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Land Usage Impacts on Springhead Salamander Populations, at Callaway Extended Properties, Harris County, Georgia

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Columbus State University

The College of Science

The Graduate Program in Environmental Science

Land Usage Impacts on Springhead Salamander Populations, at Callaway Extended Properties, Harris County, Georgia

A Thesis in

Environmental Science

by

Neil Allen Pearce

Submitted in Partial Fulfillment
of the Requirements
for the Degree of

Master of Science

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I have submitted this thesis in partial fulfillment of the requirements for the degree of Master of Science.

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ABSTRACT

Recent scientific studies have indicated that amphibian populations appear to be declining in many areas of the world or exhibiting local population fluctuations. Some of the reasons given for this population decline are associated with land usage, and the negative biological impacts of many forms of land management practices.

A study was conducted at the Callaway Gardens Extended Properties in Pine Mountain Georgia which compared the local aquatic salamander populations of five spring-fed streams in the Cason J. Callaway Memorial Forest, and five spring-fed streams in the Lower Valley Area. Using a catch-per-unit-effort sampling methodology, a comparison was made between the mean total number of salamanders sampled in each area as well as the mean total number of salamander species sampled in each area.

The Lower Valley Area has a long and significant history of land usage and management (cotton farming, timber harvesting, controlled burns, recreational activities), while the Cason J. Callaway Memorial Forest as been left in a relatively natural forested state and has not been subject to similar management practices.

The results of the study indicated that the Lower Valley Area had significantly smaller mean-catch-per-unit effort overall totals and individual species totals than the Cason J. Callaway Memorial Forest.

Previous agricultural practices in the Lower Valley Area appear to be the primary reason for the differences in populations between the two areas. Cotton farming, which continued for many decades in the Lower Valley Area, typically involved the use of toxic chemical pesticides, and herbicides many which are prohibited for use today. The persistence of these toxic chemical compounds may still be having an adverse affect on the aquatic amphibian populations in the Lower Valley Area.

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Acknowledgements

I would like to thank Dr. Bill Birkhead, Dr. Art Cleveland, and Dr. Bill Frazier for their helpful comments and suggestions during the preparation of this thesis. Additionally, I am also deeply indebted to LuAnn Craighton, Director of Land Stewardship for Callaway Gardens. Her generous assistance in providing information concerning the Callaway properties, and in allowing me complete access to the Memorial Forest and Lower Valley, made this study possible.

Dedication

This work is dedicated to my dear wife, Leath Pearce, for her unending patience and understanding during all those many weekends I was out at Callaway Extended Properties, working on this study.

INTRODUCTION

Amphibians are abundant and functionally important animals in most freshwater and terrestrial habitats. They have a wide geographic distribution, and can be found in tropical, subtropical, and temperate regions. Amphibians are also significant components of the earth's biota. For example, some species of North American woodland salamanders such as the genus *Plethodon* can occur in densities of several thousand individuals per hectare (Merchant 1972). Their total biomass is equal to that of all the resident species of small mammals combined, and is more than twice that of all species of birds during the peak of avian breeding activity (Burton and Likens 1975a). Many species of amphibians are also wide ranging and potentially could serve as key indicator species to evaluate broad geographic or global changes in the environment.

Amphibians have proven to be particularly useful bio-indicators in determining the state of environmental health in wetland environments. Certain physiological and ecological traits such as permeable skin and complex biphasic life cycles make amphibians potentially excellent indicators of subtle changes in the ecosystem or local environment (Merchant 1972).

Recent scientific studies have indicated that amphibian populations appear to be declining sharply in many areas of the world, or are exhibiting significant local population fluctuations, (Barinaga 1990, Blaustein and Wake 1990, Borchelt 1990, Philips 1990, Wake 1991).

At the First World Conference on Herpetology in Canterbury, England in 1989, researchers from around the world agreed that they had been witnessing significant declines of the various amphibians they studied, some to the point of apparent extinction (Philips 1990). Although much of the evidence concerning amphibian decline presented at the World Conference was anecdotal, at a subsequent Amphibian Workshop held in Irvine California in February 1990, specific examples of amphibian declines were reported on almost every continent.

Habitat destruction and loss is a prominent suspect as the major cause for amphibian losses (Blaustein and Wake 1990, Philips 1990). Other hypothesized causes for these declines include chemical pollution, acid precipitation, increased ultraviolet radiation, introduction of exotic species, pathogens, natural population fluctuations and anthropogenic activities such as timber harvesting, controlled burns and recreational activities (Blaustein and Wake 1990, Philips 1990, Wake 1991, Carey 1993, Blaustein et al. 1994, Ash and Bruce 1994, Garber and Burger 1995, Blaustein et al. 1996, Lawrence et al. 1996, Ash 1997).

Some specific examples of North American decline include: the Cascade frog (*Rana cascadae*) which has shown a 20-40% decline in the

Oregon Cascade Range, the red-legged frog (*Rana aurora*) which was once present in the Willamette Valley of Oregon is now no longer present, and the spotted frog (*Rana pretiosa*) which was once abundant in the Western Cascades, is no longer found there (Philips 1990). Declines in the amphibian populations of California include: the mountain yellow-legged frog (*Rana mucosa)*, the Yosemite toad (*Bufo canorus*), the foothill yellow-legged frog (*Rana boylei*), and the California red-legged frog (*Rana aurora*). All of these frogs have shown declines in the California mountains and foothills where they were once abundant (Philips 1990).

While the evidence of amphibian declines has been mounting steadily worldwide, there are several areas of the world where there is no documented evidence that amphibian populations have been affected or fluctuating. For example, in 1935 the cane toad (*Bufo marinus*) was introduced to Australia and has since overrun Queensland and southeastern Australia. There is no evidence of any decline in the *Bufo marinus* populations (Philips 1990, Hero and Gillespie 1997). Additionally, according to Robert Inger of the Field Museum of Natural History who has studied frog populations in the streams of Borneo for over 30 years, there is very little evidence of a decline in the number of frogs in Borneo over this 30-year period (Voris and Inger 1995).

Since recent scientific studies of amphibian decline have produced somewhat contradictory results, it was felt that a study of local amphibian populations might be beneficial in adding to the body of knowledge concerning any decline of local amphibian species. Also, since most of the current literature on amphibian declines involves studies of frog and toad populations, it seemed appropriate and relevant to study local species of salamanders. The overall objective of this study was to measure the abundance and diversity of salamander species in local small spring-fed streams. The spring fed-streams selected for this study are found in the Callaway Gardens Extended Properties in Harris County, Georgia (Figure 1). Specifically, the two areas chosen within the Callaway extended Properties are the Cason J. Callaway Memorial Forest (CJC), (Figure 2), a pristine area with minimal human contact and the Lower Valley Area (LVA), (Figure 3), an area that has been subject to various different land use activities for much of its recent history. Both the CJC and LVA have controlled limited access. The purpose of the study was to determine if there was a difference between the size of the salamander populations of the CJC and the LVA, and if so, determine if long-term land use management practices at Callaway Gardens have had an impact.

STUDY SITE

Callaway Gardens and Foundation Properties consist of three tracts of land in the northern portion of Harris County Georgia, the gardens proper, the CJC and the LVA. The gardens proper and LVA are bordered on the southeast by a prominent topographic feature, the Pine Mountain Ridge. This ridge also borders the CJC on the northwest (Figure 1).

These properties are situated within two drainage systems, the Barnes Creek watershed, south of Pine Mountain ridge, and the Mountain Creek watershed on the north (Jones 1974). The climate of the region is mild with warm summers, and winters that are not severe, but which are characterized by frequent variations in temperature caused by either cold fronts from the northwest or warm winds from the Gulf of Mexico. The annual average rainfall is 49 inches, although severe droughts of several weeks duration in West-Central Georgia are not uncommon (Jones 1974).

Pine Mountain is underlain by the Hollis Quartzite which extends from Notasulga, Alabama northeastward to Barnesville Georgia. The Hollis Quartzite is an extremely hard metaquartzite, which forms rubble when it weathers (Jones 1974). Many of the springs and streams in Callaway Gardens have a substrate that is made up primarily of quartzite rubble.

The flora of the Pine Mountain area is rich in diversity. Many of the local species show an affinity with either Coastal Plain flora or

Appalachian flora, providing evidence of past floral migrations into the area. Pine Mountain is covered with a hardwood forest dominated by Chestnut Oak, while the Piedmont Plateau is dominated by old-field communities of Loblolly Pine with little diversity (Jones 1974).

The Gardens have been operated for over fifty years as a horticultural, educational and recreational facility, and have gained national prominence and attention (Schubert, 1964).

Two separate areas within the Callaway Properties were selected as the sites for this study, the Lower Valley Area (LVA) and the Cason J. Calloway Memorial Forest (CJC). The two areas have very different histories of land usage and management.

The first area of study, the (CJC), (Figure 2), is a limited activity area with minimal human usage. The CJC has been kept in a natural, almost pristine condition for as long as it has belonged to Callaway Gardens, approximately fifty years. With primitive unimproved roads and the absence of extensive agricultural activity, controlled burns, timber harvesting and other usage activities, the CJC has been purposely excluded from the type of land use management practices that were and are prevalent in the LVA.

By contrast, the second area of study, the LVA, (Figure 3), has experienced a long and diverse history of human activity and land use management. The LVA has been extensively managed and utilized for a period of well over fifty years. Agricultural activities, timber harvesting, planting of food plots, controlled burns and road building/improvements are just some of the many activities which have occurred in the Lower Valley Area for over half a century. Previous to its acquisition by Callaway Gardens, the LVA consisted of a series of farms which were used for extensive cotton farming activities. Luann Craighton, Director of Land Stewardship for Callaway Gardens has a file photograph of the LVA taken over 70 years ago. The picture showed an area with parched, weathered, over-used soils demonstrating a high degree of moisture depletion and soil erosion. Since the area was heavily farmed for cotton for many years, there was probably a very high usage rate of chemical pesticides, herbicides and fertilizers. Many of the chemicals available at the time such as DDT and Paris Green have been banned by the Environmental Protection Agency (EPA) because of their toxicity to wildlife and humans.

Figure 1: Topographic Map of Callaway Gardens in Pine Mountain Georgia (Source TopoZone.com- Pine Mountain quad)

