Characterization of Vernal Pond Amphibian Populations in the Ottawa National Forest Prior to Clear Cutting and Selective Thinning

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Abstract

Four vernal ponds in the Ottawa National Forest serve as the experimental regiments while three ponds on University of Notre Dame Environmental Research Center (UNDERC) property serve as a control regiment. Each pond was sampled during three separate sampling periods throughout the summer: May 30 – June 2, 2002, June 25 – 26, 2002, and July 15 – 16, 2002. Significant correlation and ties between air temperature and larval amphibian density, maximum vernal pond depth and larval amphibian density, conductivity and larval amphibian density, and larval amphibian density and species richness have been illustrated through this year's data. Consequently, as air temperature increases density decreases, as maximum pond depth increases density increases, as conductivity increases density decreases, and as density increases species richness increases. Such correlating and significant environmental factors that did not appear to be relevant in last year's study may now provide a series of benchmarks to which change can be compared.

Introduction

Amphibian populations play a vital role in both aquatic and terrestrial environments due to their diversity and abundance, however, they are declining at alarming rates worldwide (7). Concern is building as to why amphibians are dying off and what this may mean to human populations (6, 9, 12). Since they reside in two separate environments, have highly permeable unprotected skin, and eggs that lack hard outer shells and an amniotic sack, amphibians have become valuable indicators of early stage environmental change (1, 2). With such physical attributes, amphibians are highly sensitive to minor changes in climate, ultraviolet radiation (UV-B), predation, pollutants and toxins, diseases, and environmental modifications (1, 2, 4, 9, 10, 12).

The Ottawa National Forest, located in northern Wisconsin and Michigan's Upper Peninsula, is planning on clear cutting and selectively thinning sections of forest. In accordance with the National Forest Management Act of 1976, however, national forests are required to maintain viable numbers of all vertebrate species within their land (11). The effects of clear cutting upon vertebrate populations in the Ottawa National Forest ecosystem can be compared to regionally similar ecosystems and amphibians will be used as a marker species for evaluation of environmental alterations that may have significant ecosystem impacts. Vernal ponds on the Ottawa National Forest and a number of control ponds on the University of Notre Dame Environmental Research Center (UNDERC) will be the primary areas of investigation. Since the cutting has yet to occur, data collected in 2002 in conjunction with data collected in 2001 will create a baseline against which post-logging populations and environments can be compared.

Removal of vegetation and canopy cover surrounding the vernal ponds may have a dramatic effect upon the environment. Premature seasonal evaporation of many vernal ponds on the property due to increased sunlight exposure would present large problems for amphibian populations that annually use a pond as a breeding ground. If the pond dries earlier than the time of larval formation, the young amphibian offspring will have no place to develop and perish as a result. In addition, if species A successfully reproduces prior to the desiccation of the pond but species B does not, a disproportionate number of species A will inhabit the area in regard to species B.

Increased sunlight exposure also leads to an increase in UV-B radiation, which directly correlates with amphibian population decline through lowering the rate of reproduction, increasing infant mortality, and altering both rate and morphology of physical development (1, 2, 4). It should be noted that increased exposure to UV-B radiation also leads to physical debilitations such as eye damage, increased cancerous tumor frequency, and reduced immunosuppression, all of which lead to premature death, increased predation, and higher susceptibility to disease.

Effects upon aquatic environments aside, clear cutting and thinning will create pronounced changes in the vegetation surrounding the vernal ponds. While nearly all amphibians are born and develop in aquatic environments and return to breed, a significant portion migrate to the surrounding terrestrial environments during their non-breeding season (9, 11). Less surrounding hardwood and shrub vegetation may lead to a decrease in habitat diversity, cover, and organic matter and an increase in predation. In addition a decrease in vertebrate populations, which may have symbiotic relationships with the amphibian populations, would also be expected.

It is unknown as of yet what the actual results of clear cutting and thinning around vernal lakes in the Ottawa National Forest will be, the above hypotheses are based upon past studies. While this study will eventually cover the environmental changes following vegetation removal, for now the emphasis lies on collecting data regarding amphibian population diversity, population numbers, and natural rates of population growth and decline.

Materials & Methods

Vernal Pond Characterization

Four ponds in the Ottawa National Forest and three ponds at University of Notre Dame Environmental Research Center (UNDERC) were used for amphibian population sampling and characterized through multiple tests and measurements once at the beginning and end of the research period. Initially the circumference, length, width, and maximum depth of each pond was measured to create a numbered grid sectioning the perimeter of each pond into one meter square plots zero and one meter from the shoreline. Wooden stakes were placed 10 meters around the perimeter of each pond for reference points during sampling. Qualitative observations at each pond were water color, water turbidity, primary substrate, and the presence of fish. Additional observations regarding weather, distance from shoreline to forest edge, percent margin of emergent vegetation, and species of emergent and surrounding vegetation were also made.

Locations of each vernal pond were taken in UTM coordinates through the use of a Garmin 12 global positioning system (GPS). Ambient air and water temperatures were taken using a standard alcohol thermometer. Dissolved oxygen (DO) was measured with a YSI 55 dissolved oxygen meter, conductivity with a Hanna Instruments HI 9033 multi-range conductivity meter, and pH with a Hanna Instruments pHep 3 meter. The measurements for each of these three tests were taken at five randomly selected points around each pond.

Larval Amphibian Sampling

At least twenty percent of the shoreline area of each pond was sampled. Each meter plot around the pond was given a number and those plots zero to one meter from the shore were assigned "A" and those plots one to two meters from the shore were assigned "B". Plot number sampled was determined using a random number table and "A" and "B" were determined through a coin flip. Due to vernal pond desiccation throughout the summer, perimeter grids were updated during every sampling. Sampling of ponds on UNDERC property occurred on 2 June, 24 June, and 15 July, 2002. Sampling of ponds in the Ottawa National Forest occurred on 30 May, 25 June, and 16 July, 2002.

Once sample plots were determined, a 31 – gallon modified Rubbermaid bin with the bottom removed, measuring 0.876 m long, 0.508 m wide and 0.425 m deep, was placed into the plot and held securely to the bottom of the pond, preventing any amphibian larvae from escaping. The bin was swept thoroughly with a small fish net and the contents placed into a bucket for analysis. This process was completed three times per plot and all larval amphibians captured were taken back to the lab in labeled Ziploc containers filled with pond water. If adult amphibians were captured, species and quantity were noted and promptly returned to the pond following sampling.

Larval Amphibian Analysis

All captured larval amphibians were returned to the lab and placed into labeled tanks for quantitative analysis. Upon identification using the USGS Patuxent Wildlife Research Center dichotomous key (http://www.pwrc.usgs.gov/tadpole/), each larval amphibian was measured using General calipers. For Anurans, tail length, torso length, and total length was recorded. For Caudata, total length was recorded. Following identification and measurement larval amphibians were returned to their vernal pond of origin.

