Pre-logging Larval Amphibian Population Analysis in the Vernal Ponds of Upper Michigan

BIOS 569-Practicum in Aquatic Biology

Margaret Saunders

University of Notre Dame, Notre Dame, Indiana 46556

Sunny K. Boyd

2004

Abstract

Due to their biphasic lifestyle and permeable skins, amphibians are commonly used as bioindicators. Habitat alteration has been found to be one of the major causes of the current global amphibian decline. This study will examine the larval amphibian populations in four ponds in the Ottawa National Forest and three control ponds at the University of Notre Dame Environmental Research Center in Upper Michigan. The forest surrounding the vernal ponds in the Ottawa National Forest is designated for logging, two for clear-cutting and two for selective logging. The seven ponds yielded a total of 386 larvae belonging to four species collected during three sampling periods in May, June and July of 2004. Population density peaked in July for all the ponds but most had their highest species richness in June. Two of the Ottawa ponds were completely desiccated at the time of the July sampling. Significant correlations were found between the water temperature and the number of species as well as between water pH and tadpole density. After logging occurs, the data will used to compare to the 2001, 2002, 2003, and 2004 seasons to formulate a management plan for the Ottawa National Forest which takes amphibians into account.

Introduction

The success of an amphibian population is closely linked to the natural and manmade fluctuations occurring in the environment. Amphibians are sensitive to disturbances in both the terrestrial and aquatic habitats because of their biphasic life cycle. Throughout their lives, amphibians are exposed to water, sunlight, and soil conditions due to respiration through their moist permeable skin. Their eggs are likewise exposed because gelatinous membranes take the place of protective shells (Blaustein and Wake, 1995; Gibbons, 2000). Since most amphibians do not journey more than a few hundred meters in a lifetime, their survival as a population can be used to indicate the relative health of local conditions (Gibbons, 2000). Starting in 1990, awareness of the global decline of amphibians has spread and prompted research about the amphibians themselves and their usefulness as bioindicators (Blaustein and Wake, 1995). The global decline has been linked to habitat loss, pathogens, introduction of exotic species, pollution, pesticides, heavy metals, and increases in UV radiation (Blaustein, 1998). Many of scientists agree that the leading cause of amphibian decline is habitat loss (Gibbons, 2000).

Because the populations of amphibians naturally fluctuate, long-term analysis of their natural population changes must be gathered to compare to anthropogenic alterations. This experiment addresses a continuing yearly study, begun in 2001, which sought to gather data on amphibian populations in vernal ponds designated for logging and on the control ponds which will not be altered. In the study conducted in the summer of 2001 a total of 451 larval amphibians were collected belonging to four species. The following year only yielded 57 individuals belonging to six species while in 2003, 244 larvae were found belonging to five species. Across the seven ponds, species richness was found to be fairly consistent for the past three years (Boyd 2003). The larval amphibian density fluctuated across the ponds and the three years (Boyd 2003).

This project will then be carried on after the logging has occurred in the Ottawa National Forest to ascertain how the populations have been affected. The results of this study will be used to understand the population dynamics of the amphibian population in the Upper Peninsula of Michigan so that an appropriate management plan can be constructed for the Ottawa National Forest. An effective management plan needs to manage habitats with regard to both the population and the landscape (Semlitsch, 2000). Just planning for the protection of the basins of the wetlands will be meaningless if the surrounding terrestrial zone is ultimately destroyed (Gibbons, 2000). Management practices must be tailored to the local conditions which require long term studies of the environment. This study will provide valuable information on the effects that logging and selective logging have on amphibians, specifically tadpole abundance, development, and species diversity.

A Maryland study on mature amphibians in logged and burned forests found that the presence and abundance of amphibian populations was changed (McLeod and Gates, 1998). The loss of canopy cover resulted in negative effects on the amphibians because of fluctuations of air and soil temperatures, humidity, light intensity and wind speed (McLeod and Gates, 1998). The resulting loss of leaf litter and migration corridors in the study increased the probability of dehydration and death in young amphibians leaving their breeding ponds (McLeod and Gates, 1998).

Previous studies Conducted by Skelly in southeastern Michigan have shown that the natural local population extinctions and colonizations occur regularly. The influencing factors were the fluctuations in the hydroperiod and canopy cover of the ponds over successive years (Skelly 1999). Therefore, amphibians experiencing widespread habitat destruction may not receive the saving influx of new individuals and local populations may disappear. In another experiment, Skelly found that spring peeper, *Pseudacris crucifer*, and wood frog, *Rana sylvatica*, larvae grew more slowly in closed canopy ponds than in open canopy ponds (Skelly 2003). This supports the assumption that differences in development rates will be significant after logging occurs. In fact, and overabundance of canopy may also contribute to the extinction of local populations (Skelly 2002).

This study seeks to evaluate the effects that clear-cutting and selective logging have on the various larval amphibian populations found in the selected vernal ponds. The null hypothesis would be that no change is incurred by the larval amphibian populations when the surrounding forest is logged. It is expected that a correlation will exist between the larval amphibian population density and air temperature; water temperature, amount of dissolved oxygen; water conductivity; water pH; species richness (German and Slavick, 2002).

Materials and Methods

During this study, vernal pond characteristics and tadpole population data was collected from seven vernal ponds. In the Ottawa National Forest, the vernal ponds of OTT 2 and 3, which have been designated for clear-cutting in the future and OTT 5 and 6 which will be selectively logged were contrasted to the control vernal ponds of ND1, ND2, and ND3 found on the UNDERC property (Appendix A). During each of the three weeks the pond circumference, length, width, and maximum depth of each pond was measured and used to construct a grid around the pond perimeter consisting of 1-m^2 plots placed at zero (designated A) and one meter (designated B) from the shoreline. This was repeated for each week because of the occurrence of pond desiccation and wooden stakes were placed along the perimeter of the pond at ten meter intervals to serve as reference points.

Observations about the water color, turbidity, primary substrate, presence of fish, weather, nearness of forest edge, percent margin of emergent vegetation, and the species of the vegetation was noted each week. The air and water temperature was taken with a thermometer while the dissolved oxygen levels were measured with a YSI 55 dissolved oxygen meter. The conductivity was measured with the Hanna Instruments HI 9033 multi-range conductivity meter. The water pH was noted using a Hanna Instruments pHep 3 meter capture.

Each week, about one third to one forth of the plots from each pond were sampled using a random number table to pick the plots with a coin was flipped to determine whether plot A or B is sampled. Then a 31-gallon Rubbermaid bin with the bottom removed was quickly placed into the desired plot and held firmly against the substrate. Two small fish nets were used to remove any tadpoles into containers filled with pond water. The tadpoles were identified and measured back in the lab. Tadpoles from the separate ponds were identified by species and analyzed by measuring the tail length, snout-vent length, and total length with general calipers. After the data collection, they were released into their respective ponds. These materials and methods followed the previous years of study and were set forth by German and Slavick (2002).

Analysis of the data was carried out using SYSTAT with regression scatter plots. Graphs comparing the air and water temperature, amount of dissolved oxygen, water conductivity, maximum depth, water pH, and species richness with larval amphibian population density will be carried out and any correlation will be examined.