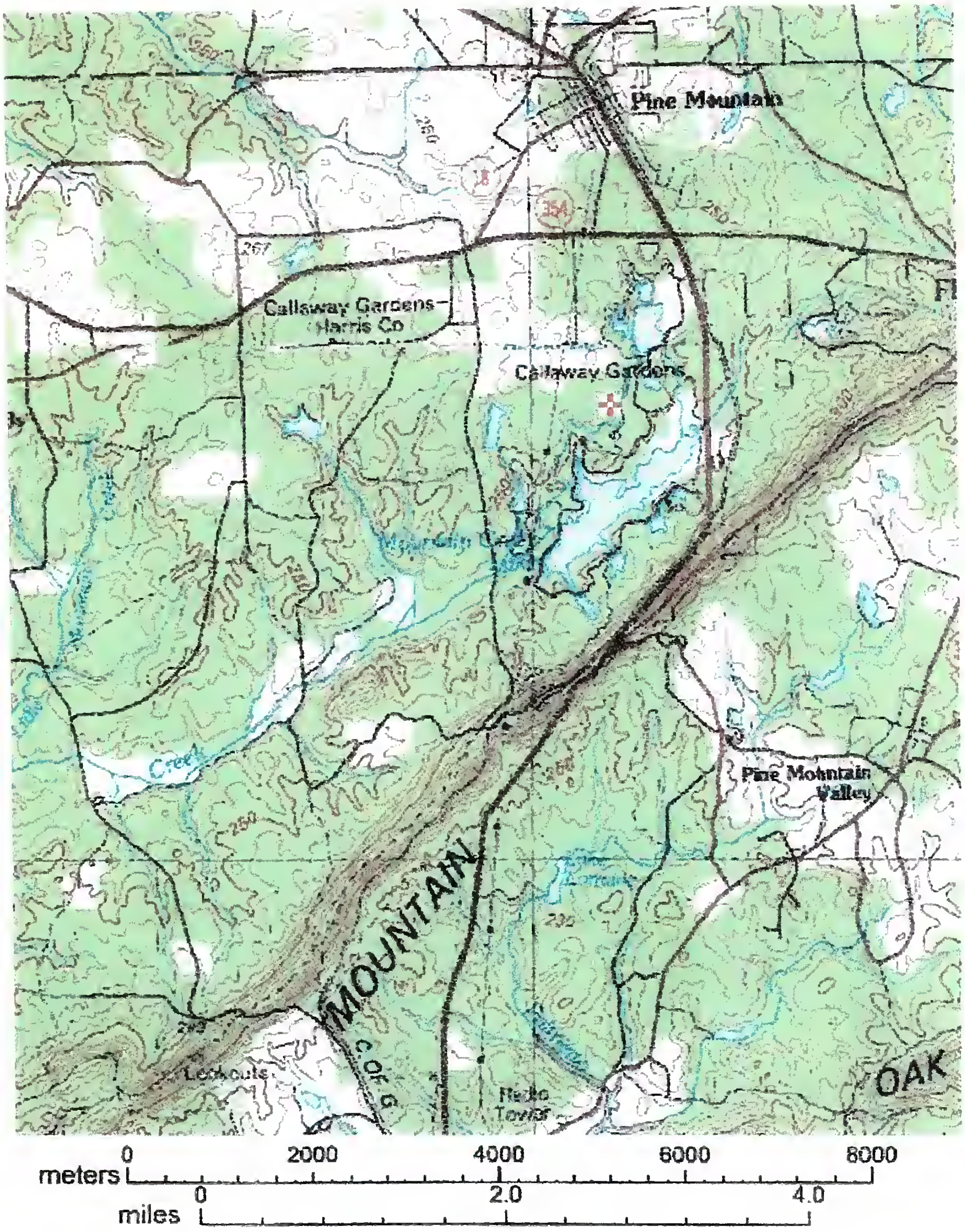
Pine Mountain
Callaway Gardens-Harris Co
Callaway Gardens
Mountain Creek
Creek
Pine Mountain Valley
MOUNTAIN
OAK
Lookouts
Radio Tower
C of G
267
260
250
235
0
2000
4000
6000
8000
meters
0
2.0
4.0
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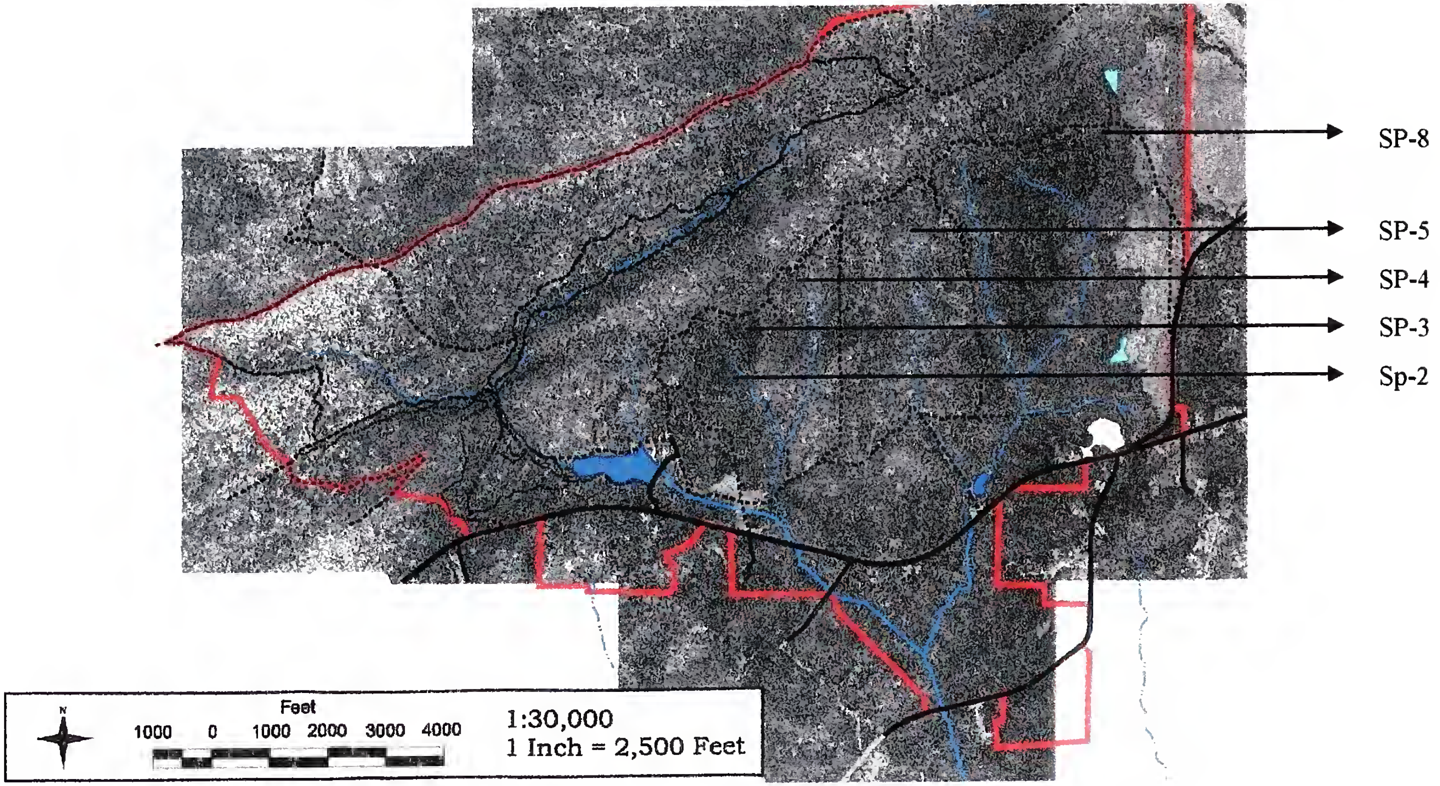
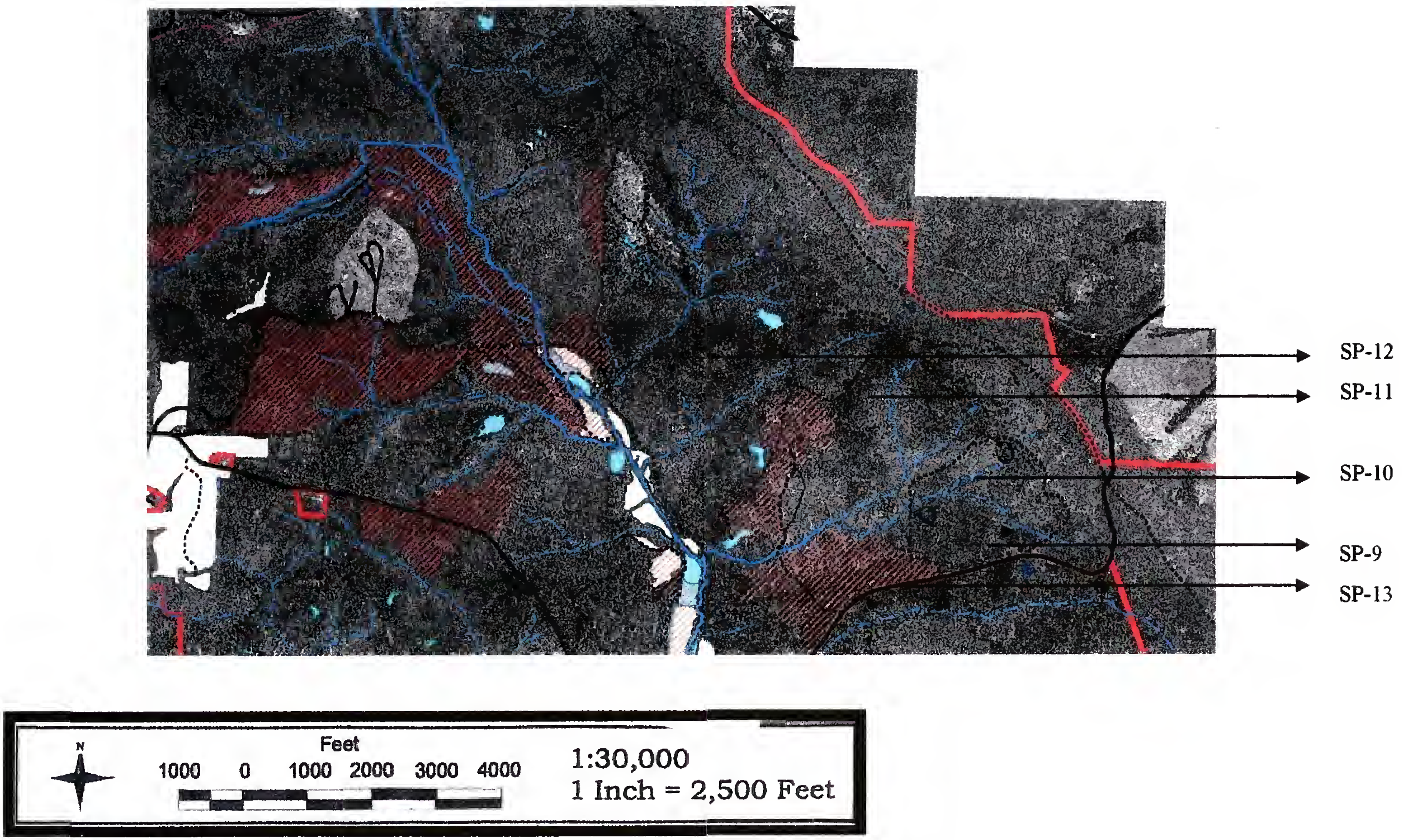
Figure 2: Sampling points in the Cason J. Callaway Memorial Forest.
(Source Callaway Gardens-Aerial Map of Gardens)



Sampling Points in Cason J. Callaway Memorial Forest

Figure 3: Sampling points in the Lower Valley Area.
(Source Callaway Gardens-Aerial Map of Gardens)



Sampling Points in the Lower Valley Area

MATERIALS AND METHODS

The primary purpose of this study was to determine if there was a difference between first-order, spring-fed, stream-inhabiting salamander populations between the CJC and LVA. If such a difference were found to exist, it was proposed to examine the role that long-term land use management practices may have had on salamander populations and species diversity in these streams. The study compared the salamander populations and species diversity of five selected first-order, spring-fed streams in the LVA, with five selected first-order, spring-fed streams in the CJC complex, using funnel traps as a means of sampling.

The streams that were selected for this study had to meet certain criteria. Each stream had to flow year round, continuing to flow during the spring and summer months when there is often limited rainfall. Each stream had to be easily accessible from the unimproved roads that traversed the CJC and the LVA. Each stream also had to be geographically separate from the other streams used in the study, so that salamanders would not be migrating from one stream to the other.

Each of the channels of the selected streams varied in width from 1 - 1.5 meters and visibly flowed for at least 50-100 meters. The water depth of each stream varied from 2.5-10 centimeters, and the stream channel substrates consisted of sand, mud, fractured quartzite rock chips, and various sized cobbles and boulders. Some of the stream channels consisted of only one type of substrate, while others consisted of two or more types of substrate as one moved along the length of the stream channel.

A total of twenty funnel traps were used for sampling during this study (Enge, 1997). Ten funnel traps were placed in five streams in the CJC and ten funnel traps were placed in five streams in the LVA. Two funnel traps measuring 90 centimeters long and 20 centimeters wide were placed in each stream channel, each trap approximately 50-75 meters from the other. Drift fences constructed of thin aluminum sheathing (each section measuring 60 cm long and 25 cm high) were used to channel or direct the salamanders into the funnel traps (Enge, 1997). Two sections of drift fence were used to direct movement to the front opening of each trap and two sections of drift fence were used to direct movement to the rear opening of each trap. The drift fences were secured using wooden stakes where the substrate was sandy or muddy, and were long enough to block the channel in order to minimize the movement of salamanders around each trap (Enge, 1997). In streams where the substrate was chipped rock or cobbles, pieces of rock were used to secure the drift fences rather than stakes. The traps were placed as deeply as possible into the substrate of each stream channel so that the two entrances of the traps were flush with the bottom of the spring channel. The contents of each trap at each stream location was sampled and identified at least once every seven days for the duration of the study, (November 2000 - March 2002).

During each sampling event the total number of salamanders and the total number species were determined by combining the contents of both funnel traps at each site. At the conclusion of the study the total number of salamanders recorded at each site and the total number of each species were divided by the total number of sampling events (number of times traps are checked) at each site to determine the mean catch-per-unit-effort for each stream location. The mean catch-per-unit-effort (both totals and number of species) was then considered as an indicator of salamander population abundance and salamander species richness for each stream location and for each area (Heyer et al. 1994).

The sampling methodology of catch-per-unit-effort without removal refers to the fact that salamanders which were caught in the funnel traps were not removed from the salamander population, nor were they marked to indicate that they had been previously sampled. Since each salamander at each stream location had the same probability of being re-sampled one or more times in subsequent sampling events, the possibility that some animals were being counted more than once was a condition that was assumed equal at all sites.

Because of the significant distances between stream locations it was highly improbable that aquatic salamanders were migrating between streams. In order to eliminate recruitment as a factor in salamander counts, larval and juvenile specimens were not counted during sampling events. Additionally, the likelihood of deaths within the sample population was a condition that was assumed equal at all of the sites. For all of the above reasons, I made the assumption that each of these streams was isolated from the others used in this study.