Drift Fence Pilot Experimentation

UNDERC numbered vernal pond two was used for a drift fence experimentation trial lasting forty-eight hours. 175 meters of drift fencing were used with bucket traps placed flush with the fence every 20 meters. Traps were checked every 12 hours and all catches recorded.

Data Analysis

Bar charts were created using Microsoft Excel, regression scatter plot graphs were created using Systat, and Pearson correlations were conducted using SPSS. To determine larval amphibian density, the total number of individuals captured at each vernal pond was divided by the number of plots sampled. Standard deviation was calculated for each density determined. Pond size (m^2) was determined using the radius formula, A = π*a*b, where a and b are length and width radii.

Results

Species richness in all of the vernal ponds, both control (UNDERC) and experimental (Ottawa National Forest), varied greatly among sampling times and ponds (Fig. 1). The greatest diversity was found in ND-N2 during the 6/25/02 – 6/26/02 sampling period, which was also the most species rich pond over the course of all sampling periods. Except for V.P. 2, low species richness relative to ND-N2 was found in the other ponds. Richness tended to be highest during the second

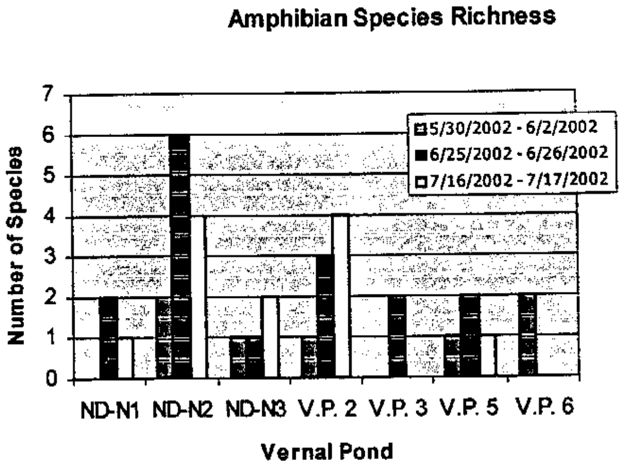
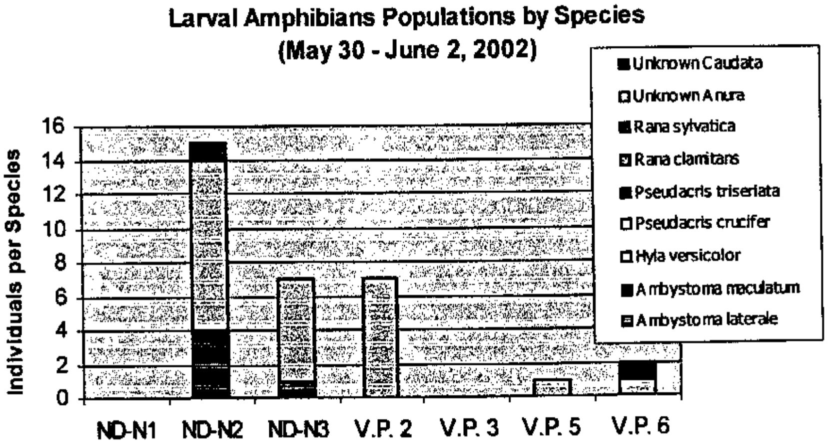


Figure 1 – Total Richness of each vernal pond during the three sampling periods.



sampling period and lowest during the first sampling period, indicating that mid-June is the most common spawning time. Compared to data collected summer 2001, overall species richness increased by two species in ND-N2, one species in ND-N3, two species in V.P. 2, one species in V.P. 3, and decreased by one species in ND-N1. There were three collection periods summer 2002 and two collection periods summer 2001.

Early in the summer it appears that *Rana sylvatica* is the most abundant species with a large number of individuals unidentified anurans and caudata. ND-N2 has the largest amphibian community while ND-N3 and V.P. 2 each follow with roughly one-half that population size. During the second sampling period the number of *Rana sylvatica* captured increase from 5 to 25, with 8 individuals in ND-N2 and 17 individuals in V.P. 2. *Hyla versicolor* is the second most abundant

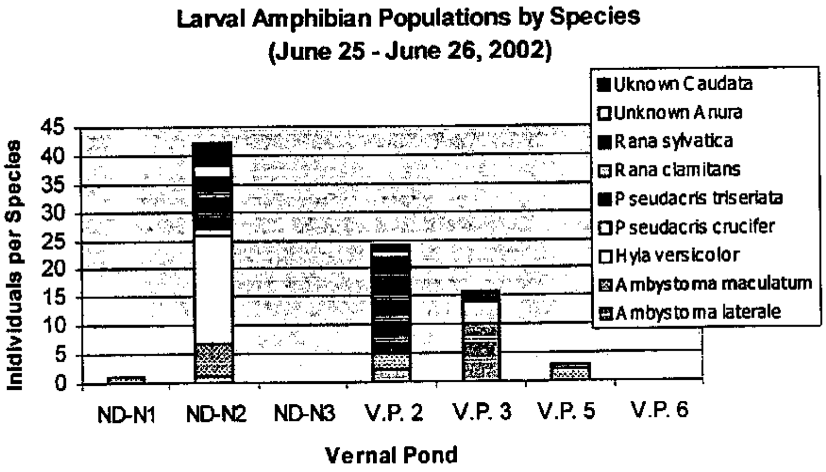


Figure 3 - Total number of individuals of each species captured at each vernal pond during the second sampling period.

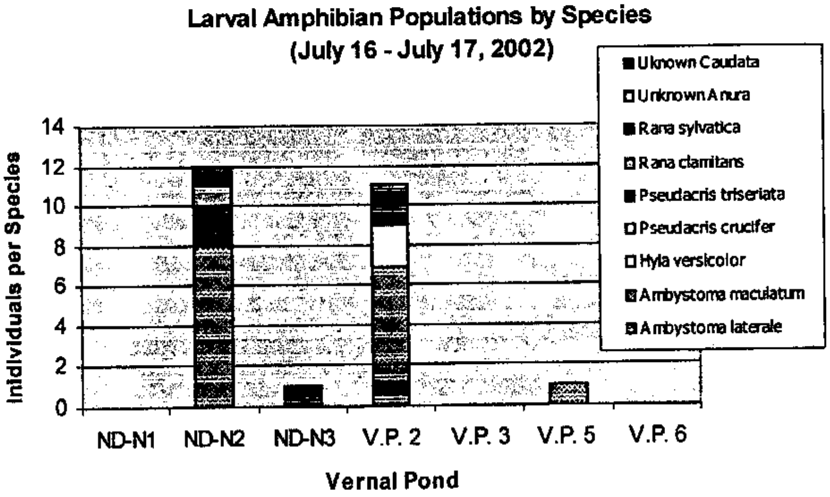


Figure 4 - Total number of individuals of each species captured at each vernal pond during the third sampling period.

species during the second sampling period with nineteen individuals in ND-N2. *Pseudacris triseriata* is the most widespread species with populations in ND-N1, ND-N2, V.P. 2 and V.P. 5.