Results

During the summer of 2004, species richness (Fig. 1) increased from May to June in each of the ponds in the Ottawa National Forest. OTT3 and OTT6 could not be sampled in July due to complete desiccation. The pond with the highest species richness was OTT2 in which four species were collected in the

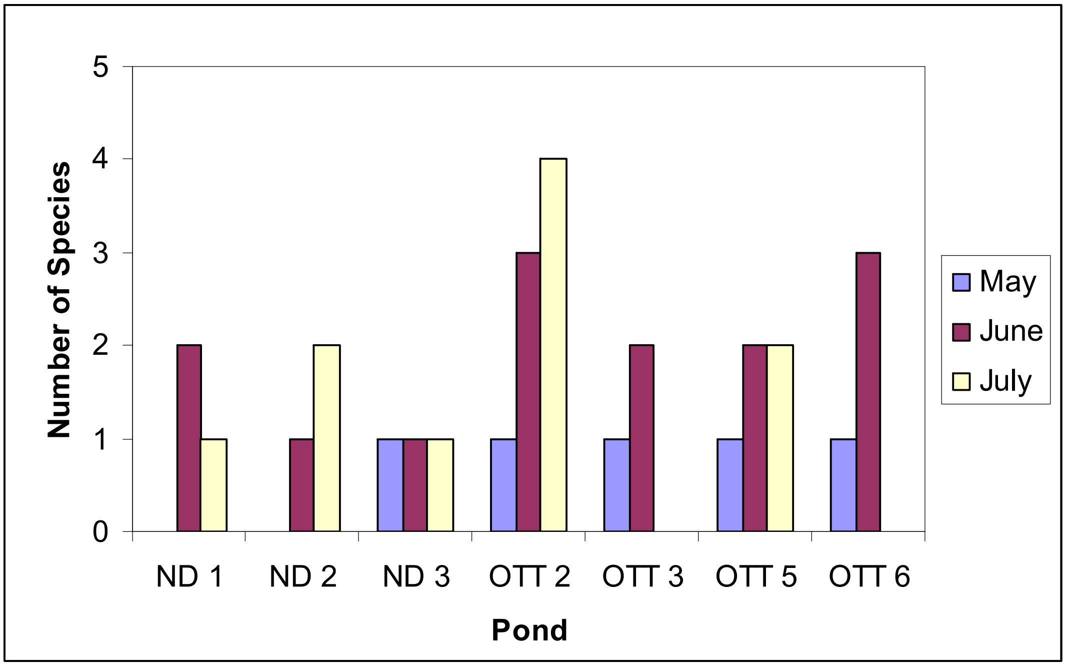


Figure 1: Species richness for amphibian larvae during 2004 sampling (May 5/27-6/2/04, June 6/22-6/24/04, July 7/12-7/13/2004).

July sampling. The May sampling produced only one species in all of the ponds, except ND1 and ND2, in which no larval amphibians were found. No fluctuation occurred in ND3 where one species was found during each sampling period.

A total of four species, *Psuedacris crucifer, Ambystoma laterale, Ambystoma maculatum,* and *Rana sylvatica,* were collected in May, June, and July of 2004 (Fig. 2). All four species were found in the July sampling of OTT2. The only species present in May was *R. sylvatica*. In June and July, *R. sylvatica* was the species which most consistently occurred in the ponds. Both salamander species, *A. laterale* and *A. maculatum*, were found in more ponds during June than July. Total desiccation of OTT3 and OTT6 in July eliminated sampling.

This study yielded a total of 386 amphibian larvae for the summer of 2004. The number of larval anurans collected increased in most of the ponds from May to July (Fig. 3). A slight decrease occurred from May to June in ND3. OTT6 had the highest number of individuals collected in one sampling as well as the largest total number of individuals over the summer even though desiccation prevented the July sampling. Overall, the June sampling had the highest total number of tadpoles collected from all the ponds. Most of the ponds in the Ottawa National Forest produced a higher total number of individual larval amphibians than ND1, ND2, and ND3. Only OTT3 was lower than ND2. The most abundant

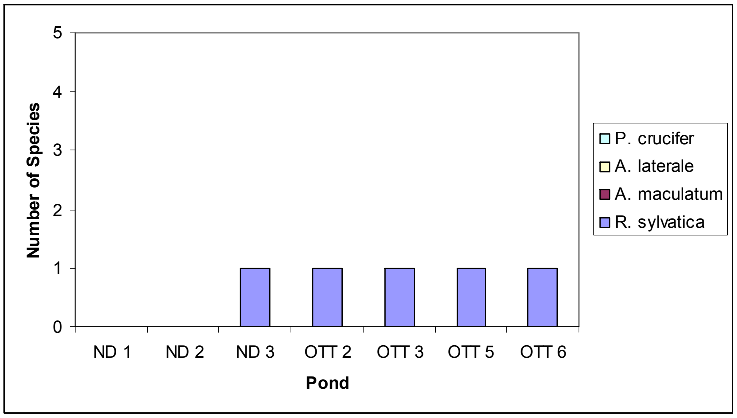


Figure 2A: May (5/27-6/2/04) species richness by species type.

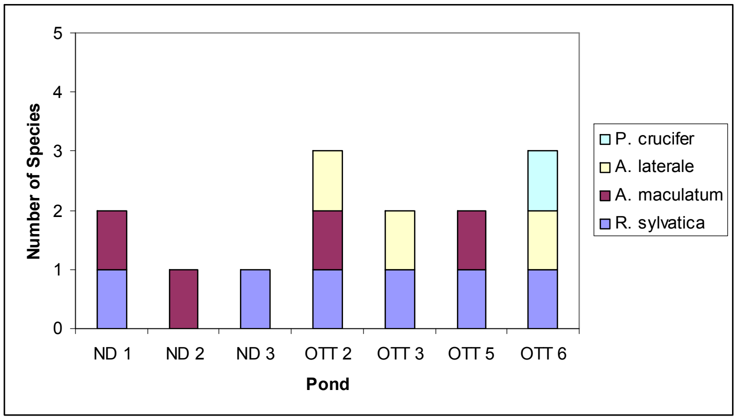


Figure 2B: June (6/22-6/24/04) species richness by species type.

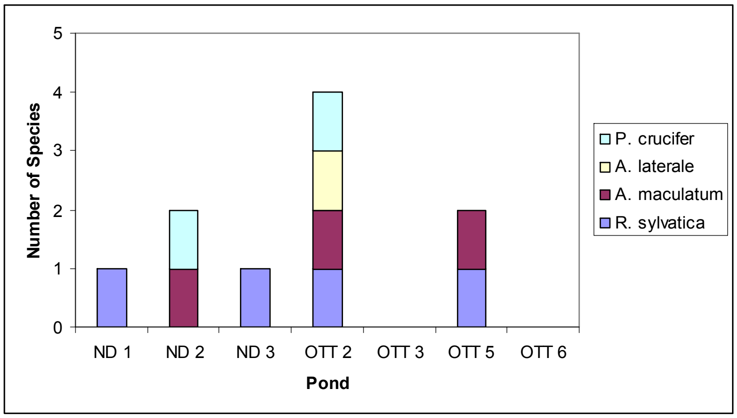


Figure 2C: July (7/12-7/13/04) species richness by species type.