During each sampling event the following information was recorded on data collection worksheets in the CJC and LVA areas:

a. Total number of salamanders sampled per stream location; and

b. Total number of salamanders sampled by species per stream location.

The following data was calculated for each area and each site:

a. Mean catch-per-unit-effort total for all salamanders sampled at each stream;

b. Mean catch-per-unit-effort total for each species sampled at each stream;

c. Mean catch-per-unit-effort total for all salamanders sampled in each of the two areas; and

d. Mean catch-per-unit-effort total for each species sampled in each of the two areas.

The mean catch-per-unit-effort values, with standard deviations and 95% confidence limits were calculated for both salamander totals and species totals for both the CJC and the LVA.

The Null Hypothesis, that there was no significant difference between the salamander mean-catch-per-unit-effort totals numbers and species mean-catch-per-unit-effort number totals numbers in the CJC and LVA, was tested against alternative hypotheses using a two tailed test, at both the .05 and .01 levels of significance.

In March 2002 just prior to the conclusion of the sampling, a portable Hydrolab electronic water testing kit was used to test the water in each of the streams in the study. Each spring in both the CJC and LVA was tested for: pH, temperature, dissolved oxygen, percentage of dissolved oxygen, redox, specific conductivity and turbidity. A regression analysis using the results of this testing was conducted at the .95 confidence level to see if a linear correlation existed between the numbers of salamanders sampled and each of the tested water parameters for each stream. If a linear correlation could be shown to exist, then the correlation coefficient was tested using the null hypothesis at the.05 level of significance.

RESULTS

Of all of the potential salamander taxa which may exist at Callaway Gardens (Table 1), a total of 3 taxa were consistently identified from all sampling events in both the CJC and LV areas during the duration of this study (November 2000 - March 2002). All of the taxa sampled belong to the family *Plethodontidae* (Conant and Collins 1998). The primary species collected included *Desmognathus fuscus*, *Pseudotriton ruber*, and *Eurycea cirrigera* (Mount 1996, Collins 1997, Conant and Collins 1998). A few specimens of the spring salamander *Gyrinophilius porphyriticus* were periodically sampled in the CJC, but the numbers were so few (3) that they were not included as part of the comparisons between the primary species. Although each of the primary taxa were sampled and found in both study areas they were not found in every spring. Although they were present at sites 9 and 11 in the LVA all three species were absent from sampling sites 10, 12, and 13 in the same area.

Of all the taxa sampled in the CJC, *D. fuscus* accounted for 67.2% of all salamanders collected. *E. cirrigera* was the next largest group with 24.4% followed by *P. ruber* with 8.3 %. Of the taxa sampled in the LVA, *D. fuscus* accounted for 69.3%, with *P. ruber* with 22.3%, followed by *E. cirrigera* with 8.4%.

The total number of salamanders sampled in the CJC was 831, with a mean catch-per-unit-effort value of 23.74 (Table 2). The total number of salamanders sampled in the CJC by sampling point is shown in Figure 4. The mean catch-per-unit-effort totals for the CJC by sampling points is shown in Figure 6.

The total number of salamanders sampled in the LVA was 166, with a mean catch-per-unit-effort total of 4.74 (Table 3). The total number of salamanders sampled in the LVA by sampling point is shown in Figure 5. A comparison of the total numbers of salamanders caught in both the CJC and LVA is shown in Figure 6. The mean catch-per-unit-effort totals for the LVA by sampling points is shown in Figure 8.

A comparison of all the sampling totals and the mean catch-per-unit-effort totals for the CJC and the LVA is shown in Table 4.

At the .95 confidence level, the confidence limits for the CJC mean catch-per-unit-effort sampling range from 20.87 to 26.61. The .95 confidence limits for the LVA mean catch-per-unit-effort sampling range from 3.88 to 5.59.

In regard to species totals in the CJC, 559 *D. fuscus*, 203 *E.cirrigera* and 69 *P. ruber* were sampled. The mean catch per-unit-effort values for these species are: *D. fuscus*, 15.97, *E. cirrigera*, 6.57 and *P. ruber*, 1.97 (Figure 7). The .95 confidence limits for these species are: *D. fuscus* - (13.74 - 18.22), *E. cirrigera* - (5.23 - 7.91), and *P. ruber* - (1.2 - 2.74).

In the LVA, salamanders were found in only two of the five streams being sampled (9&11). Species totals were: *D. fuscus*, 115, *E. cirrigera*, 14, and *P. ruber*, 37. The mean catch-per-unit-effort values for these species are: *D. fuscus*, 3.28, *E. cirrigera*, .40, and *P. ruber*, 1.05 (Figure 9). The .95 confidence limits for these species are: *D. fuscus* - (2.55 - 4.00), *E. cirrigera* - (0.188 - 0.612), *P. ruber* - (0.716 - 1.38).

The Null Hypothesis (that the mean catch-per-unit-effort total numbers for the CJC and LVA were equal was rejected at both the .05 and .01 levels of significance using a two tailed test. The mean-catch-per-unit-effort total numbers for the CJC indicate that the CJC has a significantly larger salamander population than the LVA.

In applying the Null Hypothesis to the species mean-catch-per-unit effort totals for the CJC and LVA, the following results were noted:

a) *D. fuscus* - the Null Hypothesis is rejected at the .05 and the .01 levels of significance using a two tailed test. The number of *D. fuscus* in the CJC is significantly larger than the number of *D. fuscus* found in the LVA.

b) *E. cirrigera* - the Null Hypothesis is rejected at the .05 and .01 levels of significance using a two-tailed test. The number of *E. cirrigera* in the CJC is significantly larger than the number of *E. cirrigera* found in the LVA.

c) *R. ruber* - the Null Hypothesis is rejected at the .05 and .01 levels of significance using a two-tailed test. The number of *P. ruber* in the CJC is significantly larger than the number of *P. ruber* found in the LVA.

In an attempt to determine if some parameter or characteristic of the water was having effect on the presence or absence of salamanders, a Hydrolab stream testing kit was used to test the water in all of the streams of both the CJC and LVA (Table 5). One stream at sampling point 3 in the CJC had water levels which were too low to conduct testing. Parameters such as pH, turbidity, dissolved oxygen, temperature, specific conductance and redox potential were compared between each of the streams. The purpose was to determine if there were any significant differences in the water characteristics of each stream which could account for the lower salamander population of the LVA.

To determine if there was a linear correlation between some of the more critical parameters in Table 5 and the numbers of salamanders sampled, a regression analysis was completed for pH, dissolved oxygen, specific conductance, and redox potential values.

A regression analysis for pH was conducted at the .95 confidence level using the pH value of the spring water for each sampling point in the CJC as the independent variable. The total number of each salamander species for each sampling point in the CJC was used as the dependant variable. The analysis indicated a negative correlation with an r value of -.087 (Figure 11). To determine if this correlation was significant, the r-value was tested using the null hypothesis at the .05 level of significance. The null hypothesis was that there was no significance to the correlation coefficient (r) number. Since r = -.087 falls on the critical value of r interval of -.576 to .576 the null hypothesis is accepted and the correlation coefficient of -.087 is not significant at the .05 level of significance.

A regression analysis for pH was conducted at the .95 confidence level using the pH value of the spring water for each sampling point in the LVA as the independent variable. The total number of each salamander species for each sampling point in the LVA was used as the dependant variable. The analysis indicated a negative correlation with an r value of -.132 (Figure 12). To determine if this correlation was significant, the r-value was tested using the null hypothesis at the .05 level of significance. The null hypothesis was that there was no significance to the correlation coefficient (r) number. Since r = -.132 falls on the critical value of r interval of -.514 to .514 the null hypothesis is accepted and the correlation coefficient of -.132 is not significant at the .05 level of significance.

A regression analysis for pH was conducted at the .95 confidence level using the ph value of the stream water for each sampling point in the CJC and LVA as the independent variable. The total number of each salamander species for each sampling point in the CJC and LVA was used as the dependant variable. The analysis indicated a negative correlation with an r value of -.086 (Figure 13). To determine if this correlation was significant, the r-value was tested using the null hypothesis at the .05 level of significance. The null hypothesis was that there was no significance to the correlation coefficient (r) number. Since r = -.050 falls on the critical value of r interval of -.381 to .381 the null hypothesis is accepted and the correlation coefficient of -. 050 is not significant at the .05 level of significance.

A regression analysis for dissolved oxygen was conducted at the .95 confidence level using the dissolved oxygen value of the stream water for each sampling point in the CJC as the independent variable. The total number of each salamander species for each sampling point in the CJC was used as the dependant variable. The analysis indicated a negative correlation with an r value of -.176 (Figure 14). To determine if this correlation was significant, the r-value was tested using the null hypothesis at the .05 level of significance. The null hypothesis was that there was no significance to the correlation coefficient (r) number. Since r = -.176 falls on critical value of r interval of -.576 to .576 the null hypothesis is accepted and the correlation coefficient of -.176 is not significant at the .05 level of significance.

A regression analysis for dissolved oxygen was conducted at the .95 confidence level using the dissolved oxygen value of the stream water for each sampling point in the LVA as the independent variable. The total number of each salamander species for each sampling point in the LVA was used as the dependant variable. The analysis indicated a negative correlation with an r value of -.231 (Figure 15). To determine if this correlation was significant, the r-value was tested using the null hypothesis at the .05 level of significance. The null hypothesis was that there was no significance to the correlation coefficient (r) number. Since r = -.231 falls on critical value of r interval of -.514 to .514 the null hypothesis is accepted and the correlation coefficient of -.231 is not significant at the .05 level of significance.

A regression analysis for dissolved oxygen was conducted at the .95 confidence level using the dissolved oxygen value of the stream water for each sampling point in the CJC and the LVA as the independent variable. The total number of each salamander species for each sampling point in the CJC and LVA was used as the dependant variable.

The analysis indicated a negative correlation with an r value of -.039 (Figure 16). To determine if this correlation was significant, the r-value was tested using the null hypothesis at the .05 level of significance. The null hypothesis was that there was no significance to the correlation coefficient (r) number. Since r = -.039 falls on critical value of r interval of -.381 to .381 the null hypothesis is accepted and the correlation coefficient of -.381 is not significant at the .05 level of significance.

A regression analysis for specific conductance was conducted at the .95 confidence level using the specific conductance value of the stream water for each sampling point in the CJC as the independent variable. The total number of each salamander species for each sampling point in the CJC was used as the dependant variable. The analysis indicated a negative correlation with an r value of -.639 (Figure 17). To determine if this correlation was significant, the r-value was tested using the null hypothesis at the .05 level of significance. The null hypothesis was that there was no significance to the correlation coefficient (r) number. Since r = -.639 falls outside the critical value of r interval of -.576 to .575 the null hypothesis is rejected at the .05 level of significance and the number is significant. When the correlation coefficient r is tested at the .01 level of significance, r = -.639 falls on the critical value of r interval of -.708 to .708 and the null hypothesis is accepted. The correlation coefficient of -.639 is not significant at the .01 level of significance.

A regression analysis for specific conductance was conducted at the .95 confidence level using the specific conductance value of the stream water for each sampling point in the LVA as the independent variable. The total number of each salamander species for each sampling point in the LVA was used as the dependant variable. The analysis indicated a negative correlation with an r value of -.289 (Figure 18). To determine if this correlation was significant, the r-value was tested using the null hypothesis at the .05 level of significance. The null hypothesis was that there was no significance to the correlation coefficient (r) number. Since r = -.289 falls on the critical value of r interval of -.514 to .514 the null hypothesis is accepted at the .05 level of significance and the number -.289 is not significant at the .05 level of significance.

A regression analysis for specific conductance was conducted at the .95 confidence level using the specific conductance value of the stream water for each sampling point in the CJC and the LVA as the independent variable. The total number of each salamander species for each sampling point in the CJC and LVA was used as the dependant variable. The analysis indicated a negative correlation with an r-value of -.285

(Figure 19). To determine if this correlation was significant, the r-value was tested using the null hypothesis at the .05 level of significance. The null hypothesis was that there was no significance to the correlation coefficient (r) number. Since r = -.285 falls on the critical value of r interval of -.381 to .381 the null hypothesis is accepted at the .05 level of significance and the number -.285 is not significant at the .05 level of significance.

A regression analysis for redox potential was conducted at the .95 confidence level using the redox value of the stream water for each sampling point in the CJC as the independent variable. The total number of each salamander species for each sampling point in the CJC was used as the dependant variable. The analysis indicated a negative correlation with an r-value of -.098 (Figure 20). To determine if this correlation was significant, the r-value was tested using the null hypothesis at the .05 level of significance. The null hypothesis was that there was no significance to the correlation coefficient (r) number. Since r = -.098 falls on the critical value of the r interval of -.576 to .576 the null hypothesis is accepted at the .05 level of significance and the number -.098 is not significant at the .05 level of significance.

