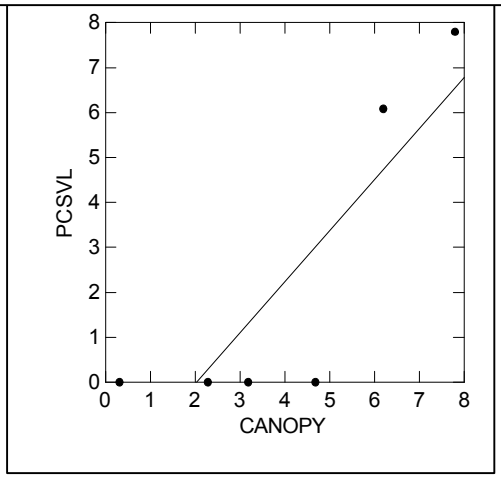

Figure 18. Species/Water Temperature Correlation

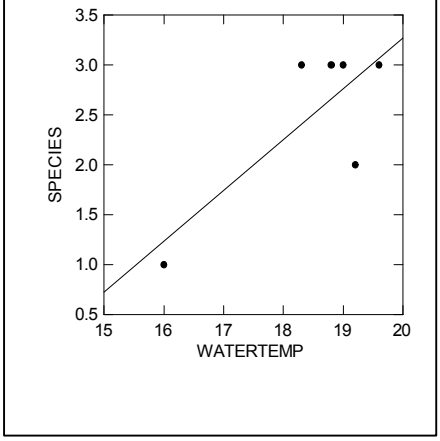

Figure 19. Water Temperature / P.crucifer Snout-vent Length

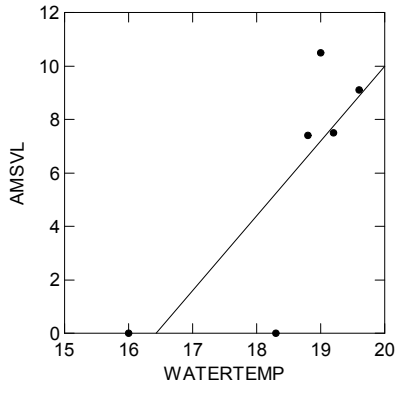

Figure 20. Dissolved Oxygen vs. A.laterale Density Correlation

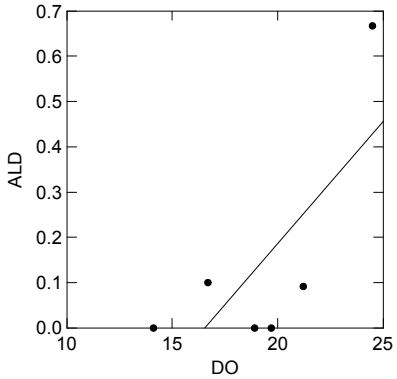

Figure 21. Dissolved Oxygen vs. A.laterale Biomass

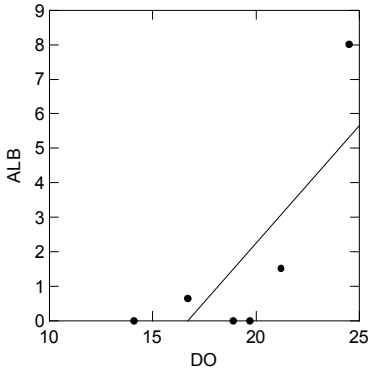

Figure 22. Dissolved Oxygen vs. A.maculatum Biomass

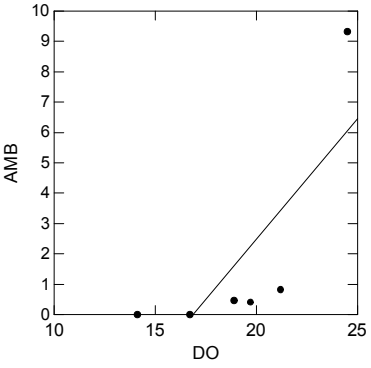

Figure 23. Dissolved Oxygen vs. Salamander Biomass

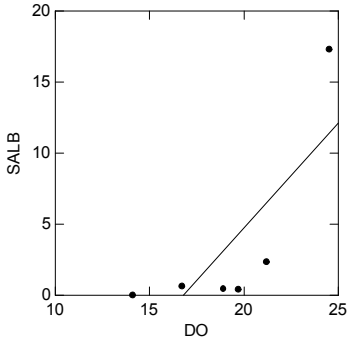

Figure 24. May Density 2002/2003

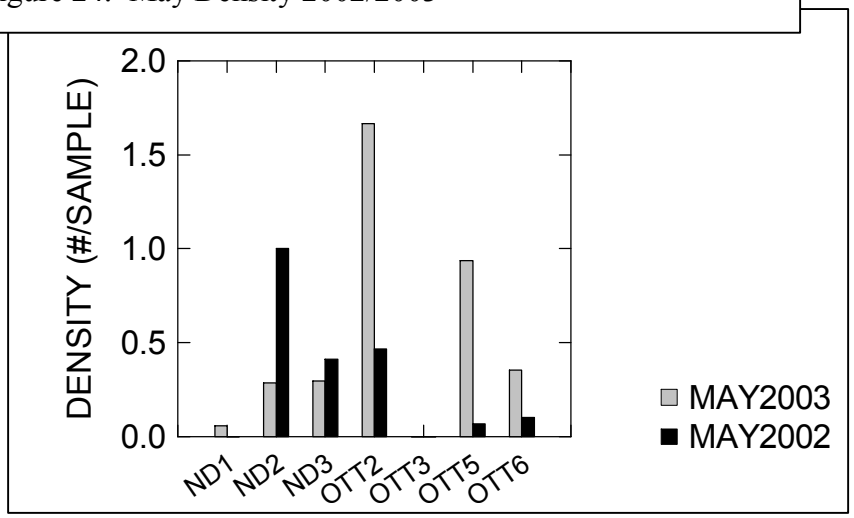

Figure 25. June Density 2002/2003

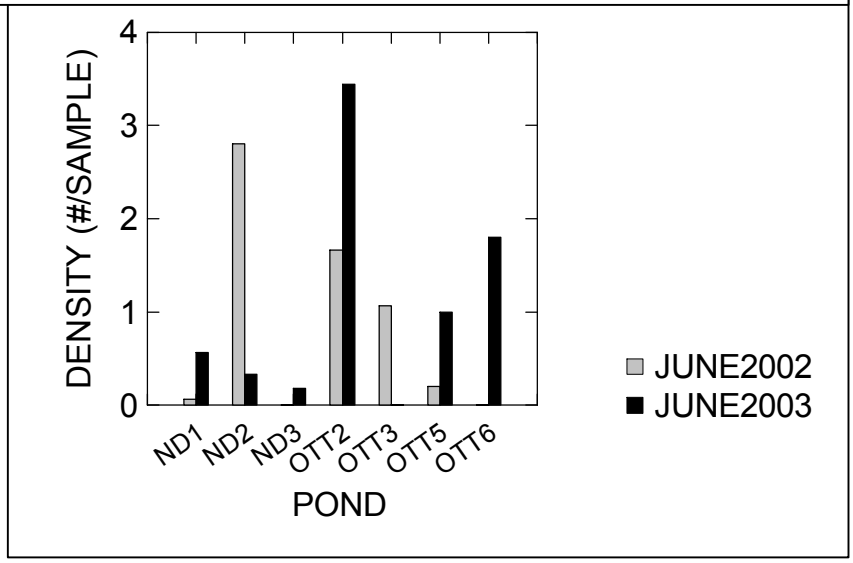

Figure 26. July Density 2002/2003

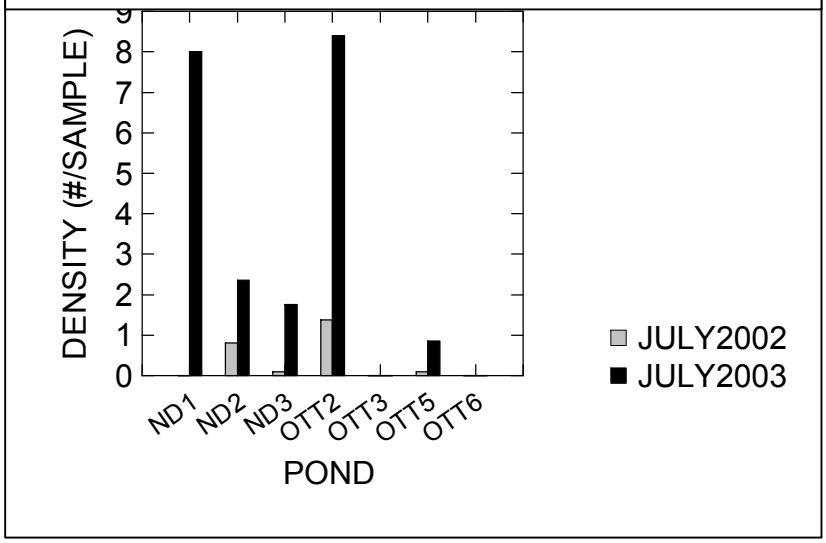

Table1. SPECIES INCIDENCE - 2003

Pond	*R. sylvatica*	*P. crucifer*	*H.versicolor*	*A.maculatum*	*A.laterale*
ND1					
ND2					
ND3					
OTT2					
OTT3					
OTT5					
OTT6					

Table 2. May Sampling Correlations