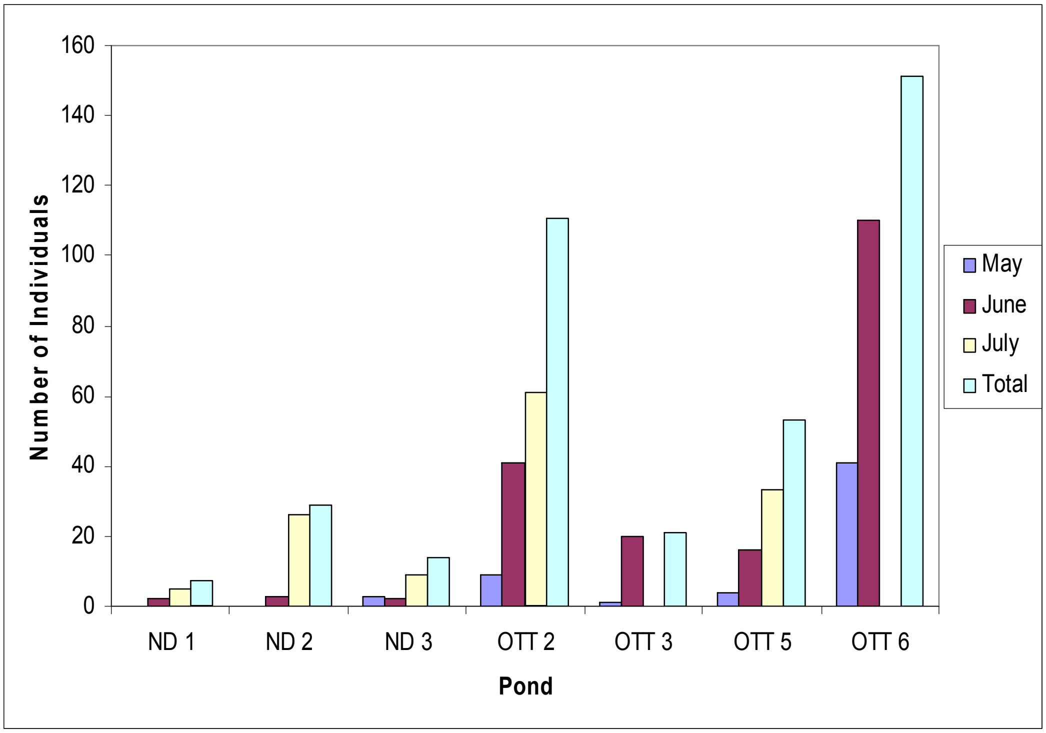


Figure 3: Number of larval amphibians collected for the 2004 season.

anuran collected was *R. sylvatica* while the most abundant urodele was *A. maculatum* (Fig. 4). Four out of the seven ponds maintained *R. sylvatica* as the most commonly collected species throughout the summer.

Relying on the individual number of amphibian larvae per pond to compare pond abundance ignores the differences in pond size and subsequently the varying numbers of plots sampled. Therefore, the monthly density for each pond was calculated by dividing the number of individuals in that pond by the number of plots sampled (Fig. 5). Population density showed a general increase over time. For each of the ponds not desiccated by July, the highest population density was consistently found in that month. Overall, the ponds in the Ottawa National Forest had greater densities than those on the UNDERC property. The pond with the highest monthly density was OTT2 which also had the highest average density. However, in June OTT3 and OTT6 had higher densities of larval amphibians.

The estimated biomass was found by summing the individual species' biomasses which were calculated by multiplying the species mean snout-vent length by the species density in each pond. Figure 6 confirms the trend observed in figure 5 of the increasing abundance of larval amphibians in ponds still holding water. OTT6 and OTT3 lack July biomass results due to desiccation. In June, the Ottawa ponds had greater amphibian larval biomasses than the UNDERC ponds. OTT2 had by far the largest estimated biomass at the conclusion of the study.

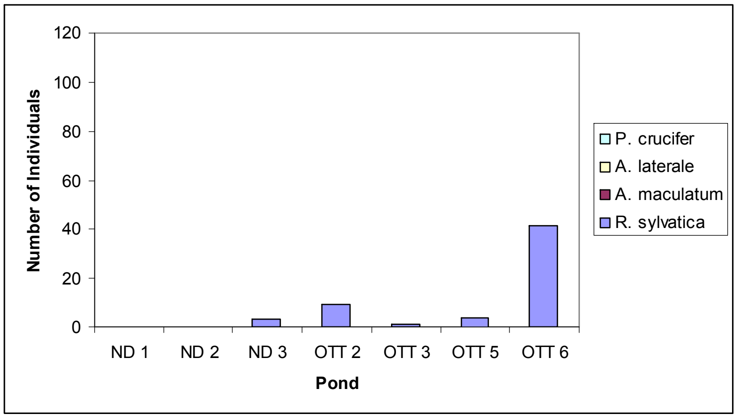


Figure 4A: May 2004 collection of the number of individual amphibian larvae by species.

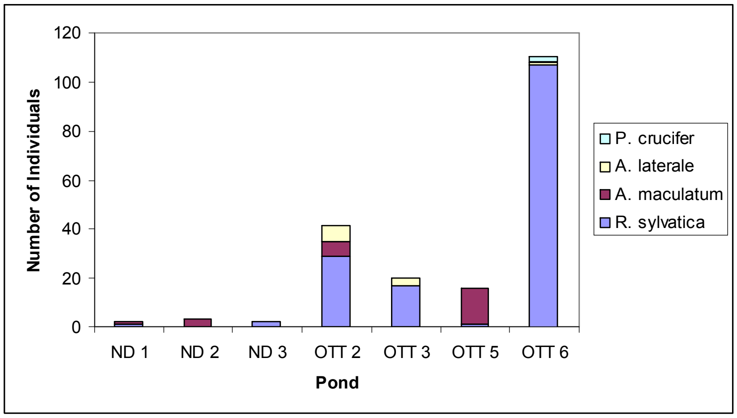


Figure 4B: June 2004 collection of the number of individual amphibian larvae by species.

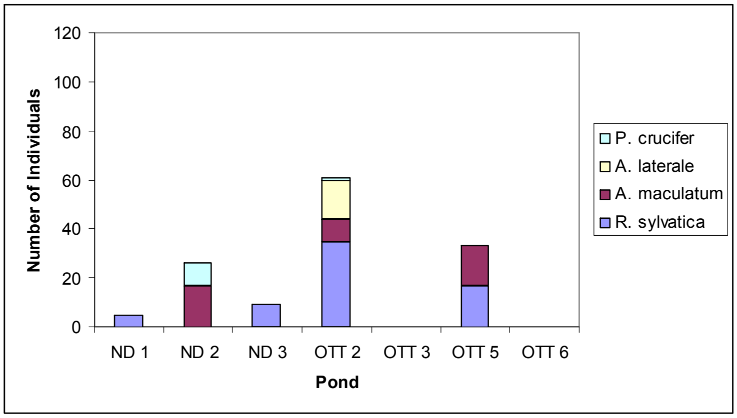


Figure 4C: July 2004 collection of the number of individual amphibian larvae by species.