A regression analysis for redox potential was conducted at the .95 confidence level using the redox value of the stream water for each sampling point in the LVA as the independent variable. The total number of each salamander species for each sampling point in the LVA was used as the dependant variable. The analysis indicated a negative correlation with an r-value of -.024 (Figure 21). To determine if this correlation was significant, the r-value was tested using the null hypothesis at the .05 level of significance. The null hypothesis was that there was no significance to the correlation coefficient (r) number. Since r = -.024 falls on the critical value of the r interval of -.514 to .514 the null hypothesis is accepted at the .05 level of significance and the number -.024 is not significant at the .05 level of significance.

A regression analysis for redox potential was conducted at the .95 confidence level using the redox value of the stream water for each sampling point in the CJC and the LVA as the independent variable. The total number of each salamander species for each sampling point in the CJC and the LVA was used as the dependant variable. The analysis indicated a negative correlation with an r-value of -.082 (Figure 22). To determine if this correlation was significant, the r-value was tested using the null hypothesis at the .05 level of significance. The null hypothesis was that there was no significance to the correlation coefficient (r) number. Since r = -.082 falls on the critical value of the r interval of -.381 to .381 the null hypothesis is accepted at the

.05 level of significance and the number -.082 is not significant at the .05 level of significance.

DISCUSSION AND CONCLUSION

In comparing the mean catch-per-unit-effort totals for salamanders sampled in the CJC to the mean catch-per-unit-effort totals for salamanders sampled in the LVA, there appear to be significant differences in both total population numbers and in total numbers of each of the three dominant species between the two sites.

The CJC appears to have significantly larger numbers of salamanders in all the spring fed springs sampled than the LVA. In fact, three of the five streams in the LVA failed to produce a single salamander over the entire course of this study. The total numbers for each of the species in the CJC also appears to be significantly greater than the species totals in the LVA.

In order to validate the data being recorded in the LVA, fifty meter long transects were established in the stream channels of two LVA streams which had not produced any salamanders (12&13). Every rock in each stream channel along the transect was turned over and examined for evidence of salamanders. No salamanders were found in either stream. This exercise was repeated in the CJC, establishing transects in streams 2&3. The majority of the rocks that were turned over had salamanders hiding underneath. The total number of salamanders counted in each stream was between 60-80 salamanders.

Statistical analyses of the results from the Hydrolab water testing were unable to detect any significant correlation between the parameters tested and the numbers of salamanders sampled in the water of each of the streams. It was thought that differences in pH or turbidity levels or the amount of dissolved oxygen might account for population differences, but that was not the case. The pH levels of all the streams ranged from 4.94 - 6.90, with the mean pH being 5.71. Salamanders were found in streams on the lower end of the pH scale, (4.94), and on the upper end of the scale (6.03) and no discernible relationship between pH and population levels could be detected. The turbidity levels in all streams was zero, and the percentage of dissolved oxygen ranged from a low of 6.3% to a high of 18.6%, with the mean percentage of dissolved oxygen (DO) being 12.03%. Some streams with higher levels of dissolved oxygen such as sites 2, 4, 5 and 8 with respective DO percentages of 12.4, 14.8, 12.3 and 16.2 had large salamander populations while other sites (12, 13) with the same or even higher levels of DO didn't have any salamanders. Specific conductance and redox parameters for each of the streams were also analyzed statistically, but no correlation could be found between them and the numbers of salamanders in each of the streams. As a result, the data obtained from the Hydrolab water testing could not be used to demonstrate a significant correlation between the tested water parameters and the total numbers of salamanders and salamander species sampled in each of the streams.

Previous land usage practices in the Lower Valley Area may be the primary reason for the differences in populations between the CJC and the LVA particularly farming activities. Before Callaway Gardens purchased the LVA property, the farming of cotton continued for many decades in the Lower Valley Area. Much of the industry in the neighboring counties of Troup and Muscogee during this period (1900-1950) was involved with the spinning of cotton and the operation of cotton mills (Schubert 1964). As a result, much of the surrounding arable land was used for cotton farming.

During the period 1930-1960 various chemical fertilizers, herbicides, pesticides and fungicides were used to improve the fertility of the cotton fields and control weeds and insect pests such as the boll weevil, which were a continuous problem for cotton farmers (Berg 1982). Several of these chemical compounds were soluble in water and included arsenic and mercury as ingredients, which are highly toxic to all forms of aquatic life (Berg 1982). The list of common pesticides which were available at the time included DDT, Paraquat, and Paris Green (which is no longer manufactured). These pesticides included chemicals such as mercuric chloride, copper sulfate, cuprous oxide, methyl parathion and other highly toxic, persistent chemicals (Berg 1982). There was also little guidance at the time on how these chemicals (pesticides, herbicides) were to be applied, where they were to be applied and in what dosages. In referring to the toxicity of these chemicals, the Farm Chemical Handbook warns that many can be easily absorbed through the skin and are highly toxic (Berg 1982).

Dr. Franz Froelicher, a Chemist with the U.S. Army Corps of Engineers, Savannah District explained that Paris Green was one of the commonest pesticides used during this period for cotton farming, and was one of the most toxic since it contained arsenic (personal communication). Dr. Froelicher is very familiar with agricultural pesticides, in addition to being a chemist with the Corps of Engineers, his father was a noted chemist who helped develop DDT during World War II as a delousing agent.

A photograph of the LVA taken during the 1940s or 1950s which was made available by Callaway Gardens shows an area of dry parched farmland soils, depleted of moisture, with rills and gullies indicating significant surface runoff. A chemical analysis of the water in each of the CJC and LVA streams needs to be conducted to determine if toxic metals such as mercury and arsenic or other chemical residues from pesticides and herbicides are responsible for the small salamander population in the LVA.

Other land usage activities, which have occurred in the LVA, include controlled burns and timber harvesting. The records concerning these activities and the timeframes of when and where they occurred are not well documented. Generally speaking, land use management activities which occurred more than fifteen years ago are difficult to document (L. Creighton, personal communication). Interviews with Callaway officials and subsequent communications revealed that the land management activities of the past 10-12 years are well recorded. Land management activities such as tree removal, controlled burns and road improvements have been conducted in the LVA within the past ten years. During the 18 months of this study at Callaway evidence of both controlled burns and road improvements in the LVA have been witnessed.

Several studies on the effect of timber harvesting on woodland salamander populations have indicated that woodland salamander populations can be severely impacted by timber harvesting, particularly clear cutting (Raymond, L.R. and L.M. Hardy 1991, Petranka et al. 1993, Petranka 1994). Yet a recent study concerning the disappearance and return of *Plethodontid* salamanders to clear-cut plots in the Southern Blue Ridge Mountains indicates that timber harvesting may not have a lasting impact on salamander populations (Ash 1997). Populations of *plethodontid* salamanders which were reduced as a result of commercial timber harvesting were shown to have rebounded in a period of 5-7 years after the timber harvesting.

Removal of dead and diseased trees and commercial timber harvesting are management practices which have been conducted in the LVA in the past ten years. But the frequency of these past activities was low and current records indicate that the commercial timber removal occurred in sections of the LVA that did not impact the spring-fed streams which were part of this study.

Based on all the information that was gathered as a result of this study and from communications with the land management officials at Callaway Gardens, it is proposed that the differences in salamander populations and species richness between the CJC and the LVA could be linked to the cotton farming history of the LVA. Cotton was farmed in the LVA for several decades, and the persistent toxic chemical pesticides and herbicides which were typically used, may still be having an adverse effect on wildlife today.

Chemical analyses of the water and the sediment in each of the streams of the CJC and LVA that were included in this study needs to be completed in order to determine if pesticides or herbicides or other farm related chemicals are the reason for the differences between the total numbers and species richness of salamanders in the CJC and the LVA.

Figure 4: Total number of all salamanders sampled in the CJC by sampling point.

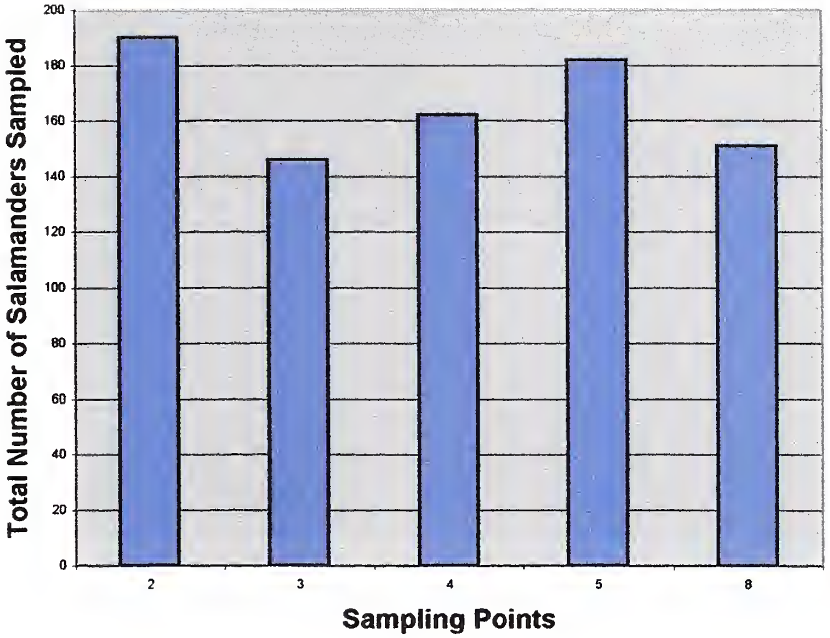

Total Number of Salamanders Sampled
200
180
160
140
120
100
80
60
40
20
0
2
3
4
5
8
Sampling Points

Figure 5: Mean catch-per-unit-effort totals for each sampling point in the CJC.

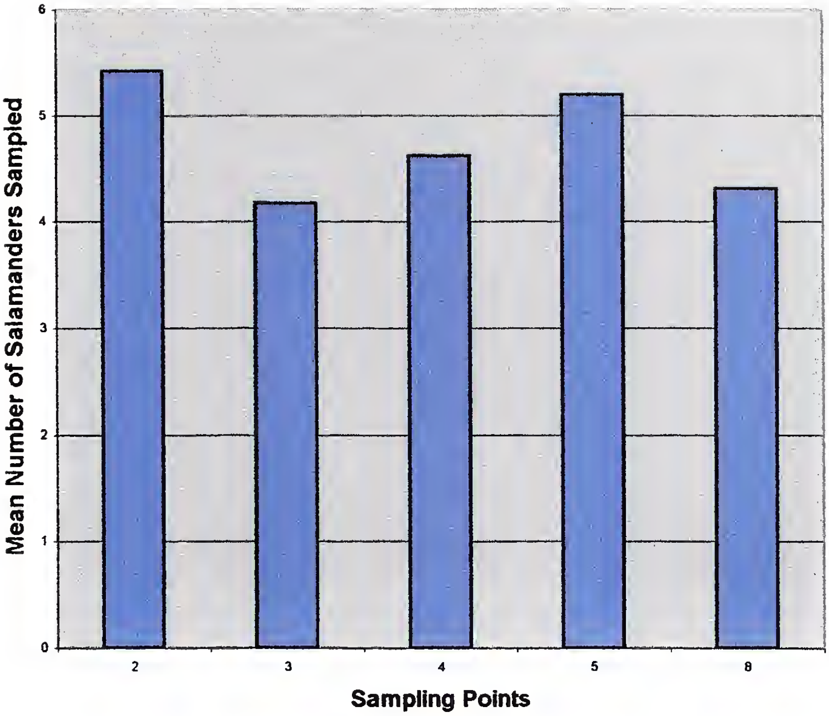

Mean Number of Salamanders Sampled
6
5
4
3
2
1
0
2
3
4
5
8
Sampling Points

Figure 6: Total number of salamanders sampled in the LVA by sampling point.