	AIR TEMP	WATER TEMP	MAXIMUM DEPTH	PH	DO
AIRTEMP	0.000				
WATERTEMP	0.046	0.000			
MAXDEPTH	0.427	0.671	0.000		
PH	0.059	0.228	0.178	0.000	
DO	0.438	0.059	0.809	0.966	0.000
CONDUCTIVITY	0.206	0.094	0.773	0.280	0.868
SPECIES	0.538	0.187	0.122	0.776	0.355
PLOTS	0.662	0.611	0.152	0.507	0.086
INDIVIDUALS	0.252	0.396	0.363	0.375	0.530
SNOUT-VENT LENGTH	0.449	0.089	0.165	0.602	0.248
R.SYLVATICA DENSITY	0.308	0.287	0.293	0.456	0.296
R.SYLVATICA BIOMASS	0.305	0.349	0.234	0.580	0.308

	CONDUCTIVITY	SPECIES	PLOTS	INDIVIDUALS	SVL
CONDUCTIVITY	0.000				
SPECIES	0.399	0.000			
PLOTS	0.682	0.715	0.000		
INDIVIDUALS	0.673	0.311	0.622	0.000	
SVL	0.284	0.000	0.859	0.538	0.000
RSYLVATICA DENSITY	0.691	0.397	0.338	0.000	0.666
RSYLVATICA BIOMASS	0.796	0.343	0.353	0.000	0.565

	RSYLVATICA DENSITY	RSYLVATICA BIOMASS
RSYLVATICA DENSITY	0.000	
RSYLVATICA BIOMASS	0.000	0.000

Table 3. June Sampling Correlations

	AIRTEMP	WATERTEMP	MAXDEPTH	PH	DO
AIRTEMP	0.000				
WATERTEMP	0.003	0.000			
MAXDEPTH	0.712	0.931	0.000		
PH	0.748	0.470	0.068	0.000	
DO	0.090	0.069	0.689	0.655	0.000