By the final sampling period *Rana sylvatica* (4 individuals) is no longer the most abundant species but instead replaced by *Pseudacris triseriata* (14 individuals) (Fig. 4). Both *Rana Sylvatica* and *Pseudacris triseriata* have populations in 3 ponds; ND-N2, ND-N3, and V.P.2, and ND-N2, V.P. 2, and V.P. 5 respectively. In addition, 8 of 10 adults captured throughout the summer were *Rana sylvatica*.

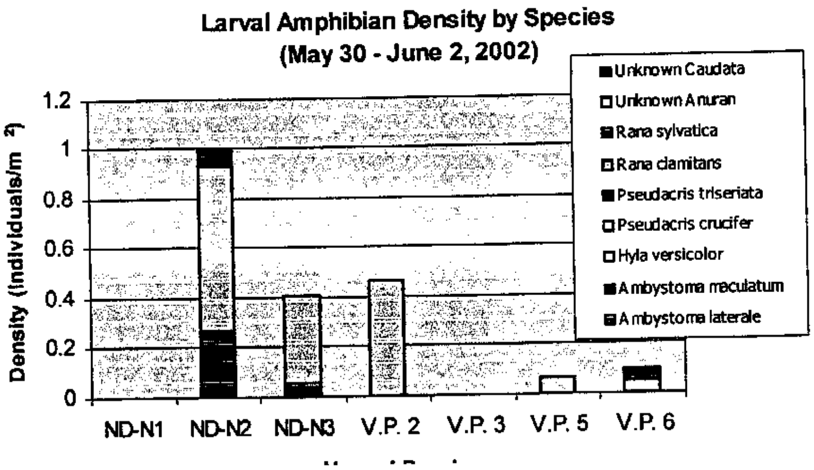


Figure 5 – Density of larval amphibian species at each vernal pool during the first sampling period.

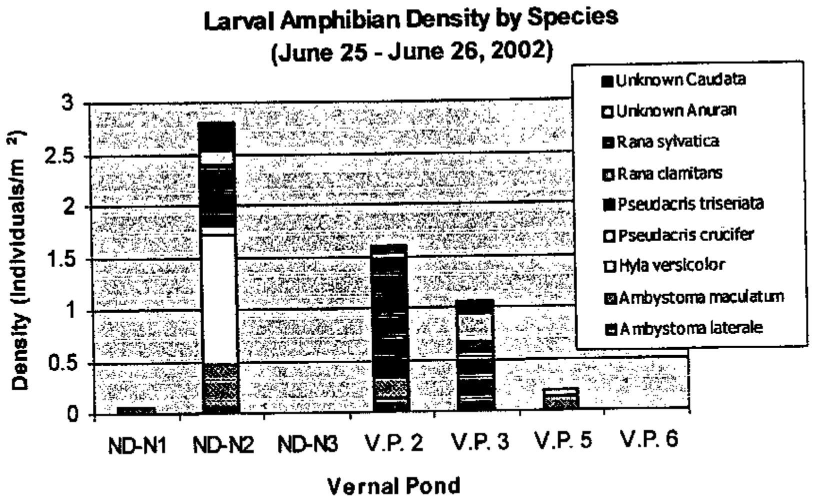


Figure 6 - Density of larval amphibian species at each vernal pool during the second sampling period.

ND-N2 and V.P. 2 had the most abundant amphibian populations throughout the summer, with ND-N2 having a cumulative total of 69 individuals captured and V.P. 2 having a cumulative total of 42 individuals captured. Despite an increase in diversity over last years sampling, the total number of individuals captured decreased dramatically, even with 3 sampling periods as opposed to 2. Approximate values for individuals caught over 3 sampling periods this summer are 1 for ND-N1, 69 for ND-N2, 8 for ND-N3, 42 for V.P. 2, 16 for V.P. 3, 5 for V.P. 5, and 2 for V.P 6. Approximate values for individuals caught over two sampling periods last summer are 30 for ND-N1, 105 for ND-N2, 132 for ND-N3, 170 for V.P. 2, 0 for V.P. 3, 53 for V.P. 5, and 39 for V.P. 6. Larval amphibian density for the first sampling period was the highest in ND-N2 with 1.0 individuals/m^2 (Fig. 5). V.P. 2 and ND-N3 have roughly half this density.

Density of nearly all the pools with the exception of V.P. 6 and ND-N3 increased during the second sampling period (Fig. 6). ND-N2 once again had the highest density with 2.8 individuals/m^2 and was followed by V.P. 2 and V.P. 3 with 1.6 and 1.1 individuals/m^2 respectively. A drop in density at all vernal pools with the exception of ND-N3 characterized the third sampling period (Fig. 7). V.P. 2 had the highest density with 1.4 individuals/m^2 with ND-N2 following at 0.8 individuals/m^2 and ND-N3 and V.P. 5 following with 0.06 and 0.1 respectively. Density of larval amphibians this decreased by a very large margin compared to sampling data from last summer, in which ND-N3 had an approximate density of 14 individuals/m^2 and V.P. 2 had an approximate

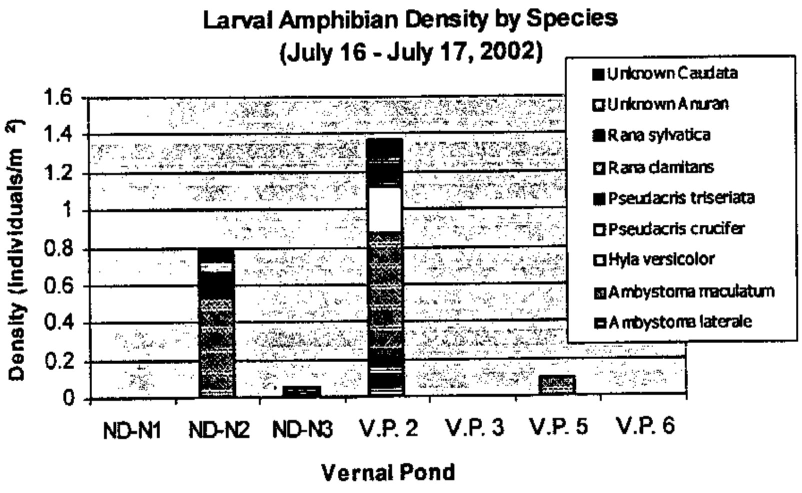


Figure 7 - Density of larval amphibian species at each vernal pool during the third sampling period.

density of 15 individuals/m^2 for the first of the two sampling periods. Of all ponds sampled last summer, the lowest density of a pool in which larval amphibians were caught was approximately 1.5 individuals/m^2 in ND-N1 during the first sampling period.

Rana sylvatica was the most abundant and had the highest density of all species for the first two sampling periods and replaced by *Pseudacris triseriata* during the final sampling, most likely due to metamorphosis. In addition, *Pseudacris triseriata* was the most widespread of all species, covering four vernal ponds, ND-N1, ND-N2, V.P. 2, and V.P. 5, during the second sampling period. No *Pseudacris triseriata* were collected last summer, instead *Rana sylvatica* was the most abundant and dense species and *Ambystoma jeffersonium* the second most abundant and dense species.