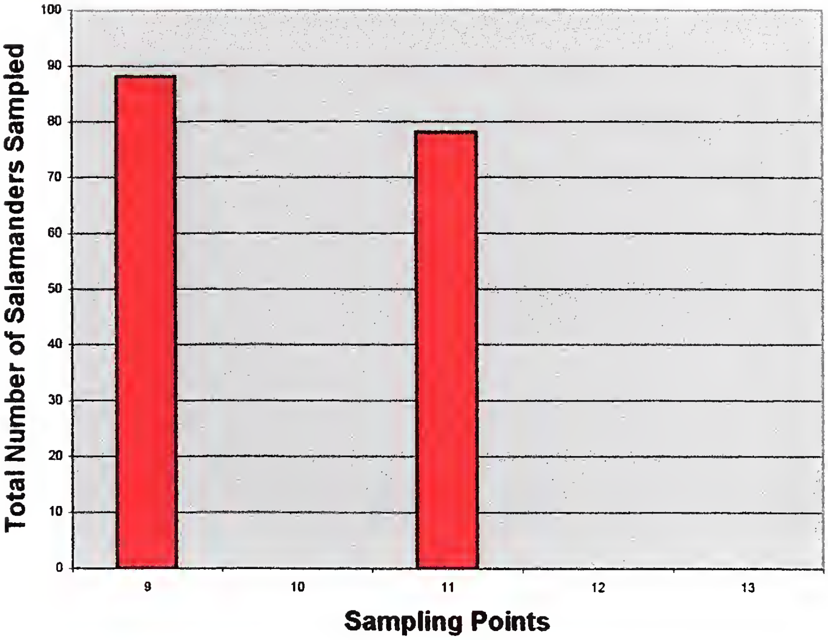

Total Number of Salamanders Sampled
100
90
80
70
60
50
40
30
20
10
0
9
10
11
12
13
Sampling Points

Figure 7: Mean catch-per-unit-effort totals for each sampling point in the LVA.

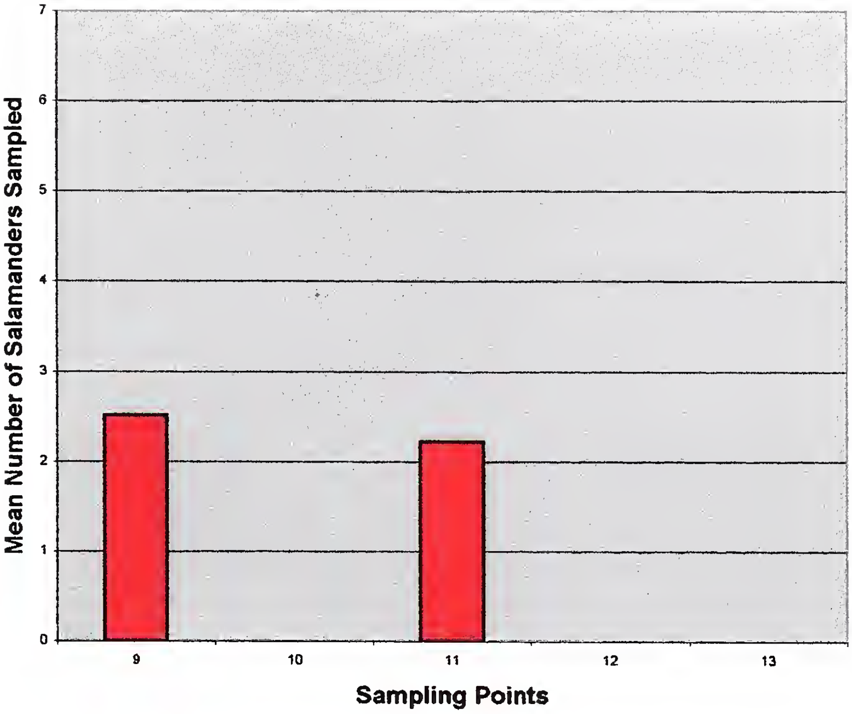

Mean Number of Salamanders Sampled
0
1
2
3
4
5
6
7
9
10
11
12
13
Sampling Points

Figure 8: Comparison of the total number of salamanders sampled in the CJC and LVA by sampling point

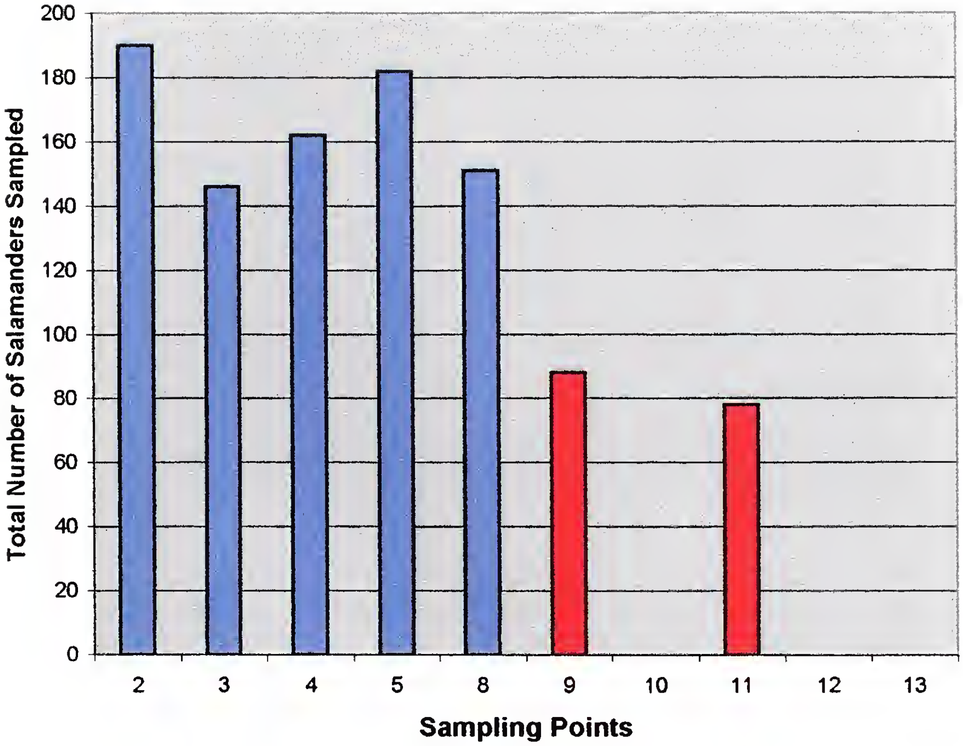

200
180
160
140
120
100
80
60
40
20
0
Total Number of Salamanders Sampled
2
3
4
5
8
9
10
11
12
13
Sampling Points

Figure 9: Mean catch-per-unit-effort totals for each species sampled in the CJC .

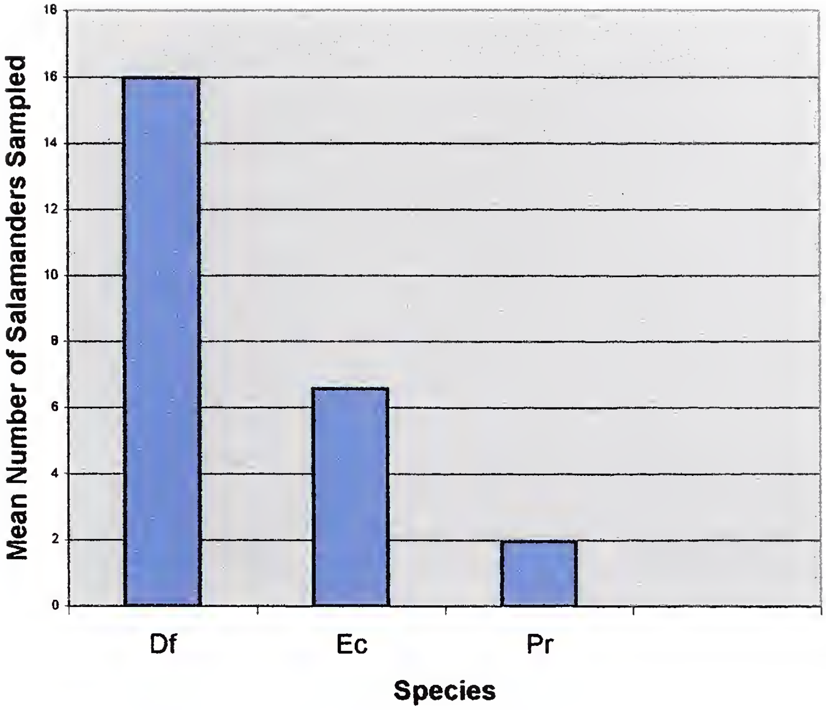

Mean Number of Salamanders Sampled
18
16
14
12
10
8
6
4
2
0
Df
Ec
Pr
Species

Figure 10: Mean catch-per-unit-effort totals for each species in the LVA.

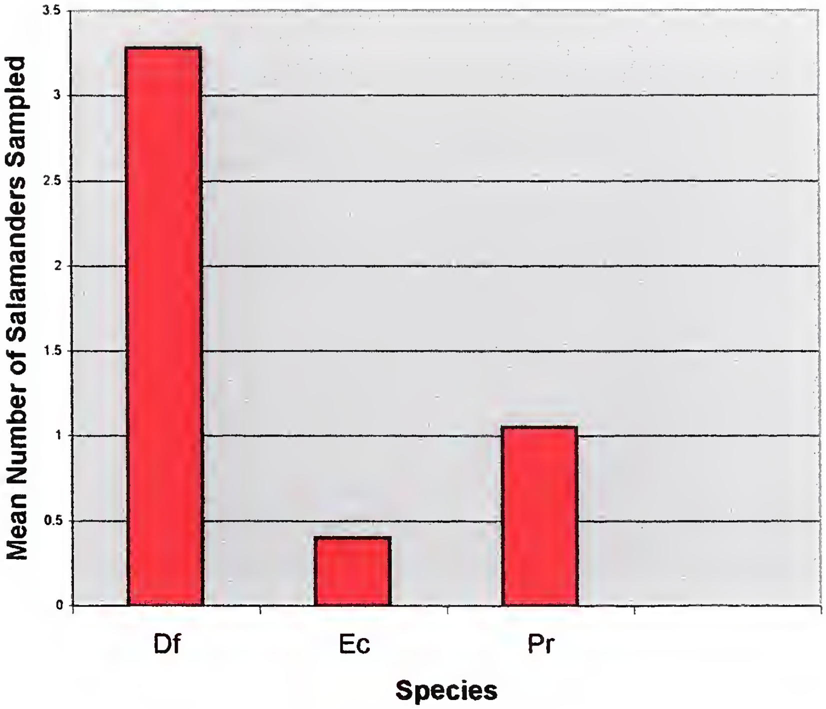

Mean Number of Salamanders Sampled
3.5
3
2.5
2
1.5
1
0.5
0
Df
Ec
Pr
Species

Figure 11: CJC Regression Analysis for pH using species totals for each sampling point.

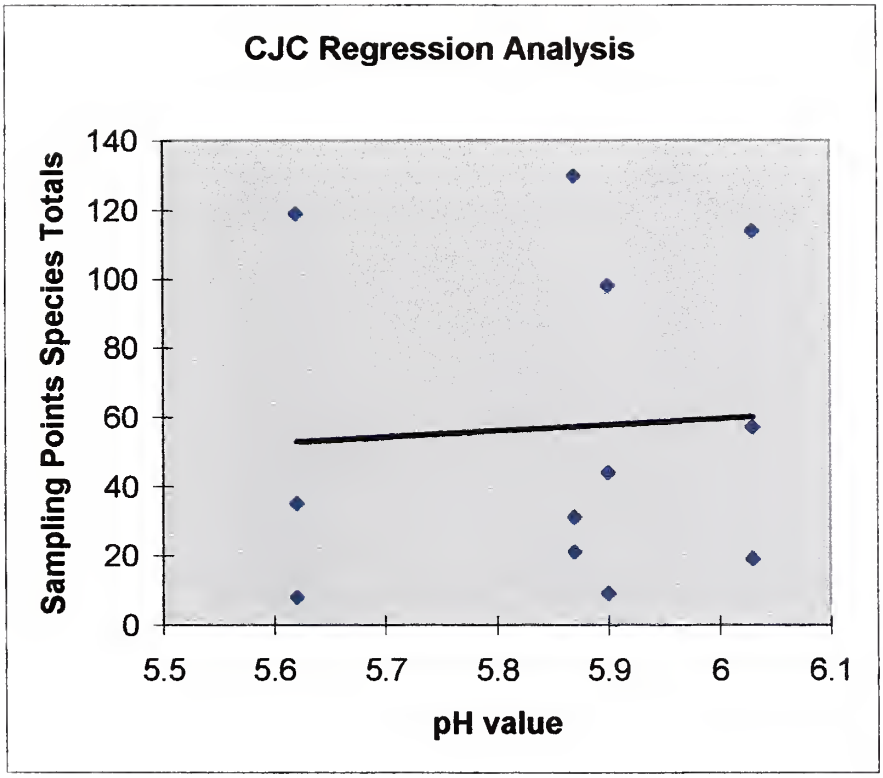

CJC Regression Analysis
Sampling Points Species Totals
140
120
100
80
60
40
20
0
5.5
5.6
5.7
5.8
5.9
6
6.1
pH value

Figure 12: LVA Regression Analysis for pH using species totals for each sampling point.