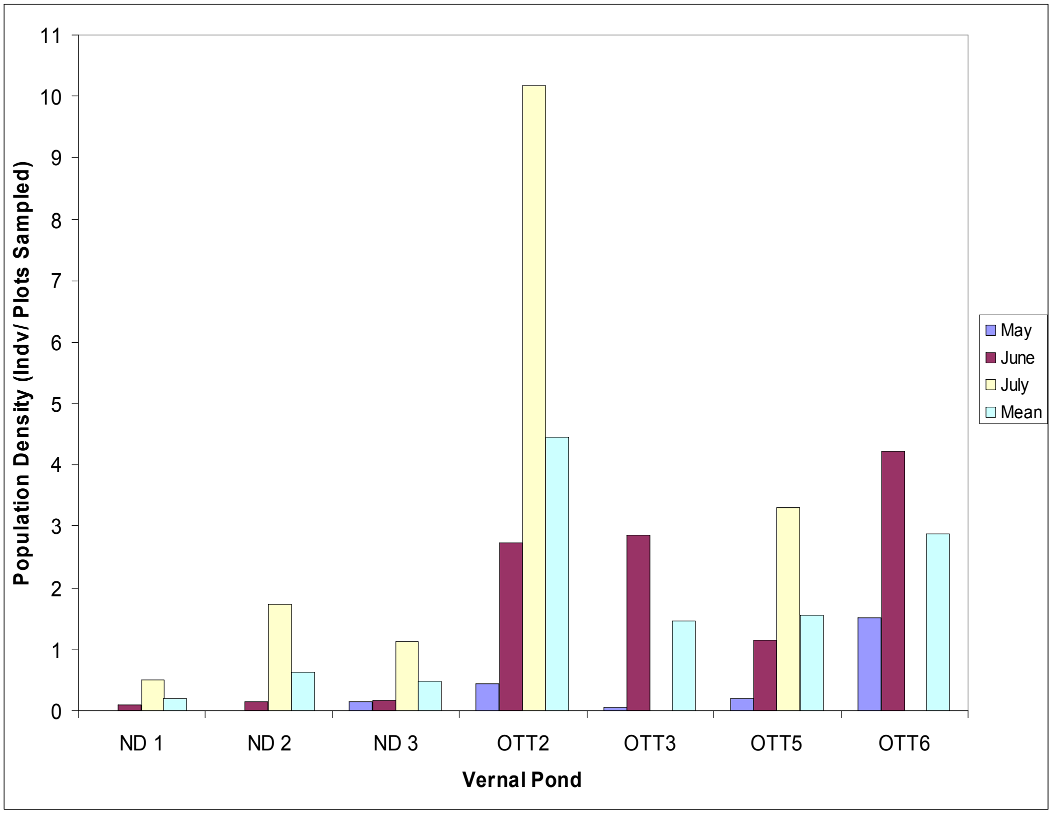


Figure 5: 2004 amphibian larvae population density (number of individuals collected / number of plots sampled).

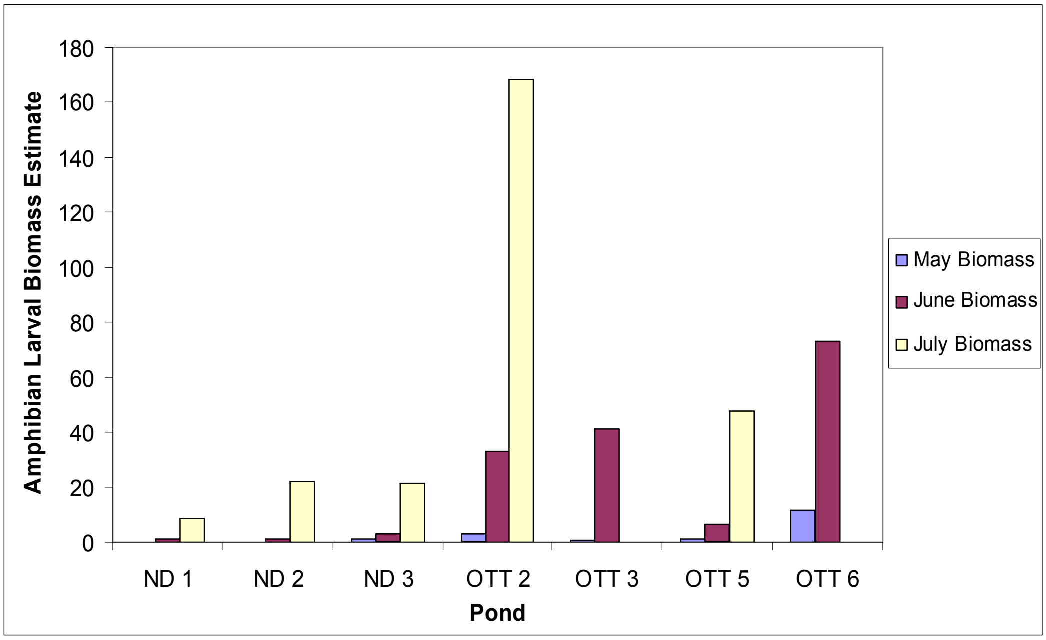


Fig. 6: 2004 estimate of amphibian larval biomass (sum of each species biomass by pond, species biomass determined by the product of mean species snout-vent length and species density).

In June, most ponds had a higher tadpole biomass than salamander biomass with the exception of OTT5 and ND2 (Fig. 7). The estimated salamander, *A. maculatum* and *A. laterale*, biomass in July was greater than the tadpole, *R. sylvatica* and *P. crucifer*, biomass in ND2 and OTT5.

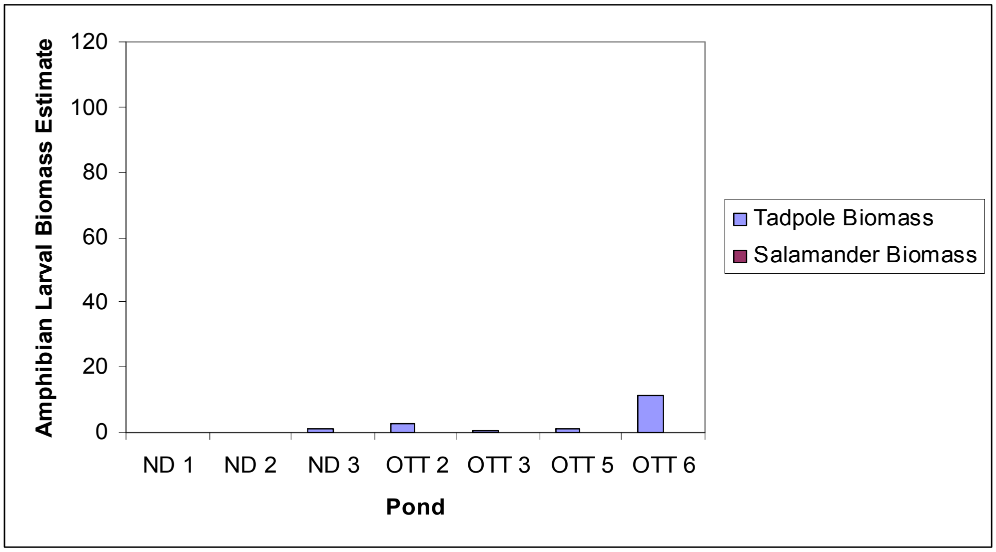


Figure 7A: May comparison of the estimated biomass of tadpoles and salamanders. OTT3 had a small tadpole biomass.