No *Ambystoma jeffersonium* were collected this summer and the UNDERC area is outside their range (5), however a large number of *Ambystoma laterale*, a morphologically similar species, were collected. As a result it is likely that all *Ambystoma jeffersonium* identified last summer were in fact *Ambystoma laterale*. Of the two caudata species collected this year, *Ambystoma laterale* was the most abundant, dense, and widespread. The least abundant, dense, and widespread of all species collected was *Rana clamitans*, found only in ND-N2 during the final sampling period.

Correlation between environmental data taken for all vernal ponds during the first and third sampling periods and larval amphibian populations during these sampling periods shows some relevant relationships (Table 1). During the first sampling period the most relevant correlations were species richness and pond size (F-value = 0.712, p = 0.072), and larval amphibian density and maximum depth (F-value = 0.761, p = 0.047) (Table 1a). Correlation between species richness and pond size strongly indicates that as pond size increases so does species richness. While the correlation between pond size and richness is not significant, more replication might drop the significance to below 0.05. Strong correlation between larval amphibian density and maximum depth indicates that as maximum depth increases so does amphibian density. Further significant correlations between water temperature and air temperature (*F*-value = 0.841, $p = 0.018$), dissolved oxygen and air temperature (*F*-value = 0.862, $p = 0.012$), pH and air temperature (*F*-value = 0.743, $p = 0.056$), and pH and pond size (*F*-value = 0.767, $p = 0.044$) are also found amongst first sampling period data.

During the third sampling period correlations occur between conductivity and species richness (*F*-value = -0.861, $p = 0.061$), air temperature and larval amphibian density (*F*-value = -0.845, $p = 0.072$), and species richness and larval amphibian density (*F*-value = 0.903, $p = 0.036$) (Table 1b). Thus as conductivity increases species richness decreases, as air temperature increases larval amphibian density decreases, and as larval amphibian density increases species richness increases. In addition, as maximum depth increases pH increases (*F*-value = 0.989, $p = 0.011$) and as water temperature increases pH increases (F-value = 0.927, $p = 0.024$). While correlations between species richness and dissolved oxygen (*F*-value = 0.777, $p = 0.122$) and between water temperature and maximum depth (*F*-value = 0.888, $p = 0.122$) appear during the third sampling period, both correlations are not significant.

Corresponding to significance in correlation are regression plots of various environmental data compared to larval amphibian density. During the first collection period strong regression between maximum depth and density ($r^2 = 0.5075$) reinforces the statement that as maximum depth increases larval amphibian density increases (Fig. 11f).

Table 1 – *F*-values of Pearson correlations between vernal pool factors at several vernal pools during the first (a) (May 30 – June 2, 2002) and third (b) (July 15 – July 16, 2002) sampling periods. Bold *F*-values are significant at P =< 0.08.

Pearson Correlation 5/30/2002 – 6/2/2002

	Air Temperature	Water Temperature	pH	Conductivity	Dissolved Oxygen	Maximum Depth	Pond Size	Species Richness
Water Temperature	0.841**							
PH	0.743	0.589						
Conductivity	-0.454	-0.289	-0.221					
Dissolved Oxygen	0.862**	0.629	0.937***	-0.240				
Maximum Depth	-0.588	-0.670	-0.353	0.169	-0.310			
Pond Size	0.445	0.420	0.767**	-0.233	0.567	-0.514		
Species Richness	0.012	0.097	0.493	-0.213	0.310	0.177	0.712*	
Density	-0.443	-0.455	-0.050	-0.236	-0.188	0.761**	-0.044	0.544

n = 7

* = P =< 0.08

** = P =< 0.05

*** = P =< 0.01

(a)

Pearson Correlation 7/15/2002 – 7/16/2002

	Air Temperature	Water Temperature	pH	Conductivity	Dissolved Oxygen	Maximum Depth	Pond Size	Species Richness
Water Temperature	0.058							
PH	-0.107	0.927**						
Conductivity	0.189	0.224	0.057					
Dissolved Oxygen	-0.171	0.345	0.304	-0.713				
Maximum Depth	-0.030	0.888	0.989**	0.432	-0.661			
Pond Size	0.031	0.553	0.239	0.239	0.483	-0.239		
Species Richness	-0.615	-0.085	0.062	-0.861*	0.777	-0.435	0.009	
Density	**-0.845**	-0.271	-0.053	-0.673	0.448	-0.269	-0.211	.903**

n = 7

* = P =< 0.08

** = P =< 0.05

(b)

While correlation between pond size and species richness was very close to significant (Table 1a), regression between the two ($r^2 = 0.0803$) indicates otherwise (Fig. 8). As for the other regressions of environmental factors with larval amphibian density, none of the r^2 values are large (Fig. 10). During the third sampling period all three significant correlations involving species richness and larval amphibian density had strong regression plots. Species richness compared to larval amphibian density show not only the strongest correlation effecting density but the strongest regression as well (r^2 = 0.8148), backing the claim that as larval amphibian density increases species richness increases.

Both air temperature compared to larval amphibian diversity (r^2 = 0.7141) and conductivity compared to species richness (r^2 = 0.7417) (Fig. 9) also show strong regressions that back negative correlation, meaning that as air temperature increases larval amphibian density decreases, and as conductivity increases species richness decreases. Conductivity compared to density (r^2 = 0.4531) and pH compared to density (r^2 = 0.3784) have notable regression, indicating possible connection. Strength of correlation between pH and density is fairly weak (*F*-value = -0.053) (Table 1b); therefore a trend is

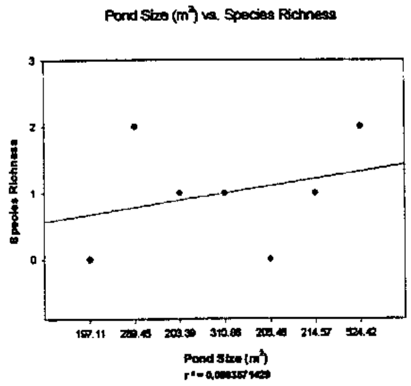


Figure 8 – Pond Size (m^2) vs. Species Richness.

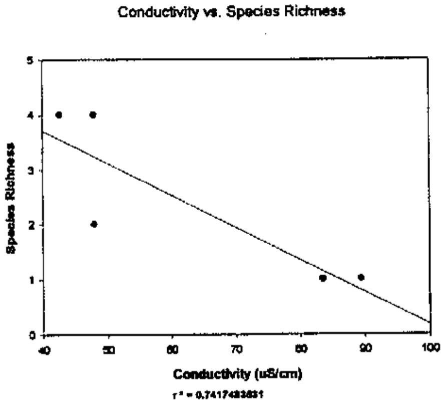


Figure 9 – Conductivity (uS/cm) vs. Species Richness.