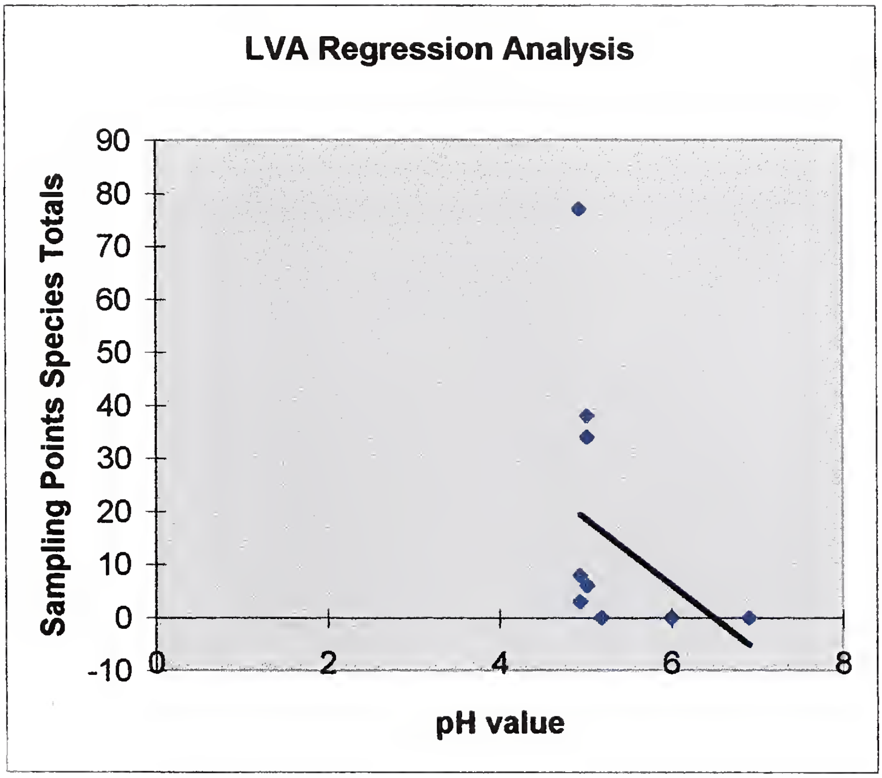

LVA Regression Analysis
Sampling Points Species Totals
90
80
70
60
50
40
30
20
10
0
-10
0
2
4
6
8
pH value

Figure 13: CJC and LVA Regression Analysis for pH using species totals for each sampling point.

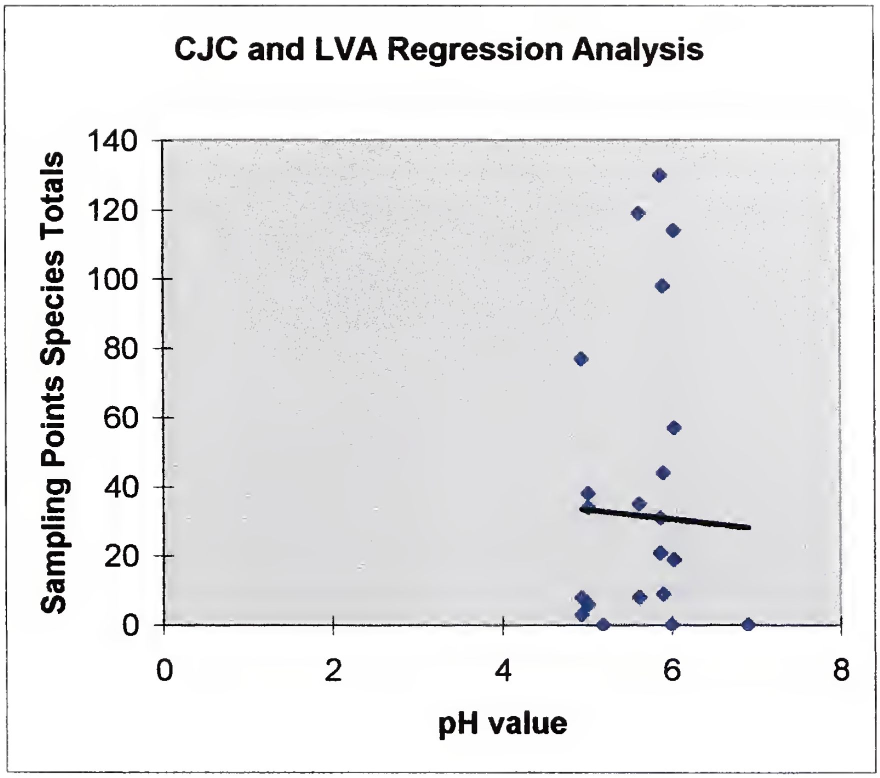

CJC and LVA Regression Analysis
Sampling Points Species Totals
140
120
100
80
60
40
20
0
0
2
4
6
8
pH value

Figure 14: CJC Regression Analysis for Dissolved Oxygen using species totals for each sampling point.

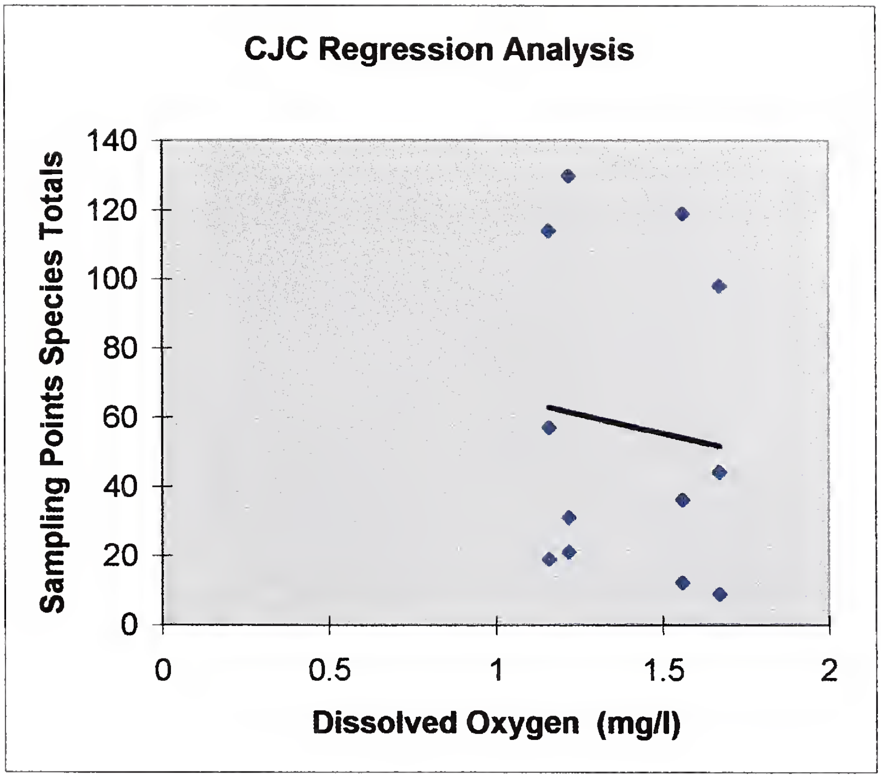

CJC Regression Analysis
Sampling Points Species Totals
140
120
100
80
60
40
20
0
0
0.5
1
1.5
2
Dissolved Oxygen (mg/l)

Figure 15: LVA Regression Analysis for Dissolved Oxygen using species totals for each sampling point.

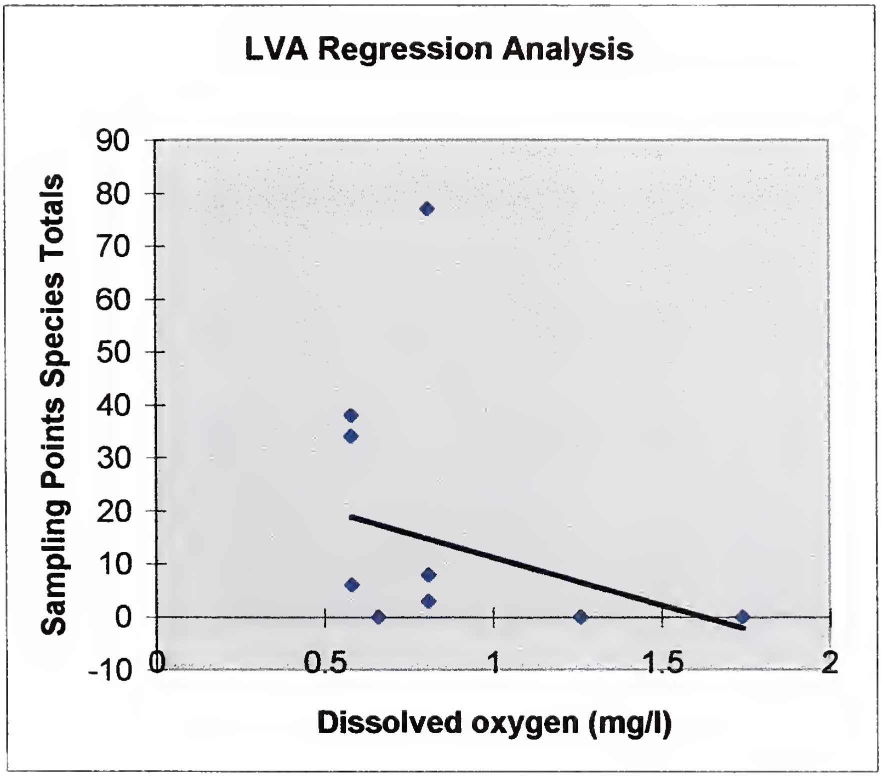

LVA Regression Analysis
Sampling Points Species Totals
90
80
70
60
50
40
30
20
10
0
-10
0
0.5
1
1.5
2
Dissolved oxygen (mg/l)

Figure 16: CJC and LVA Regression Analysis for Dissolved Oxygen using species totals for each sampling point.

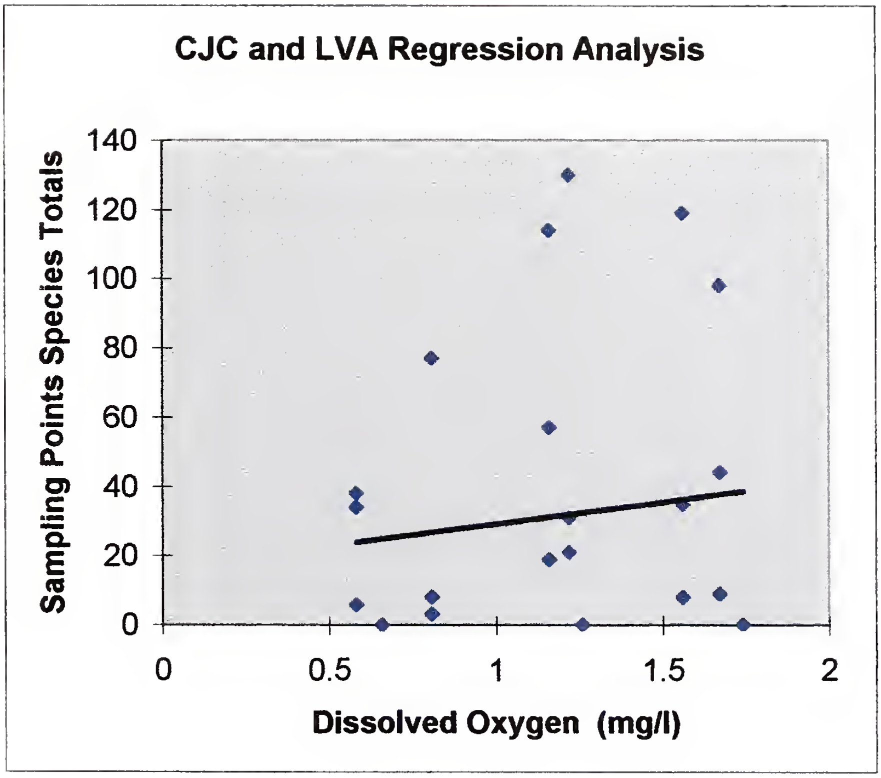

CJC and LVA Regression Analysis
Sampling Points Species Totals
140
120
100
80
60
40
20
0
0
0.5
1
1.5
2
Dissolved Oxygen (mg/l)

Figure 17: CJC Regression Analysis for Specific Conductance using species totals from each sampling point.