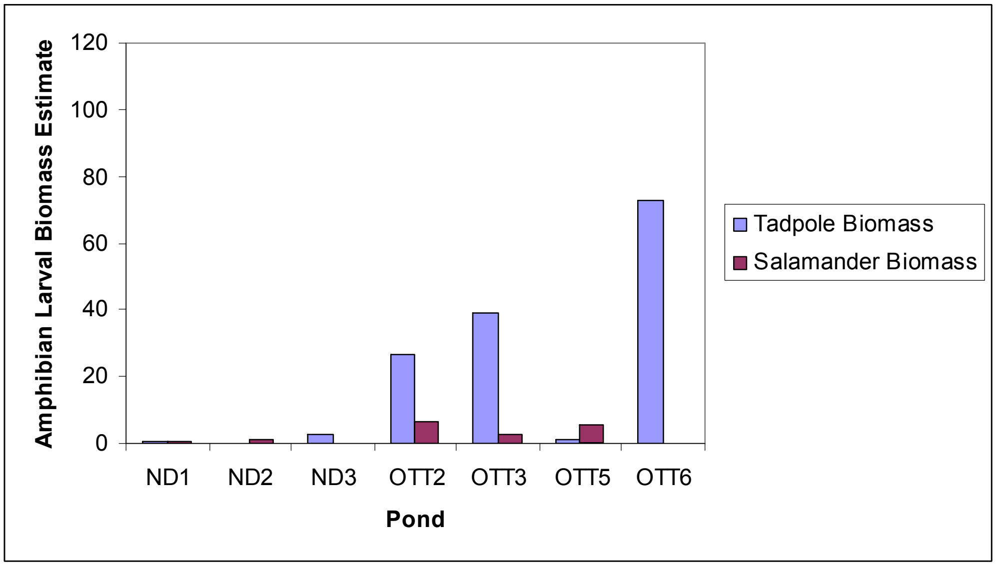


Figure 7B: June comparison of the estimated biomass of tadpoles and salamanders. ND1 had a small biomass for tadpoles and salamanders.

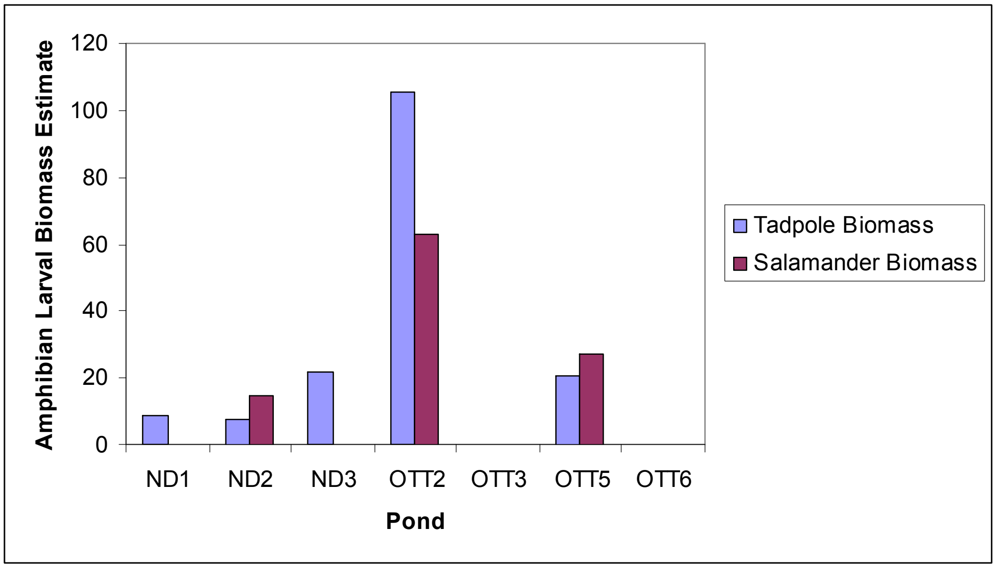
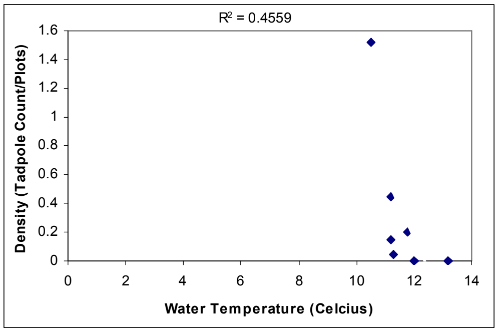


Figure 7C: July comparison of the estimated biomass of tadpoles and salamanders. OTT3 and OTT6 were completely desiccated.

Correlations were examined for May to uncover any relationships between the site and larval characteristics. The characteristics chosen for analysis were larval amphibian population density and water temperature; air temperature; water pH; water conductivity; amount of dissolved oxygen; maximum depth; perimeter; number of tadpoles; species richness and water temperature. The significant correlation (P=0.031) found in Figure 8 was between water temperature and the number of species found in each pond (Pearson's correlation table Appendix B). A positive correlation was found between the pond perimeter and the number of tadpoles (P=0.044; 8H). There was a positive trend observed between perimeter and larval amphibian density (P=0.061; 8G).

The equivalent correlations carried out for the June site characteristics and larval characteristics did not yield any significant relationships (Pearson's correlation table Appendix B). The potential relationships of the particular combinations are shown in Figure 9A-I.

For the July sampling, one significant correlation existed when the larval amphibian population density and water temperature; air temperature; water pH; water conductivity; amount of dissolved oxygen; maximum depth; perimeter; number of tadpoles; species richness and water temperature were analyzed (Pearson's Correlation table Appendix B). A significant correlation (P=0.025) is shown between water pH and tadpole density (Fig. 10C).