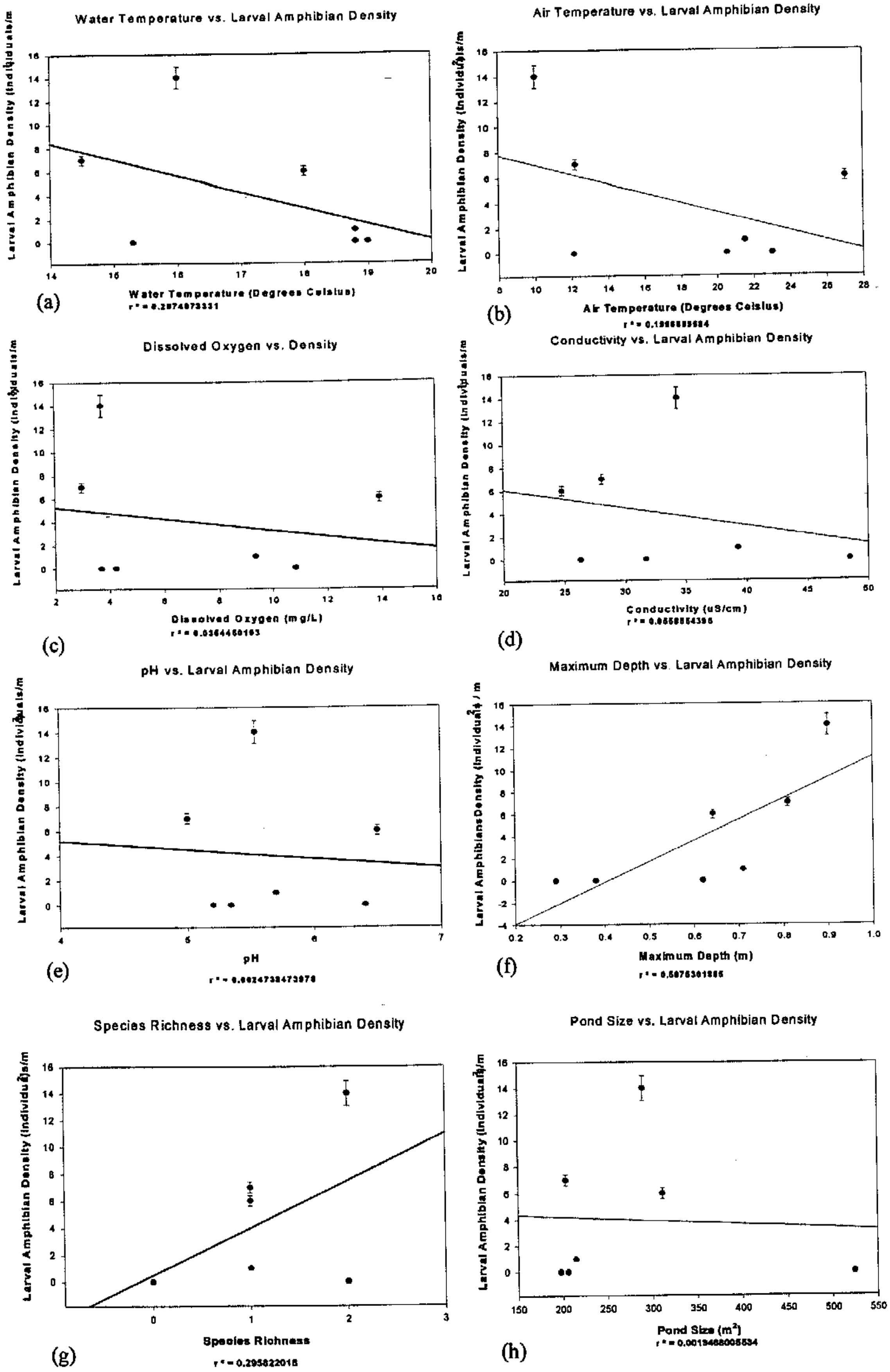


Figure 10 – Total larval amphibian density (individuals/m^2) per plot at each vernal pond during the first sampling period (May 30 – June 2, 2002) as compared to (a) water temperature, (b) air temperature, (c) dissolved oxygen, (d) conductivity, (e) pH, (f) maximum depth, (g) species richness, and (h) pond size.