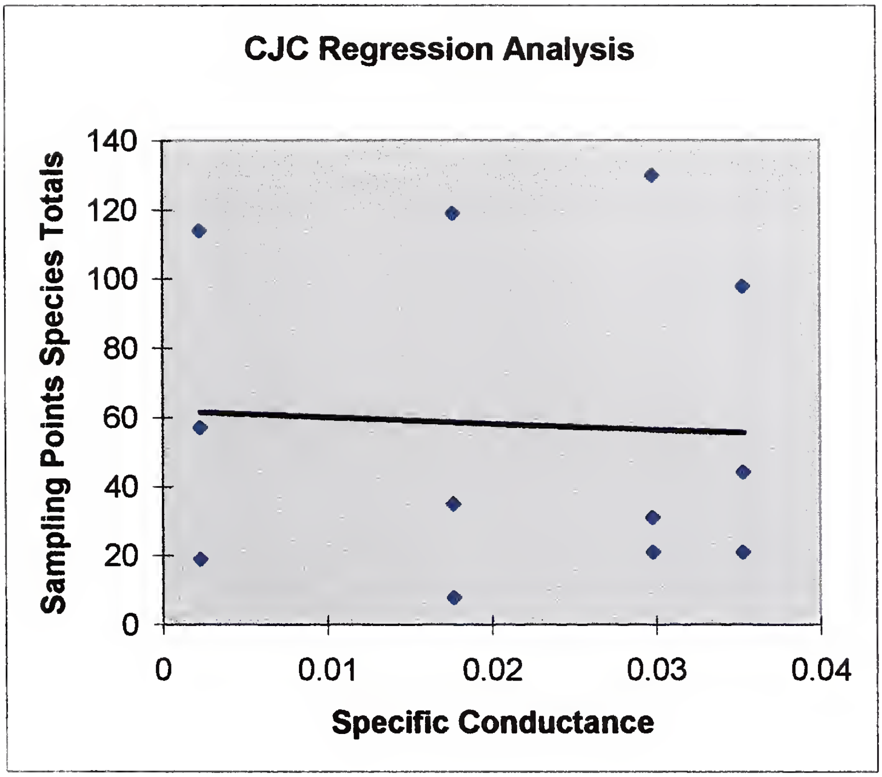

CJC Regression Analysis
Sampling Points Species Totals
140
120
100
80
60
40
20
0
0
0.01
0.02
0.03
0.04
Specific Conductance

Figure 18: LVA Regression Analysis for Specific Conductance using species totals for each sampling point.

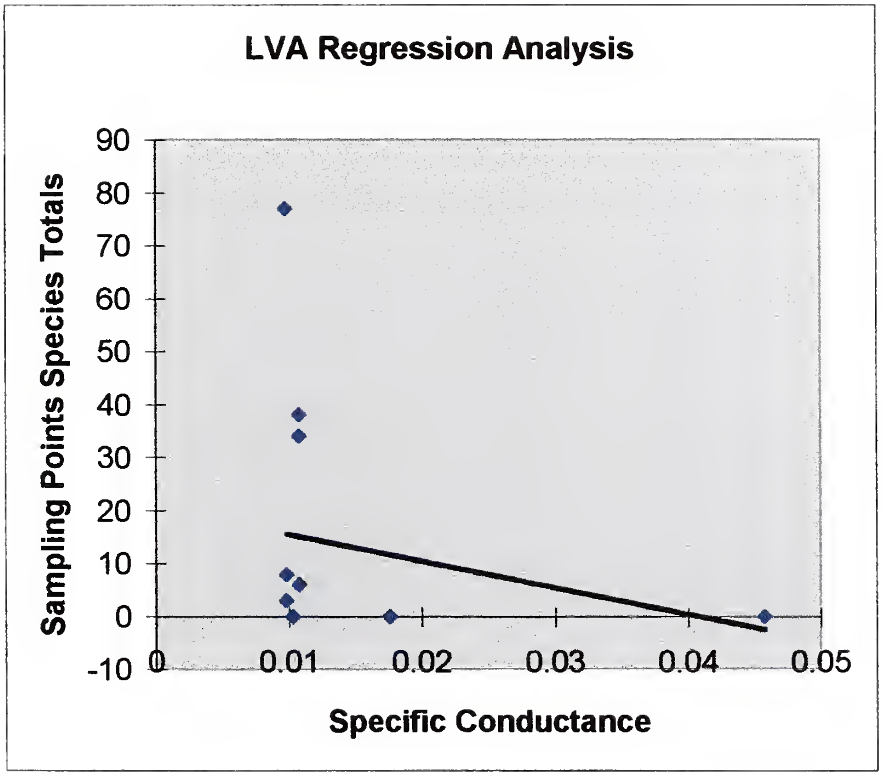

LVA Regression Analysis
Sampling Points Species Totals
90
80
70
60
50
40
30
20
10
0
-10
0
0.01
0.02
0.03
0.04
0.05
Specific Conductance

Figure 19: CJC and LVA Regression Analysis for Specific Conductance using species totals for each sampling point.

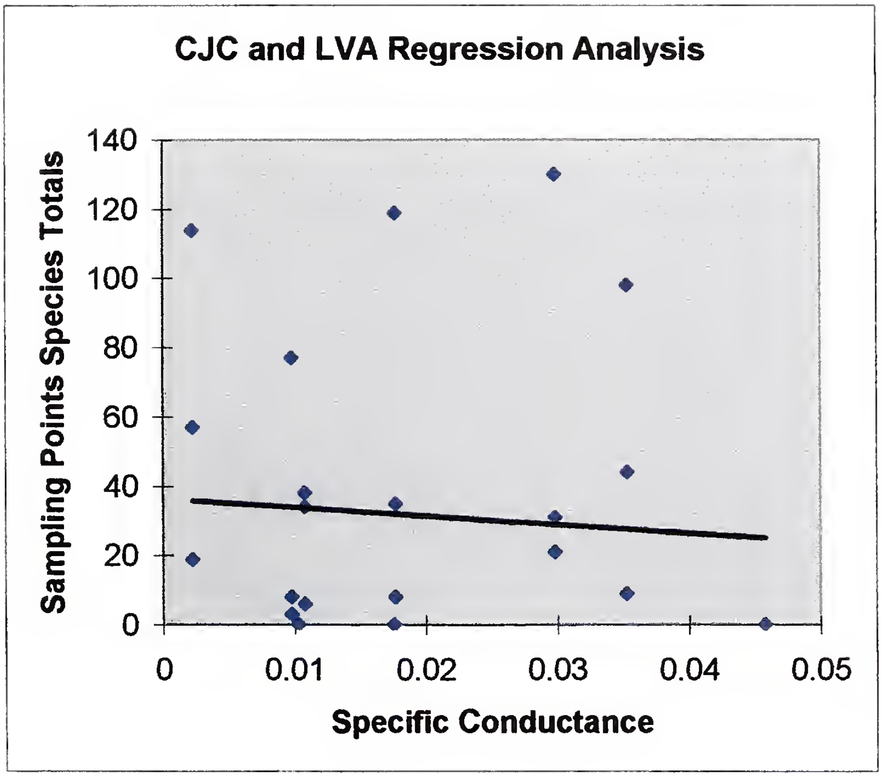

CJC and LVA Regression Analysis
Sampling Points Species Totals
140
120
100
80
60
40
20
0
0
0.01
0.02
0.03
0.04
0.05
Specific Conductance

Figure 20: CJC Regression Analysis for Redox using species totals for each sampling point.

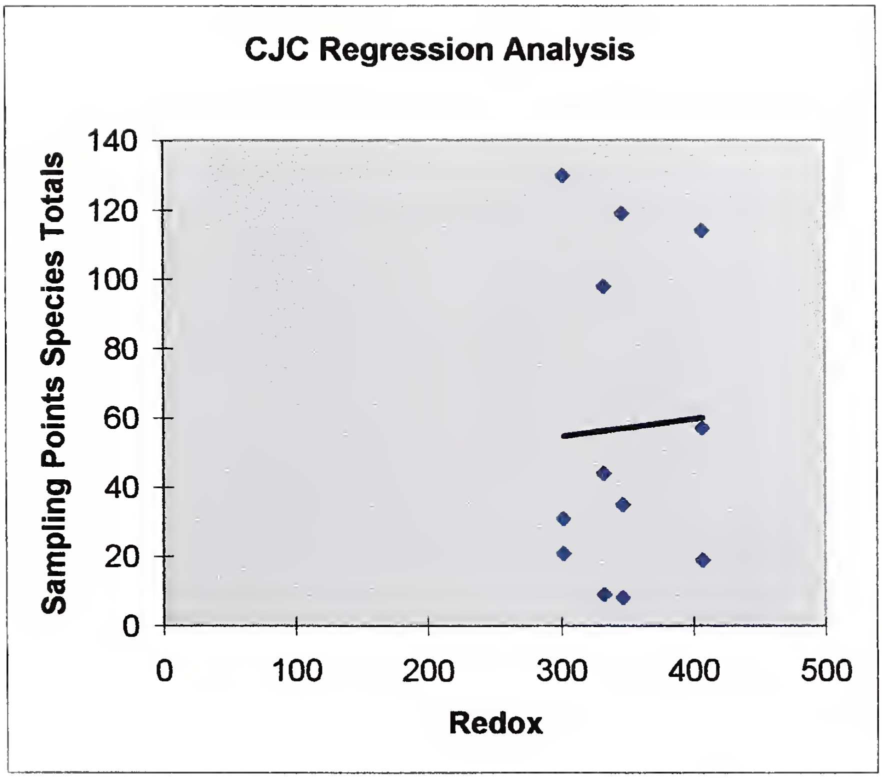

CJC Regression Analysis
Sampling Points Species Totals
140
120
100
80
60
40
20
0
0
100
200
300
400
500
Redox

Figure 21: LVA Regression Analysis for Redox using species totals for each sampling point.

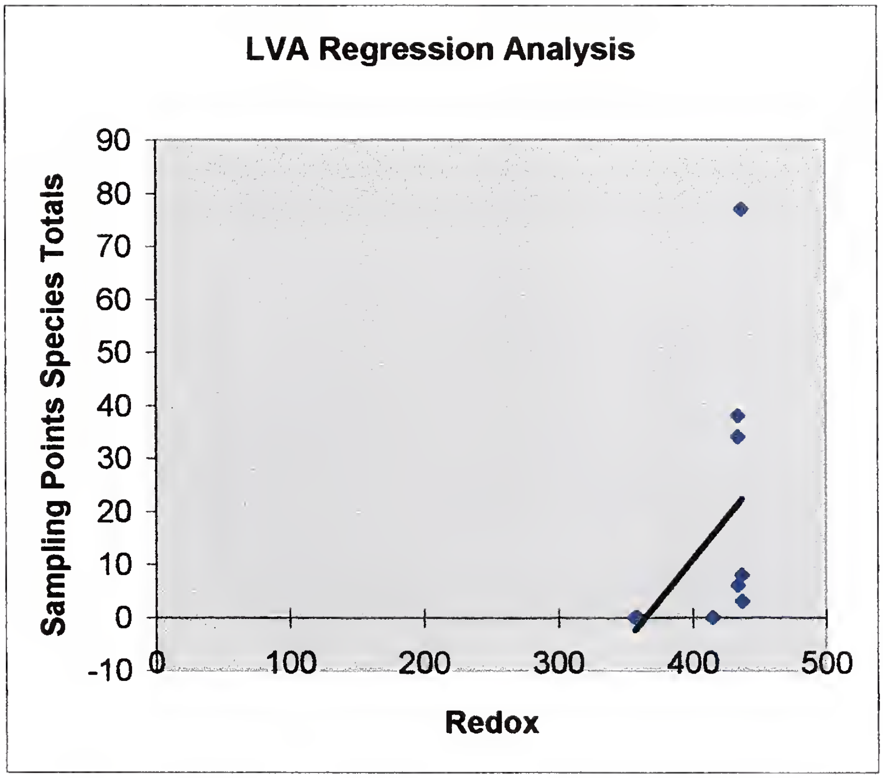

LVA Regression Analysis
Sampling Points Species Totals
90
80
70
60
50
40
30
20
10
0
-10
0
100
200
300
400
500
Redox

Figure 22: CJC and LVA Regression Analysis for Redox using species totals for each sampling point.