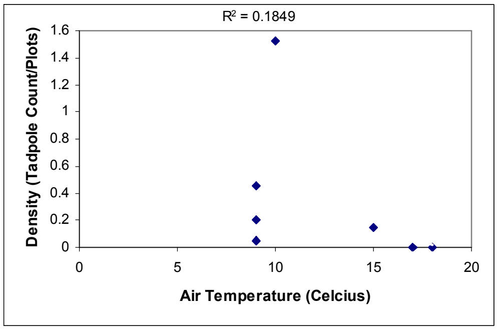
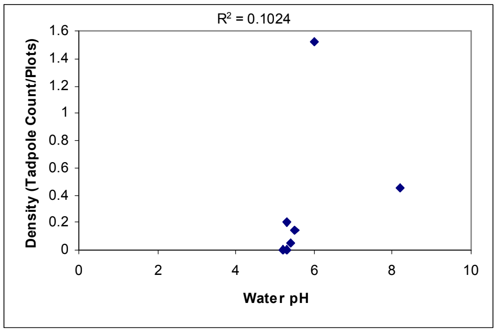


Figure 8A

Figure 8B



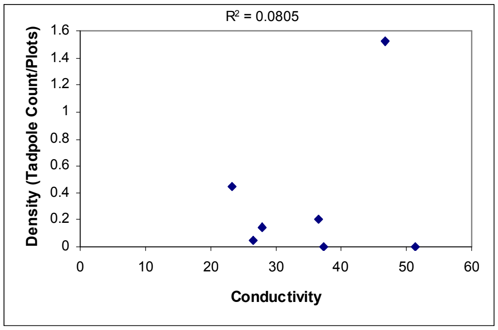
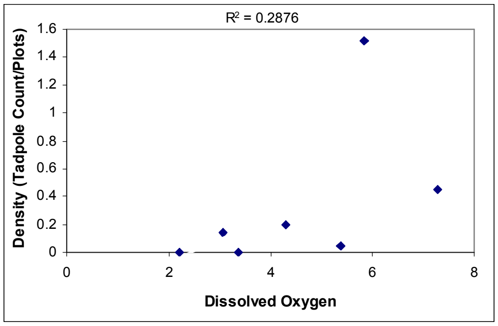