CONDUCTIVITY	0.391	0.555	0.404	0.810	0.732
SPECIES	0.135	0.063	0.923	0.556	0.126
PLOTS	0.818	0.687	0.339	0.031	0.863
INDIVIDUALS	0.283	0.402	0.425	0.467	0.113
R.SYLVATICA SVL	0.645	0.961	0.159	0.355	0.802
P.CRUCIFER SVL	0.895	0.913	0.796	0.305	0.748
A.MACUMATUM SVL	0.102	0.064	0.412	0.373	0.010
A.LATERALE SVL	0.364	0.302	0.938	0.593	0.181
TOTAL DENSITY	0.397	0.524	0.449	0.399	0.143
RSYLVATICA DENSITY	0.311	0.432	0.403	0.360	0.129
PCRUCIFER DENSITY	0.989	0.911	0.161	0.492	0.514
AMACULATUM DENSITY	0.498	0.594	0.962	0.729	0.063
ALATERALE DENSITY	0.521	0.627	0.779	0.547	0.091
TADPOLE DENSITY	0.384	0.520	0.221	0.290	0.316
SALAMANDER DENSITY	0.505	0.606	0.883	0.648	0.072
SHANNON INDEX	0.230	0.168	0.976	0.616	0.112
PERCENT OPEN CANOPY	0.503	0.293	0.657	0.219	0.616
AREA	0.743	0.485	0.036	0.001	0.566
RSYLVATICA BIOMASS	0.297	0.397	0.419	0.362	0.127
PCRUCIFER BIOMASS	0.986	0.916	0.176	0.523	0.516
AMACULATUM BIOMASS	0.518	0.617	0.946	0.704	0.070
ALATERALE BIOMASS	0.503	0.589	0.878	0.595	0.069
TADPOLE BIOMASS	0.321	0.429	0.329	0.328	0.192
SALAMANDER BIOMASS	0.509	0.603	0.915	0.652	0.068