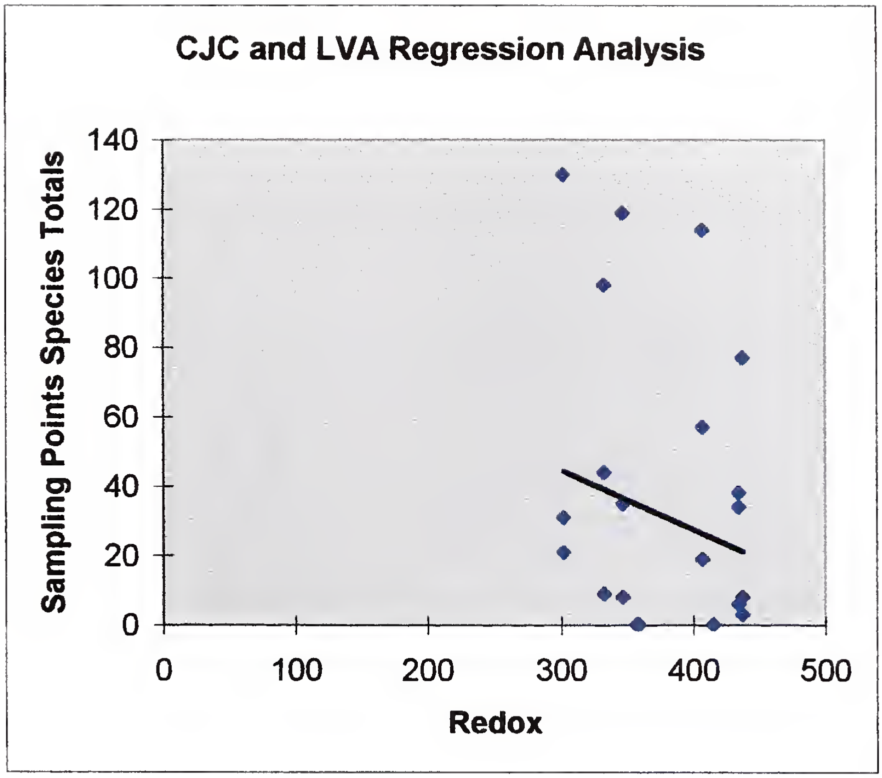

CJC and LVA Regression Analysis
Sampling Points Species Totals
140
120
100
80
60
40
20
0
0
100
200
300
400
500
Redox

Table 1: Potential salamander species at Callaway Gardens.

Potential Salamander Species at Callaway Gardens

(Provided by John Jensen a non-game biologist, Georgia Environmental Protection Division)

Family Ambystomatidae

Ambystoma maculatum
Ambystoma opacum

Family Plethodontidae

Desmognathus fuscus
Desmognathus monticola
Eurycea cirrigera
Eurycea guttolineata
Gyrinophilus porhyriticus
Hemidactylium scutatum
Plethodon glutinosus
Plethodon serratus
Plethodon websteri
Pseudotriton montanus
Pseudotriton ruber

Table 2: List of salamanders sampled in the Cason J. Callaway Memorial Forest.

TABLE OF SALAMANDERS SAMPLED IN THE CJC

Sampling pt.	2			3			4			5			8			
Species	D. fuscus	E.cirrigera	P.ruber	D. fuscus	E.cirrigera	P .ruber	D. fuscus	E.cirrigera	P.ruber	D. fuscus	E.cirrigera	P .ruber	D. fuscus	E.cirrigera	P .ruber	Total
Sampling Date Week of:																
11/5/2000	4	1	1	3	1	0	5	2	2	6	1	2	4	3	2	37
11/12/2000	0	0	0	2	0	1	0	0	2	3	0	0	3	0	0	11
11/19/2000	2	1	1	4	3	1	6	1	0	7	1	1	6	3	0	37
12/2/2000	1	0	0	3	0	0	2	1	0	0	1	0	4	2	0	14
12/9/2000	2	2	2	0	0	0	2	0	0	7	0	2	2	0	0	19
12/16/2000	5	2	0	2	0	1	6	2	1	4	1	0	5	3	0	32
1/15/2001	0	0	0	2	0	0	2	0	0	0	0	0	3	0	0	7
1/21/2001	4	3	2	5	2	1	2	2	0	4	0	0	7	3	0	35
1/28/2001	5	0	0	2	0	0	6	0	0	3	1	1	2	0	0	20
2/18/2001	1	2	1	4	0	0	1	0	0	2	0	0	2	0	0	13
2/25/2001	4	0	0	2	0	0	3	1	0	0	0	0	0	0	0	10
3/10/2001	3	7	0	3	1	0	5	1	0	7	0	0	1	0	0	28
3/17/2001	3	0	0	1	0	0	7	0	0	8	2	0	1	0	0	22
3/24/2001	4	2	0	4	0	0	6	0	0	6	1	1	3	0	0	27
4/1/2001	8	2	1	4	0	0	0	2	0	9	2	1	1	1	1	32
4/8/2001	4	0	0	3	0	0	2	0	0	5	1	1	0	0	0	16

TABLE OF SALAMANDERS SAMPLED IN THE CJC (CONTINUED)

Sampling pt.	2			3			4			5			8			
Species	D. fuscus	E.cirrigera	P ruber	D. fuscus	E.cirrigera	P .ruber	D. fuscus	E.cirrigera	P.ruber	D. fuscus	E.cirrigera	P .ruber	D. fuscus	E.cirrigera	P .ruber	Total
Sampling Date Week of:																
4/15/2001	2	0	0	0	0	0	4	0	0	1	2	0	2	0	0	11
4/22/2001	2	1	0	1	0	0	2	2	0	5	1	5	0	0	1	20
4/29/2001	8	0	0	3	0	0	3	0	0	5	2	0	1	6	0	28
5/6/2001	3	2	1	5	1	0	5	2	0	6	0	1	2	1	1	30
5/20/2001	4	1	0	3	2	0	4	1	0	4	2	1	2	3	0	27
5/26/2001	5	0	0	2	2	0	2	0	0	2	0	0	2	0	0	15
6/3/2001	3	3	1	5	2	0	2	3	0	3	3	2	4	1	1	33
6/10/2001	4	0	0	0	0	0	5	0	0	3	0	0	4	0	0	16
6/17/2001	4	3	4	3	4	3	0	1	1	2	0	0	6	2	0	33
6/30/2001	4	4	0	3	4	1	2	2	0	4	0	1	3	0	0	28
9/8/2001	4	4	2	3	2	2	4	4	0	2	1	1	6	5	0	40
9/16/2001	3	6	1	2	3	0	7	0	0	3	0	0	3	1	1	30
9/23/2001	6	2	0	5	1	0	5	2	1	3	2	0	2	2	0	31
9/30/2001	0	0	0	6	0	0	6	0	0	0	2	0	4	2	1	21
10/13/2001	0	2	0	1	2	0	0	1	0	3	0	1	4	1	0	15
10/21/2001	6	0	1	3	0	0	2	2	1	2	0	0	5	2	0	24
11/4/2001	3	2	0	2	3	0	4	0	0	4	1	0	0	0	0	19
11/25/2001	0	2	1	3	0	1	4	2	0	7	3	0	4	0	0	27
1/12/2002	3	3	0	4	3	1	3	1	0	0	1	0	0	3	1	23
Total	114	57	19	98	36	12	119	35	8	130	31	21	98	44	9	831

Mean total sampled 23.74

Table 3: List of salamanders sampled in the Lower Valley Area.

LIST OF SALAMANDERS SAMPLED IN THE LOWER VALLEY AREA

Sampling pt.	9			10			11			12			13			
Species	D. fuscus	E.cirrigera	P.ruber	D. fuscus	E.cirrigera	P .ruber	D. fuscus	E.cirrigera	P.ruber	D. fuscus	E.cirrigera	P .ruber	D. fuscus	E.cirrigera	P.ruber	Total
Sampling Dates Week of:																
11/5/2000	3	1	0	0	0	0	0	0	2	0	0	0	0	0	0	6
11/12/2000	2	0	0	0	0	0	1	0	2	0	0	0	0	0	0	5
11/19/2000	1	0	0	0	0	0	1	0	1	0	0	0	0	0	0	3
12/2/2000	2	0	0	0	0	0	0	0	1	0	0	0	0	0	0	3
12/9/2000	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3
12/16/2000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1/15/2001	4	0	0	0	0	0	3	1	0	0	0	0	0	0	0	8
1/21/2001	4	0	0	0	0	0	1	0	1	0	0	0	0	0	0	6
1/28/2001	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	3
2/18/2001	2	0	0	0	0	0	0	0	2	0	0	0	0	0	0	5
2/25/2001	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1
3/10/2001	1	0	2	0	0	0	0	0	0	0	0	0	0	0	0	3
3/17/2001	2	0	0	0	0	0	0	0	2	0	0	0	0	0	0	4
3/24/2001	3	0	0	0	0	0	0	0	1	0	0	0	0	0	0	4
4/1/2001	2	0	0	0	0	0	1	0	1	0	0	0	0	0	0	4
4/7/2001	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1
4/15/2001	4	0	0	0	0	0	2	0	0	0	0	0	0	0	0	6
4/22/2001	3	0	0	0	0	0	1	0	0	0	0	0	0	0	0	4
4/29/2001	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	2

LIST OF SALAMANDERS SAMPLED IN THE LOWER VALLEY AREA (CONTINUED)

Sampling pt.	9			10			11			12			13			
Species	D. fuscus	E.cirrigera	P.ruber	D fuscus	E.cirrigera	P .ruber	D fuscus	E.cirrigera	P.ruber	D. fuscus	E.cirrigera	P .ruber	D fuscus	E.cirrigera	p.ruber	Total
Sampling Date Week of:																
5/6/2001	2	1	0	0	0	0	0	0	1	0	0	0	0	0	0	4
5/20/2001	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	2
5/26/2001	3	0	0	0	0	0	0	0	1	0	0	0	0	0	0	4
6/3/2001	0	0	0	0	0	0	1	0	2	0	0	0	0	0	0	3
6/10/2001	4	1	0	0	0	0	2	0	0	0	0	0	0	0	0	7
6/16/2001	5	0	0	0	0	0	3	0	1	0	0	0	0	0	0	9
7/1/2001	3	1	0	0	0	0	2	0	0	0	0	0	0	0	0	6
9/8/2001	0	0	0	0	0	0	3	0	1	0	0	0	0	0	0	4
9/16/2001	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4
9/22/2001	3	1	0	0	0	0	2	1	2	0	0	0	0	0	0	9
9/30/2001	6	0	1	0	0	0	4	1	1	0	0	0	0	0	0	13
10/13/2001	1	1	0	0	0	0	1	1	1	0	0	0	0	0	0	5
10/21/2001	2	0	0	0	0	0	1	2	3	0	0	0	0	0	0	8
11/4/2001	4	0	0	0	0	0	1	0	0	0	0	0	0	0	0	5
11/25/2001	2	1	0	0	0	0	0	0	3	0	0	0	0	0	0	6
1/13/2002	1	1	0	0	0	0	1	0	4	0	0	0	0	0	0	7
Total	77	8	3	0	0	0	38	6	34	0	0	0	0	0	0	166

Mean Total Sampled 4.74

Table 4: Mean catch-per-unit-effort salamander totals for the CJC and LVA.

CASON J. CALLAWAY MEMORIAL FOREST

SP	Total Sampled	Mean Catch-Per Unit-Effort Total	Total Sampled by species			Mean Catch-Per Unit-Effort Total by Species		
			Df	*Ec*	*Pr*	*Df*	*Ec*	*Pr*
2	190	5.42	114	57	19	3.25	1.62	.54
3	146	4.17	98	36	12	2.80	1.02	.34
4	162	4.62	119	35	8	3.40	1.00	.23
5	182	5.20	130	31	21	3.71	.89	.60
8	151	4.31	98	44	9	2.80	1.25	.26

LOWER VALLEY AREA

SP	Total Sampled	Mean Catch-Per Unit-Effort Total	Total Sampled by species			Mean Catch-Per Unit-Effort Total by Species		
			Df	*Ec*	*Pr*	*Df*	*Ec*	*Pr*
09	88	2.51	77	8	3	2.20	0.23	0.09
10	0	0.0	0	0	0	0.0	0.0	0.0
11	78	2.22	38	6	34	1.08	0.17	0.97
12	0	0.0	0	0	0	0.0	0.0	0.0
13	0	0.0	0	0	0	0.0	0.0	0.0

SP indicates Sampling Point, *Df*, *Desmognathus fuscus*, *Ec*, *Eurycea cirrigera*; *Pr*, *Pseudotriton ruber*

Table 5: Comparison of Hydrolab testing data for the water at all sampling sites.

RESULTS OF HYDROLAB TESTING

Sampling Points	ph	Temp C	Turbidity NTU	Specific Conductance	Redox	D.O. mg/l	% D.O.
2	6.03	2017	0	.0023	407	1.16	12.4
3	x	x	x	x	x	x	x
4	5.62	16.08	0	.0177	347	1.56	14.8
5	5.87	16.99	0	.0298	302	1.22	12.3
8	5.90	17.01	0	.0353	333	1.67	16.2
9	4.94	16.47	0	.0098	437	0.81	8.6
10	5.19	15.84	0	.0103	415	0.66	6.9
11	5.02	17.23	0	.0108	434	0.58	6.3
12	6.90	18.08	0	.0458	357	1.74	18.6
13	6.00	16.31	0	.0176	359	1.26	12.2

x – water level too low to use Hydrolab for testing

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