Figure 8C

Figure 8D



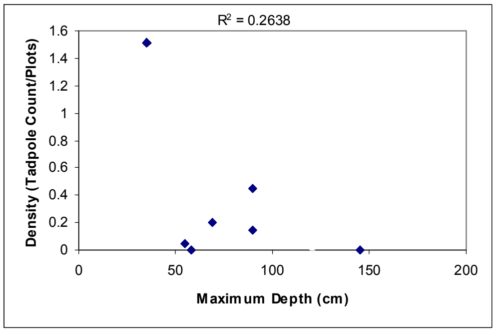


Figure 8E

Figure 8F

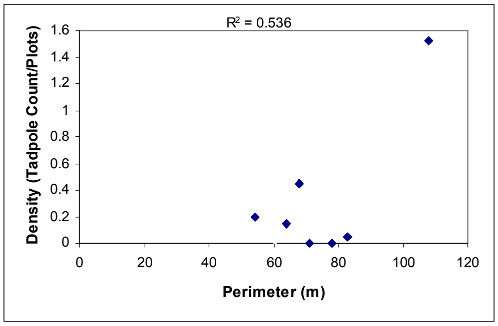


Figure 8G

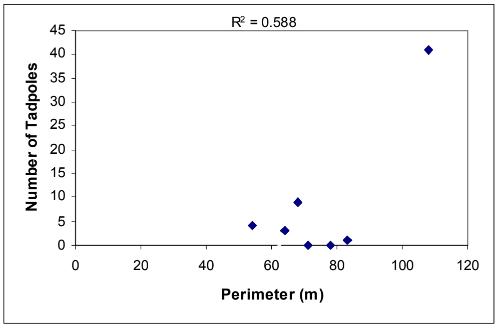


Figure 8H

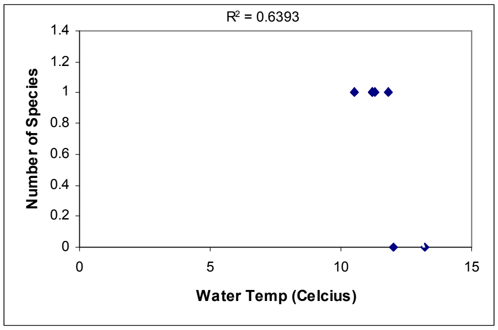


Figure 8I

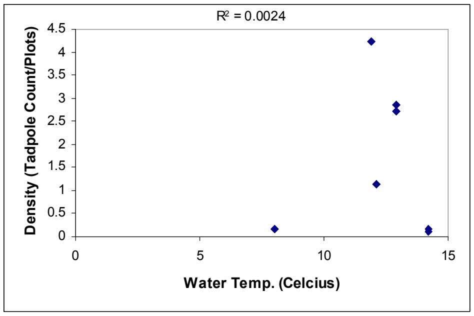


Figure 9A

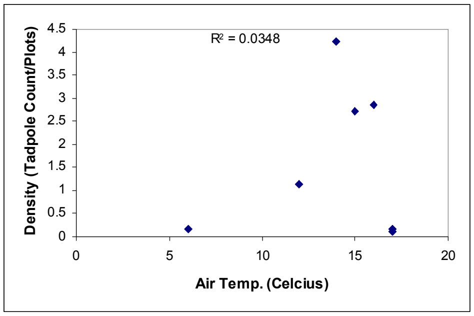


Figure 9B

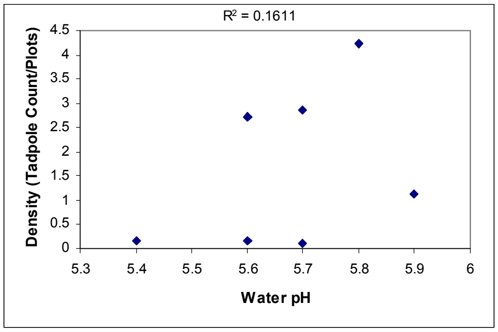


Figure 9C

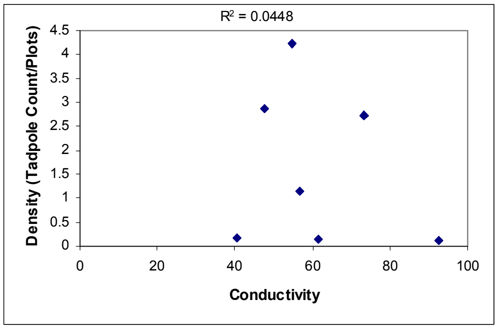


Figure 9D

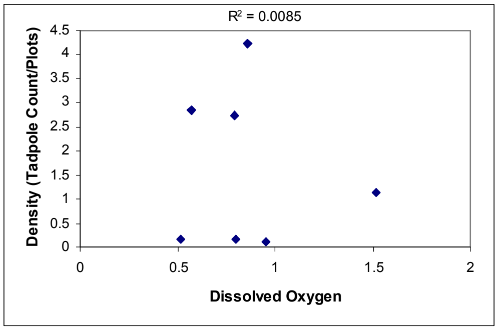


Figure 9E

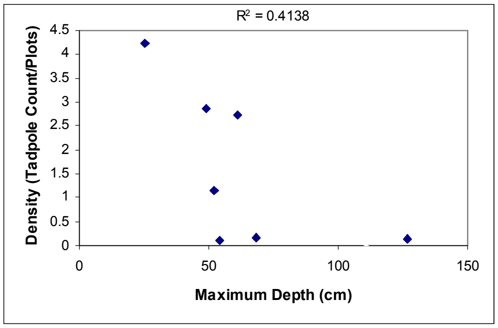


Figure 9F

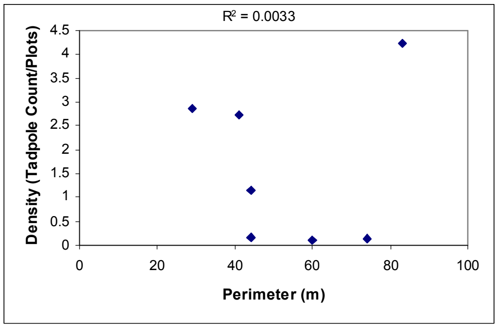


Figure 9G

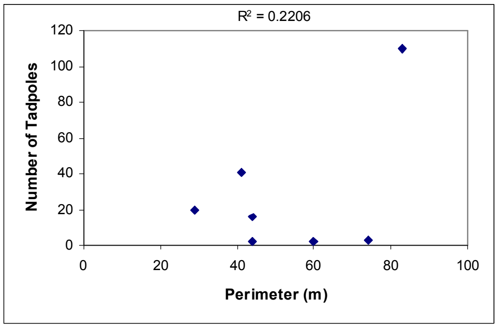


Figure 9H

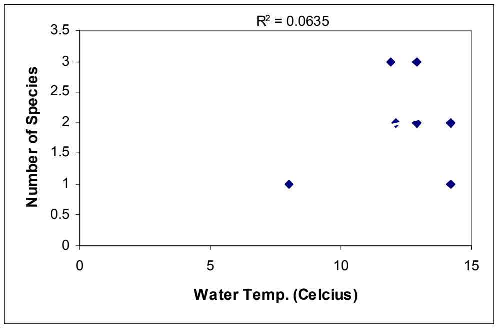


Figure 9I

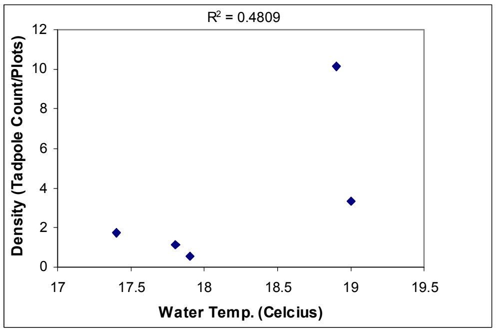


Figure 10A

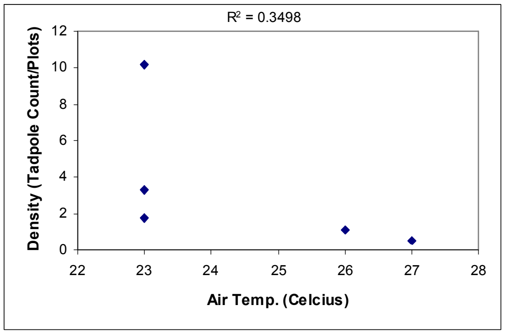


Figure 10B

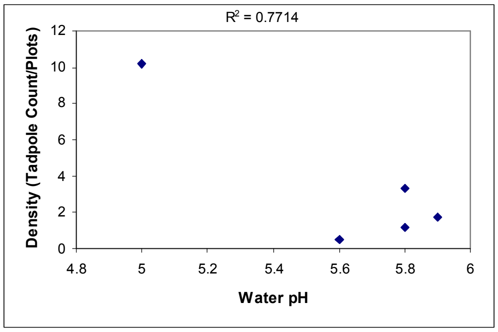


Figure 10C

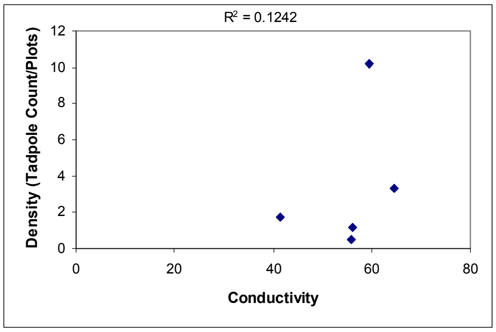


Figure 10D

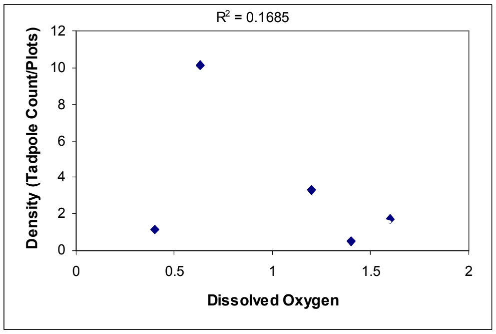


Figure 10E

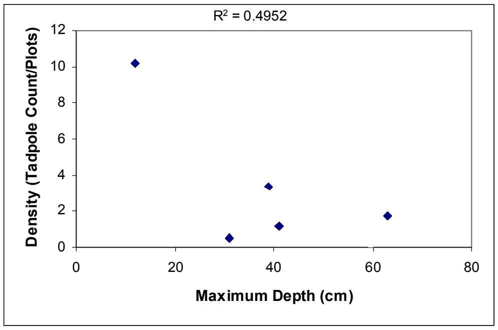


Figure 10F

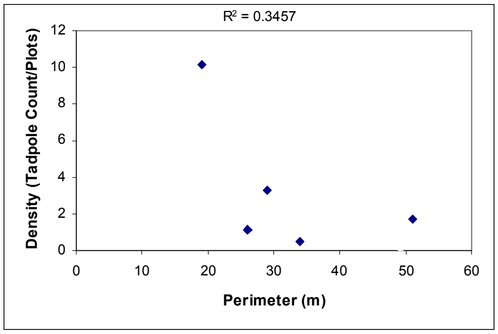


Figure 10G

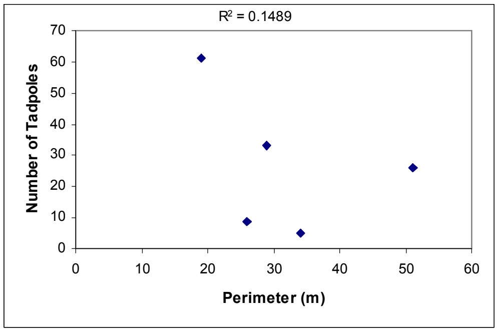


Figure 10H

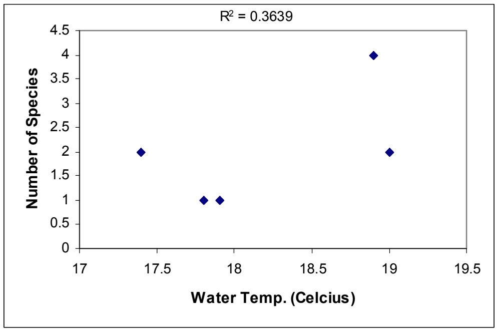


Figure 10I

In comparison with the last three years of study the biodiversity of each of the seven ponds is shown in Figure 11. A Shannon-Wiener Index is used for the calculation of biodiversity and a relatively high number is an indication of a greater number of species along with an even distribution of those species found yearly sampling of the pond.