	CONDUCTIVITY	SPECIES	PLOTS	INDIVIDUALS	RSYLVATICA SVL
CONDUCTIVITY	0.000				
SPECIES	0.682	0.000			
PLOTS	0.617	0.950	0.000		
INDIVIDUALS	0.593	0.220	0.230	0.000	
RSYLVATICA SVL	0.677	0.707	0.738	0.303	0.000
PCRUCIFER SVL	0.514	0.361	0.405	0.826	0.542
AMACULATUM SVL	0.966	0.305	0.705	0.437	0.962
ALATERALE SVL	0.824	0.223	0.171	0.215	0.665
TOTAL DENSITY	0.493	0.280	0.162	0.000	0.325
RSYLVATICA DENSITY	0.632	0.255	0.141	0.000	0.360
PCRUCIFER DENSITY	0.990	0.530	0.600	0.680	0.909
AMACULATUM DENSITY	0.386	0.517	0.391	0.032	0.324
ALATERALE DENSITY	0.358	0.441	0.231	0.009	0.345
TADPOLE DENSITY	0.671	0.214	0.133	0.005	0.403
SALAMANDER DENSITY	0.371	0.482	0.316	0.019	0.330
SHANNON INDEX	0.414	0.006	0.897	0.107	0.969
CANOPY	0.634	0.046	0.508	0.832	0.369
AREA	0.877	0.723	0.042	0.453	0.414
RSYLVATICA BIOMASS	0.647	0.219	0.126	0.001	0.445
PCRUCIFER BIOMASS	0.974	0.519	0.627	0.691	0.926
AMACULATUM BIOMASS	0.376	0.526	0.371	0.030	0.321
ALATERALE BIOMASS	0.372	0.450	0.248	0.016	0.400
TADPOLE BIOMASS	0.657	0.196	0.119	0.002	0.456
SALAMANDER BIOMASS	0.372	0.489	0.310	0.022	0.355

	PCRUCIFER SVL	AMACULATUM SVL	ALATERALE SVL	TOTAL DENSITY	RSYLVATICA DENSITY
PCRUCIFER SVL	0.000				
AMACULATUM SVL	0.612	0.000			
ALATERALE SVL	0.534	0.362	0.000		
TOTAL DENSITY	0.774	0.502	0.205	0.000	
RSYLVATICA DENSITY	0.687	0.463	0.134	0.000	0.000
PCRUCIFER DENSITY	0.221	0.203	0.991	0.704	0.701
AMACULATUM DENSITY	0.517	0.217	0.358	0.025	0.039
ALATERALE DENSITY	0.576	0.333	0.260	0.005	0.010
TADPOLE DENSITY	0.990	0.804	0.205	0.006	0.004
SALAMANDER DENSITY	0.540	0.261	0.312	0.013	0.023
SHANNON INDEX	0.316	0.351	0.376	0.141	0.158
CANOPY	0.032	0.755	0.799	0.920	0.933
AREA	0.585	0.248	0.642	0.396	0.364
RSYLVATICA BIOMASS	0.697	0.461	0.093	0.001	0.000
PCRUCIFER BIOMASS	0.201	0.206	0.993	0.716	0.716
AMACULATUM BIOMASS	0.517	0.234	0.357	0.023	0.037
ALATERALE BIOMASS	0.505	0.265	0.224	0.010	0.016
TADPOLE BIOMASS	0.836	0.597	0.114	0.002	0.000
SALAMANDER BIOMASS	0.510	0.247	0.291	0.015	0.025

	AMACULATUM BIOMASS	ALATERALE BIOMASS	TADPOLE BIOMASS	SALAMANDER BIOMASS
AMACULATA BIOMASS	0.000			
ALATERALE BIOMASS	0.000	0.000		
TADPOLE BIOMASS	0.097	0.051	0.000	
SALAMANDER BIOMASS	0.000	0.000	0.072	0.000