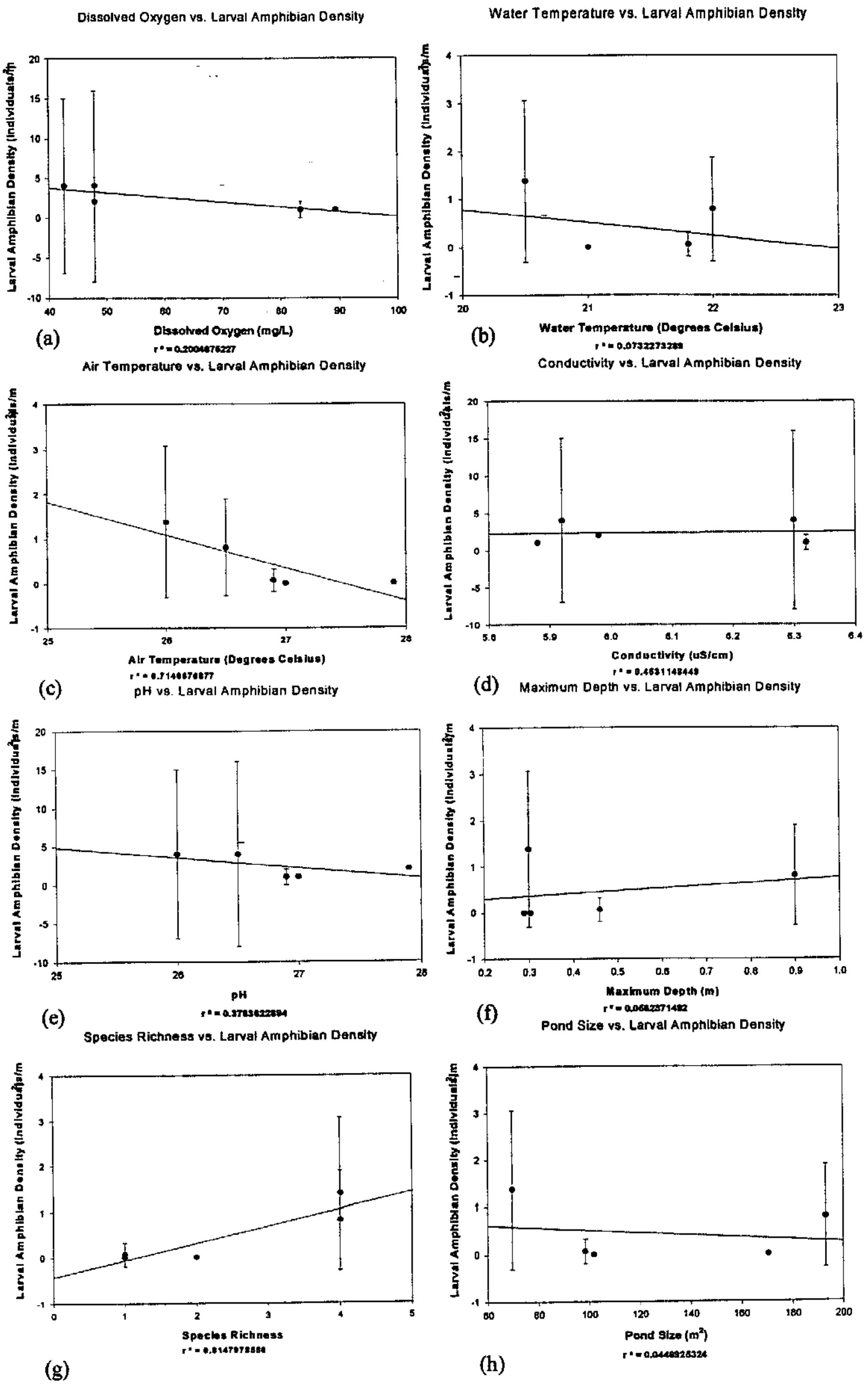


Figure 11 – Total larval amphibian density (individuals/m^2) per plot at each vernal pond during the third sampling period (July 15 - July 16, 2002) as compared to (a) dissolved oxygen, (b) water temperature, (c) air temperature, (d) conductivity, (e) pH, (f) maximum depth, (g) species richness, and (h) pond size.

not very likely. However, correlation (F-value = -0.673, $p = 0.213$)(Table 1b) and regression between conductivity and density indicate that with more replication perhaps larval amphibian density will decrease as conductivity increases.

As for regressions of other environmental factors with larval amphibian density, none were substantial (Fig. 11). While this year's data shows regressions and significance between a number of environmental factors and larval amphibian density, last year's data shows no such ties.

Regression plots of environmental factors and number of larval amphibians (Fig. 12, Fig. 13) show relationships identical to those seen in regressions of environmental factors and larval amphibian density (Fig. 10, Fig. 11). During the first sampling period a strong regression between maximum depth compared to larval amphibians collected (r^2 = 0.5980) supports earlier relationships between maximum depth and density, indicating that as maximum depth increases so does the total number of amphibians found at a vernal pond (Fig. 12f).

Earlier connections seen in correlation and regressions of each environmental factor compared to larval amphibian density are strengthened during the third sampling period. As air temperature increases the total number of larval amphibians decreases (r^2 = 0.6348), as conductivity increases the total number of larval amphibians decreases (r^2 = 0.4507), and as species richness increases the total number of larval amphibians increases (r^2 = 0.9033) (Fig. 13). A noteworthy regression between dissolved oxygen compared to number of larval amphibians collected (r^2 = 0.4975) is a new tie seen during the third collection period, indicating that as dissolved oxygen increases so does the number of larval amphibians collected (Fig. 13c).

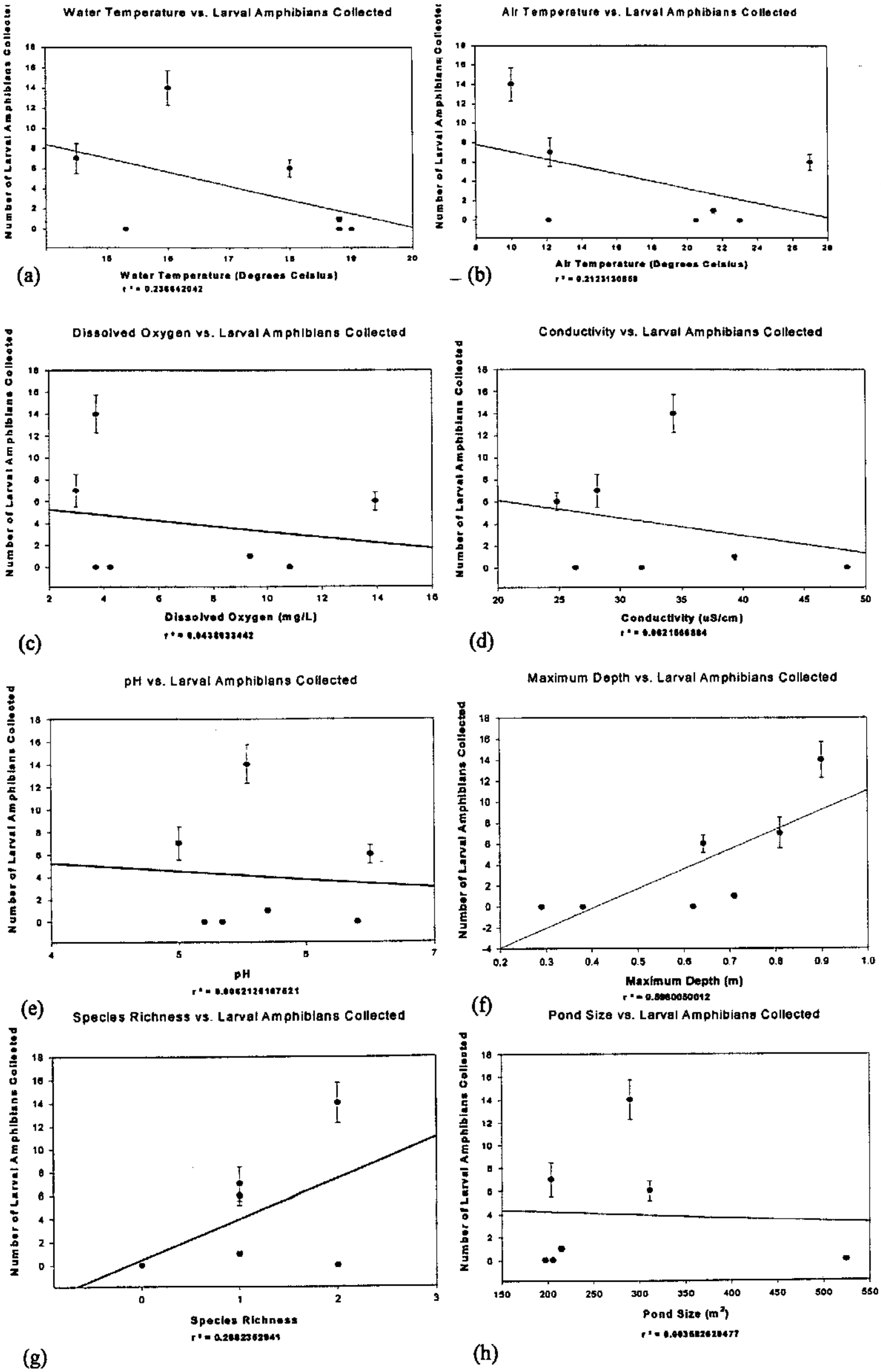


Figure 12 – Total Number of larval amphibians captured at each vernal pond during the first collection period (May 30 – June 2, 2002) as compared to (a) water temperature, (b) air temperature, (c) dissolved oxygen, (d) conductivity, (e) pH, (f) maximum depth, (g) species richness, and (h) pond size.