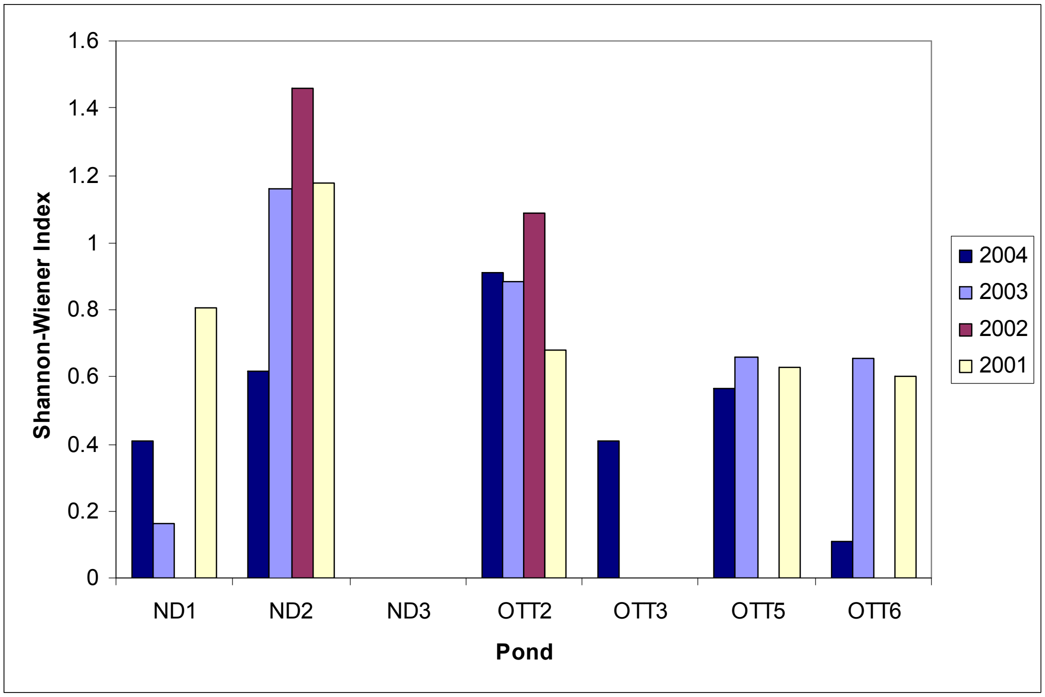


Figure 11: Shannon-Wiener index of yearly biodiversity for the seven ponds. An index of zero indicates only one species present.

Discussion

This portion of the ongoing study was designed to gather data on amphibian species diversity and abundance for comparisons to future years which will record the impact clear-cutting and selective logging practices have on the amphibian populations in upper Michigan. Different species are known to prefer various environmental conditions. Since all ponds in this study are classified as closed canopy ponds the abundance of *R. sylvatica,* a species noted for its ability to succeed in closed canopy (Skelly et al. 2002), is not surprising. During the three sampling periods in the 2004 study, *R. sylvatica* was the most abundant amphibian species found in most ponds. In years preceding the logging, the study will see if *R. sylvatica* continues to dominate or whether a species which thrives solely in open canopy ponds will supplant it. Previous studies have also found that open canopy ponds support higher species diversity.

After the logging occurs some drastic changes may be in store for the Ottawa ponds. The ponds will be exposed to an increase in UV radiation which has been cited as one of the causes for global amphibian population declines. In 2004, only two of the ponds, found in the Ottawa National Forest, were desiccated during the study. The forest completely surrounded and shaded the ponds trapping in moisture and retaining that moisture in the leaf litter. With the advent of logging, an increase in the number of desiccated ponds could follow the removal of the protective canopy cover. Amphibian species with rapid larval developments would be favored under these conditions. OTT3 and OTT6 had the highest population densities in June but by July they were no longer holding water. The amphibian larvae had to have either developed enough to leave the pond or perish as the pond dried up. Any change in dissolved oxygen due to the loss of leaf litter should be examined for impact on the development of the larvae.

Amphibians are excellent bioindicator species because they can provide information on the health of two habitats. The aquatic and terrestrial environments both have to be intact in order for a species to survive. The amphibian populations will have to contend with changes throughout their lifecycles in the logged locations. However, amphibian populations naturally fluctuate (Skelly 1999). In comparison to the past three years of study, there was a shift for the 2004 study in amphibian density. Instead of finding the highest densities in the UNDERC ponds, 2004 yielded much higher densities of larvae in the Ottawa ponds. Assertions made about the effects that logging had will have to be careful not to mistake more natural fluctuations in the populations.

However, like last year, the highest densities of larval amphibians per pond were found in the July sampling. By July, the tadpoles were sprouting legs and arms to escape the increasing desiccation of the ponds.

The forest around the ponds in the Ottawa National Forest designated for logging are made of maple trees nearing the end of their life spans. Without the logging, the forest would experience a habitat shift when the trees sickened and died. Already there were recently downed trees one of which fell between the May and June sampling into OTT6. However, the gradual turnover of the forest contrasts sharply with the abrupt and drastic changes the amphibian populations will experience with the logging. The data gathered in this ongoing study will be employed in the formation of the forest management plans to better provide for the local amphibian populations in the advent of logging. With the global decline of amphibians attracting attention worldwide, the studies undertaken have largely been focused on adult amphibians. This study will seek to provide valuable information for the management of larval amphibians as well.

Acknowledgments

Thank you to Dr. Sunny Boyd. Her experience on this project was invaluable and her help was always appreciated. Thanks also to Al Klein, my partner who shared in the triumphs and travails. To Dr. Kerry Yurewicz, thanks for the identification tips. To the UNDERC class of 2004, thank you for sharing in the enthusiasm for the hunt for tadpoles in the Ottawa National Forest. Thank you to Mary Pendergast and Andy Borden for their navigation skills. A special thank you is for Mrs. Belovsky who saved us the long walk back. Also gratitude is given to the US Forest Service for allowing research to be conducted within the Ottawa National Forest. Thank you to The Bernard J. Hank Family Endowment who's funding made this experience possible.

References

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

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

Boyd, S. K. 2003. Final report 2003. Unpublished

German, C. and J. Slavick. 2002. Characterization of Vernal Pond Amphibian Populations in the Ottawa National Forest Prior to Clear Cutting and Selective Thinning. Unpublished.

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.

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.

Semlitsch, R.D. 2000. Principles for management of aquatic-breeding amphibians. Journal of Wildlife Management 64: 615-631.

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

Skelly, D. K., E. E. Werner, and S. A. Cortwright. 1999. Long-term distributional dynamics of a Michigan amphibian assemblage. Ecology 80: 2326-2337.

Slavick, J.L., 2002. Population survey of amphibians in vernal ponds of the upper peninsula of Michigan prior to logging of surrounding forest. Unpublished.

Appendix A.

(map)

Appendix B1: May Sampling Correlation

	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

Appendix B2: May Sampling Correlations

	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 maculatum							
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- 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

Appendix B3: July Sampling Correlations

	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