Table 4. July Sampling Correlations

	AIRTEMP	WATERTEMP	MAXDEPTH	PH	DO
AIRTEMP	0.000				
WATERTEMP	0.048	0.000			
MAXDEPTH	0.581	0.541	0.000		
PH	0.337	0.675	0.828	0.000	
DO	0.700	0.972	0.377	0.129	0.000
CONDUCTIVITY	0.867	0.399	0.707	0.190	0.189
SPECIES	0.773	0.938	0.123	0.874	0.569
PLOTS	0.682	0.520	0.004	0.951	0.334
INDIVIDUALS	0.172	0.282	0.642	0.839	0.706
DENSITY	0.139	0.023	0.426	0.917	0.578
RSYLVATICA SVL	0.089	0.261	0.688	0.758	0.895
HVERSICOLOR SVL	0.616	0.591	0.025	0.510	0.733
PCRUCIFER SVL	0.616	0.591	0.025	0.510	0.733
AMACULATUM SVL	0.206	0.430	0.548	0.658	0.515
ALATERALE SVL	0.506	0.748	0.539	0.073	0.003
TOTAL DENSITY	0.139	0.023	0.426	0.917	0.578
RSYLVATICA DENSITY	0.563	0.203	0.321	0.480	0.215
HVERSICOLOR DENSITY	0.616	0.591	0.025	0.510	0.733
PCRUCIFER DENSITY	0.616	0.591	0.025	0.510	0.733
AMACULATUM DENSITY	0.009	0.156	0.718	0.316	0.635
ALATERALE DENSITY	0.705	0.680	0.731	0.316	0.183
TADPOLE DENSITY	0.880	0.378	0.428	0.339	0.197
SALAMANDER DENSITY	0.008	0.158	0.680	0.198	0.520
SHANNON INDEX	0.482	0.693	0.265	0.912	0.526
RSYLVATICA BIOMASS	0.052	0.027	0.331	0.822	0.694
PCRUCIFER BIOMASS	0.616	0.591	0.025	0.510	0.733
AMACULATUM BIOMASS	0.616	0.591	0.025	0.510	0.733
ALATERALE BIOMASS	0.008	0.152	0.694	0.309	0.642
TADPOLE BIOMASS	0.414	0.114	0.340	0.615	0.323
SALAMANDER BIOMASS	0.006	0.152	0.662	0.230	0.569
AREA	0.656	0.592	0.003	0.736	0.481

	CONDUCTIVITY	SPECIES	PLOTS	INDIVIDUALS	DENSITY
CONDUCTIVITY	0.000				
SPECIES	0.967	0.000			
PLOTS	0.558	0.078	0.000		
INDIVIDUALS	0.756	0.109	0.545	0.000	
DENSITY	0.168	0.971	0.403	0.321	0.000
RSYLVATICA SVL	0.778	0.491	0.864	0.090	0.210
HVERSICOLOR SVL	1.000	0.052	0.027	0.476	0.630
PCRUCIFER SVL	1.000	0.052	0.027	0.476	0.630
AMACULATUM SVL	0.939	0.081	0.416	0.006	0.527
ALATERALE SVL	0.257	0.656	0.493	0.641	0.781
TOTAL DENSITY	0.168	0.971	0.403	0.321	0.000
RSYLVATICA DENSITY	0.028	0.656	0.228	0.805	0.058
HVERSICOLOR DENSITY	1.000	0.052	0.027	0.476	0.630
PCRUCIFER DENSITY	1.000	0.052	0.027	0.476	0.630
AMACULATUM DENSITY	0.932	0.588	0.881	0.113	0.262
ALATERALE DENSITY	0.277	0.615	0.807	0.404	0.325
TADPOLE DENSITY	0.020	0.550	0.275	0.921	0.190
SALAMANDER DENSITY	0.818	0.702	0.834	0.184	0.316
SHANNON INDEX	0.952	0.007	0.182	0.032	0.760
RSYLVATICA BIOMASS	0.367	0.992	0.369	0.284	0.009
PCRUCIFER BIOMASS	1.000	0.052	0.027	0.476	0.630
AMACULATUM BIOMASS	1.000	0.052	0.027	0.476	0.630
ALATERALE BIOMASS	0.932	0.612	0.856	0.123	0.258
TADPOLE BIOMASS	0.048	0.732	0.256	0.670	0.024
SALAMANDER BIOMASS	0.859	0.693	0.818	0.171	0.290
AREA	0.800	0.059	0.004	0.502	0.529