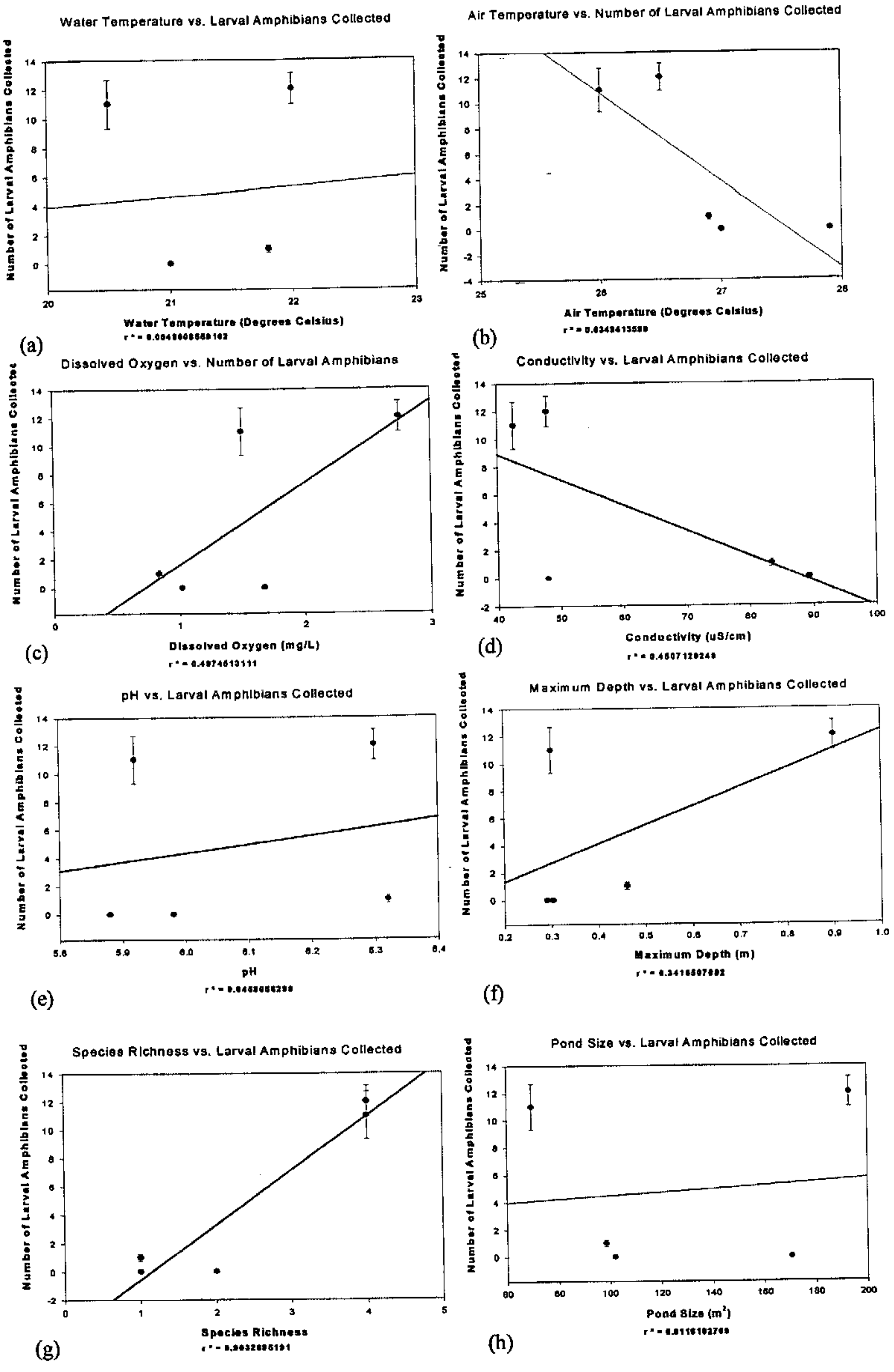


Figure 13 – Total Number of larval amphibians captured at each vernal pond during the first collection period (May 30 – June 2, 2002) as compared to (a) water temperature, (b) air temperature, (c) dissolved oxygen, (d) conductivity, (e) pH, (f) maximum depth, (g) species richness, and (h) pond size.

Last year's data shows no ties between regression plots of environmental factors to number of larval amphibians collected.

Average tadpole size, average tadpole body size, average tadpole tail size, and the range of tadpole size increased with each sampling period, showing growth in each species through the summer (Table 2). Compared to last year's data, *Rana sylvatica* tend to be smaller in the early/mid summer (first and second sampling periods respectively) (16.90 – 26.20 mm and 29.90 – 50.90 mm vs. 25 – 62 mm) though larger by the end of the summer (third sampling period) (53.00 – 61.70 mm vs. 43 – 60 mm). *Pseudacris crucifer* also tends to be smaller as compared to last year's data (17.80 mm vs. 19 – 31 mm). While no *Hyla versicolor* were found in the mid-summer last year, they were most

Table 2 – Average total tadpole size (mm), average body size (mm), average tail size (mm), and range of tadpole size (mm) for each of the species collected during the first (May 30 – June 2, 2002), second (June 24 – 25, 2002), and third (July 15 – 16, 2002) collection periods. Number of each species collected is also shown.

Collection Date		Average Tadpole Size	Average Body Size	Average Tail Size	Range of Tadpole Size	Number Collected
5/30/02	*Ambystoma laterale*	-	-	-	-	0
and	*Ambystoma maculatum*	-	-	-	-	0
6/2/02	*Hyla versicolor*	-	-	-	-	0
	Pseudacris crucifer	-	-	-	-	0
	Pseudacris triseriata	-	-	-	-	0
	Rana clamitans	-	-	-	-	0
	Rana sylvatica	21.36	8.26	13.10	16.90 - 26.20	5
6/24/02	*Ambystoma laterale*	23.62	-	-	17.60 - 31.80	13
and	*Ambystoma maculatum*	16.93	-	-	12.70 - 22.40	12
6/25/02	*Hyla versicolor*	16.12	6.38	9.74	11.40 - 25.00	19
	Pseudacris crucifer	17.80	5.70	12.10	17.80	1
	Pseudacris triseriata	17.80	6.30	11.50	17.80	1
	Rana clamitans	-	-	-	-	0
	Rana sylvatica	38.73	14.41	24.32	29.90 - 50.90	25
7/15/02	*Ambystoma laterale*	28.85	-	-	20.40 - 37.30	2
and	*Ambystoma maculatum*	30.42	-	-	20.70 - 36.00	14
7/16/02	*Hyla versicolor*	29.10	11.55	17.55	28.90 - 29.30	2
	Pseudacris crucifer	-	-	-	-	0
	Pseudacris triseriata	27.35	9.70	17.65	27.40 - 27.30	2
	Rana clamitans	67.00	20.50	46.50	67.00	1
	Rana sylvatica	57.43	19.55	37.88	53.00 - 61.70	4

abundant during the mid-summer this year with a range of 11.40 – 25.00 mm.