	RSYLVATICA SVL	HVERSICOLOR SVL	PCRUCIFER SVL	AMACULATUM SVL	ALATERALE SVL
RSYLVATICA SVL	0.000				
HVERSICOLOR SVL	0.962	0.000			
PCRUCIFER SVL	0.962	0.000	0.000		
AMACULATUM SVL	0.112	0.437	0.437	0.000	
ALATERALE SVL	0.976	0.910	0.910	0.480	0.000
TOTAL DENSITY	0.210	0.630	0.630	0.527	0.781
RSYLVATICA DENSITY	0.614	0.542	0.542	0.899	0.351
HVERSICOLOR DENSITY	0.962	.	0.000	0.437	0.910
PCRUCIFER DENSITY	0.962	0.000	.	0.437	0.910
AMACULATUM DENSITY	0.039	0.786	0.786	0.105	0.483
ALATERALE DENSITY	0.206	0.785	0.785	0.540	0.209
TADPOLE DENSITY	0.976	0.606	0.606	0.622	0.297
SALAMANDER DENSITY	0.092	0.674	0.674	0.161	0.367
SHANNON INDEX	0.279	0.170	0.170	0.015	0.559
RSYLVATICA BIOMASS	0.100	0.511	0.511	0.430	0.913
PCRUCIFER BIOMASS	0.962	.	0.000	0.437	0.910
AMACULATUM BIOMASS	0.962	0.000	0.000	0.437	0.910
ALATERALE BIOMASS	0.041	0.760	0.760	0.115	0.486
TADPOLE BIOMASS	0.514	0.539	0.539	0.955	0.490
SALAMANDER BIOMASS	0.073	0.679	0.679	0.154	0.412
AREA	0.872	0.005	0.005	0.426	0.647

	PCRUCIFER BIOMASS	AMACULATUM BIOMASS	ALATERALE BIOMASS	TADPOLE BIOMASS	SALAMANDER BIOMASS
PCRUCIFER BIOMASS	0.000				
AMACULATUM BIOMASS	0.000	0.000			
ALATERALE BIOMASS	0.760	0.760	0.000		
TADPOLE BIOMASS	0.539	0.539	0.627	0.000	
SALAMANDER BIOMASS	0.679	0.679	0.001	0.661	0.000
AREA	0.005	0.005	0.796	0.410	0.741

	AREA
AREA	0.000

	TOTAL DENSITY	RSYLVATICA DENSITY	HVERSICOLOR DENSITY	PCRUCIFER DENSITY	AMACULATUM DENSITY
TOTAL DENSITY	0.000				
RSYLVATICA DENSITY	0.058	0.000			
HVERSICOLOR DENSITY	0.630	0.542	0.000		
PCRUCIFER DENSITY	0.630	0.542	0.000	0.000	
AMACULATUM DENSITY	0.262	0.795	0.786	0.786	0.000
ALATERALE DENSITY	0.325	0.342	0.785	0.785	0.630
TADPOLE DENSITY	0.190	0.011	0.606	0.606	0.846
SALAMANDER DENSITY	0.316	0.863	0.674	0.674	0.002
SHANNON INDEX	0.760	0.752	0.170	0.170	0.325
RSYLVATICA BIOMASS	0.009	0.155	0.511	0.511	0.117
PCRUCIFER BIOMASS	0.630	0.542	0.000	0.000	0.786
AMACULATUM BIOMASS	0.630	0.542	0.000	0.000	0.786
ALATERALE BIOMASS	0.258	0.786	0.760	0.760	0.000
TADPOLE BIOMASS	0.024	0.002	0.539	0.539	0.636
SALAMANDER BIOMASS	0.290	0.826	0.679	0.679	0.001
AREA	0.529	0.391	0.005	0.005	0.822

	ALATERALE DENSITY	TADPOLE DENSITY	SALAMANDER DENSITY	SHANNON INDEX	RSYLVATICA BIOMASS
ALATERALE DENSITY	0.000				
TADPOLE DENSITY	0.511	0.000			
SALAMANDER DENSITY	0.818	0.795	0.000		
SHANNON INDEX	0.564	0.564	0.418	0.000	
RSYLVATICA BIOMASS	0.345	0.377	0.150	0.723	0.000
PCRUCIFER BIOMASS	0.785	0.606	0.674	0.170	0.511
AMACULATUM BIOMASS	0.785	0.606	0.674	0.170	0.511
ALATERALE BIOMASS	0.636	0.855	0.002	0.343	0.113
TADPOLE BIOMASS	0.371	0.030	0.694	0.864	0.093
SALAMANDER BIOMASS	0.758	0.825	0.000	0.409	0.132
AREA	0.955	0.460	0.749	0.171	0.437