Hyla versicolor found in late summer 2002 did tend to be smaller than those found in summer 2001 (28.90 - 29.30 mm vs. 15 – 37 mm). *Ambystoma laterale*, *Ambystoma maculatum*, *Pseudacris triseriata*, and *Rana clamitans* were not captured last summer though provided size data this summer (Table 2).

The drift fence pilot experiment obtained only one result in trap 5 along fence 2, a shrew, over the forty-two hour sampling period.

Discussion

Amphibian populations from summer 2001 to summer 2002decreased in both average tadpole size and density as a whole, though richness increased. Whether this is a result of increasing biological diversity in the Ottawa National Forest due to fluctuation of environmental variables or merely a result of improved collection and identification we cannot know until more data is collected in the coming years.

Most larval amphibians were abundant during the second collection period, mid-summer, with exceptions being *Ambystoma maculatum* and *Pseudacris triseriata*. While metamorphosis is most likely responsible for the decrease of mmost populations going into the third sampling period, *Ambystoma maculatum* appears to be developing into the later summer. Such small population numbers of *Pseudacris triseriata* may indicate that instead of late summer metamorphosis it is a new species to the area, trying to find a development niche that will allow for the greatest resources availability when the juveniles are fully developed.

Density fluctuation is most likely due to metamorphosis of species at different times throughout the summer as many species' life cycles are tied to the desiccation of ponds at certain times. Larger species such as *Rana clamitans* take a longer period of time between larval and adult stages, indicating more permanent standing water in a pond as would be necessary for development. Mid-June, however, is likely the major spawning time due to high vernal pond productivity during this period of the summer.

An expected effect of decreased canopy cover with clear cutting and thinning is increased sunlight exposure to the surface of the vernal ponds. Increased sunlight exposure not only allows more UV-B radiation to penetrate the pond, which is already know to be detrimental to amphibian populations (1,2,5), but increases ambient air temperature, which decreases larval amphibian densities according to our data. In addition, as ambient air temperature increases more insect larvae metamorphose from the vernal ponds in which they are developing, leading to a decrease in available food supply available to larval amphibians in those vernal ponds.

Maximum depth of vernal ponds proves to be a large factor in larval amphibian density; as depth increases so does amphibian density. Furthermore, as density increases amphibian richness increases. The maximum depth of a pond is in large part determined by rate of evaporation, therefore, if a pond is exposed to higher light levels and ambient air temperature the rate of desiccation will increase, resulting in lower larval amphibian density and richness.

Five of the seven ponds sampled had less than fifty-percent emergent vegetation cover throughout the entire summer. A decrease in emergent vegetation may be a reason for a decrease in amphibian populations over the past year, however no detailed information regarding changes in vegetation abundance is available.

An increase in emergent vegetation cover could possibly create more diverse habitat for larval amphibians to hide amongst, thus reducing predation pressure and increasing larval amphibian populations. On the downside, as predation pressure is decreased and emergent vegetation possibly increase food sources available to tadpoles, overcrowding could become a problem and mass population die-offs could result. Further investigation into effects of vegetation upon larval amphibian populations is necessary.

V.P. 3 and V.P. 6 were the only two ponds to thoroughly desiccate and even then they did not dry up until mid-July. While V.P. 3 provided a number of larval amphibians during the second sampling period, V.P. 6 provided no larval amphibian whatsoever. Accordingly, it is likely that V.P. 6 is not an amphibian source but instead an amphibian sink, providing habitat for amphibians migrating from nearby vernal ponds but lacking the characteristics of a breeding ground (9, 11).

The larval and adult amphibians captured throughout the entire study appeared to be in good health, lacking any indications of over exposure to UV-B, pollutants and toxins, diseases, or environmental modifications (1, 2, 4, 9, 10, 12).

To make the study more robust in the coming years, a number of things can be altered or added to allow a better glimpse of larval amphibian ecology amongst the larger whole at these vernal ponds. The drift fence pilot experiment was successful in the fact that the fences worked beautifully, though the traps were far too shallow to be effective. An increase in trap size and the placement of a funnel on the top of the traps would make it much more difficult for ensnared amphibians to escape.

To give more correlations and trends as the summer progresses, environmental data should be taken during every sampling period, thus seasonal environmental variance can be taken into account at a finer level. In addition, light levels and evaporation rate should be measured at each pond, giving detail as to the amount of UV-B exposure and desiccation rate. A more detailed vegetation survey would be largely useful to evaluate as well, since it is a large source of both food and habitat and may very well be largely responsible for variances in larval amphibian density and richness from pond to pond. In terms of data analysis, having detailed raw data available from previous years, especially in electronic format, would be invaluable for tracking change over time.

Important ties between larval amphibian density and richness were found through this year's study, and as time progresses larger seasonal variations will become more apparent, which is important in tracking environmental change with the introduction of clear cutting and selectively thinning.

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Appendix

Pond	ND-N1	ND-N1	ND-N2	ND-N2	ND-N3	ND-N3	V.P. 2	V.P. 2	V.P. 3	V.P. 3	V.P. 5	V.P. 5	V.P. 6	V.P. 6
Date	6/2/02	7/15/02	6/2/02	7/15/02	6/2/02	7/15/02	5/30/02	7/16/02	5/30/02	7/16/02	5/30/02	7/16/02	5/30/02	7/16/02
Water Temperature (°C)	15.3	21	16	22	14.5	21	18	20.5	18.8	-	18.8	21.8	19	-
Air Temperature (°C)	12.1	27	10	26.5	12.2	27.9	27	26	20.5	-	21.5	26.9	23	-
pH	5.34	5.88	5.54	6.3	5	5.98	6.5	5.92	5.2	-	5.7	6.32	6.4	-
Conductivity (µS/cm)	48.46	89.34	34.34	47.9	28.1	47.92	24.8	42.62	26.3	-	39.3	83.42	31.7	-
Dissolved Oxygen (mg/L)	4.232	1.014	3.718	2.748	2.98	1.674	13.925	1.498	3.7	-	9.354	0.832	10.82	-
Maximum Depth (m)	0.62	0.29	> 0.85	>0.85	0.81	0.303	0.643	0.3	0.38	-	0.71	0.46	0.29	-
Pond Size (m2)	197.11	170.48	289.45	192.95	203.39	101.94	310.86	69.54	205.46	-	214.57	98.43	524.42	-
Species Richness	0	1	2	4	1	2	1	4	0	Desiccant	1	1	2	Desiccant
Total Juveniles	0.0000	0.0000	14.0000	12.0000	7.0000	0.0000	6.0000	11.0000	0.0000	-	1.0000	1.0000	0.0000	-
Average Juveniles	0.0000	0.0000	0.9333	0.8000	0.4118	0.0000	0.4000	1.3750	0.0000	-	0.0667	0.0667	0.0000	-
Standard Deviation	0.0000	0.0000	1.7099	1.0823	1.4603	0.0000	0.8281	1.6850	0.0000	-	0.2582	0.2582	0.0000	-

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