LONG POINT WORLD BIOSPHERE RESERVE PLETHODON CINEREUS MONITORING PROGRAM: DATA ANALYSIS

JOINT EMAN / PARKS CANADA NATIONAL MONITORING PROTOCOL FOR PLETHODONTID SALAMANDERS

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1.0 INTRODUCTION

The continuing loss of biological diversity is a major problem in ecological communities across the world. Many species and genetic populations have already gone extinct and many more are now on the decline, some of which we are likely unaware of. As a result, many levels of species and ecosystem diversity require active management. The root of the word monitoring is "to warn" and one essential purpose of monitoring is to raise a warning flag that the current course of action is not working (Elzinga *et. al.,* 2001). As such, monitoring is serving an increasingly important role in conserving species by evaluating trends in populations.

The monitoring of some species provides more than beneficial information regarding the state of their own population. The trends demonstrated by some species are representative of the trends occurring at the greater ecosystem level. These species are known as indicator species, and are valuable to society as environmental indicators. "An environmental indicator is a tool for translating and delivering concise scientifically valid environmental information in a way that can be used and understood by decision makers and the general public" (Stone, 2002).

A group of species increasingly used as environmental indicators to determine ecosystem health are Plethodontid salamanders (Degraaf, 1992; Droege, 1997; Hartwell et al., 2001; Zorn & Blazeski, 2002). Salamanders are a significant part of many forested ecosystems and their loss or decline may have consequences affecting many other plant and animal species. Numbers and biomass alone dictate that the effects of changes in their populations would cascade throughout the forest as their invertebrate prey and vertebrate predators adjust (Droege *et al.,* 1997). Woodland plethodontids are useful indicator species of forest health because they are sensitive to a range of ecological stressors, particularly those that influence microclimate and air and water quality (Droege *et al.,* 1997).

Their importance and attractiveness as indicators has initiated a number of terrestrial salamander monitoring projects across North America. One such example is the Long Point World Biosphere Reserve Terrestrial Salamander Monitoring Program. The Ecological Monitoring and Assessment Network (EMAN) initiated this study five years ago and data have been collected every year since. Important data have been collected every spring, summer and fall including salamander location, type and size. However, the data and salamander populations have never been analyzed and therefore trends occurring within plethodontid populations may have been going unnoticed. The main purpose of this project was to work in an ongoing partnership with both EMAN and Parks Canada to organize and analyze the 5 years of monitoring data of the salamander, *Plethodon cinereus* (Eastern Redback Salamander).

2.0 BACKGROUND INFORMATION

It is important to understand some of the key players and concepts involved in the project before going any further. This will set the scene and lead to an understanding of the significance on a larger scale.

2.1 Ecological Monitoring

As previously mentioned, monitoring is becoming an essential tool in ensuring species health and that current management practices are indeed producing the desired effects. For example, monitoring can be utilized to evaluate if mitigation efforts of an environmental assessment are working. Furthermore, monitoring should precede any major environmental project to evaluate it and provide feedback to improve future projects. Monitoring can be defined as "the collection and analysis of repeated observations or measurements to evaluate changes in condition and progress toward meeting a management objective" (Elzinga *et. al*., 2001).

Without monitoring there is no way of identifying trends in species populations early in the process while something can still be done to reverse them. It promotes a proactive approach rather than waiting until a species or ecosystem is already in peril before reacting, and is a trend in the right direction to protecting our valuable natural resources.

"*A monitoring program's primary functions are to warn of impending population problems, to direct conservation management (activities, monies), and to generate hypotheses for research. Without such a monitoring network, populations can collapse to the point that conservation and management options become limited and expensive*" (Droege *et al*., 1997).

2.2 PLETHODON CINEREUS

Plethodon cinereus (*P. cinereus)* is a member of the Plethodontidae family, which are all lungless salamanders that rely on keeping their skin moist and the top of their mouth for respiration. They are also entirely terrestrial, meaning that in no stage of their life cycle do they rely on an aquatic environment, such as for reproduction. Instead they reproduce in moist cover objects, such as stumps, found on the forest floor. Mating occurs in both spring and fall and eggs are laid from June to July in grape-like clumps of three to twelve pea-sized eggs. The young are born as miniature versions of the adults from August to early September.

There are three different variations of *P. cinereus;* the red backed, lead backed, and erythristic form (Cook, 1984). In most localities, the 'redback' morph comprises 75% of all individuals (Lamond, 1994). The erythristic form is by far the rarest, and for the purposes of this project, all three morphs were evaluated as *P. cinereus,* rather than evaluating each morph independently. *P. cinereus* are numerous in eastern Canada wherever white pine, northern hemlock or deciduous woodland remains (Cook, 1984). They live in damp wooded areas where they hide in decaying logs or stumps, as well as leaf litter, pieces of bark and stones (Froom, 1982). During cool, moist, calm weather, usually in the evenings in the spring and fall, they disperse across the forest floor to satisfy their requirements for feeding, courting and mating (Droege *et al*., 1997). They also have stable populations due to long life spans, high survival rates and low birth rates, all which help make them good indicator species.

There are a number of other characteristics that make plethodontid salamanders very attractive as an indicator species; below is a list adopted from Droege *et al* (1997).

1. Their key roles and high densities in many forests
2. Stability in their counts and populations
3. Vulnerability to air and water pollution
4. Their sensitivity as a measure of change
5. The threatened and endangered status of several species across North America
6. Their inherent beauty and appeal as a creature to study and conserve
7. The ease with which they can be caught and handled without injuring the animal or significantly impacting their habitat.

2.3 The Long Point Terrestrial Salamander Monitoring Program

The site of the monitoring project, Long Point World Biosphere Reserve is described by Ontario Parks as follows:

"This park is part of a 40-kilometre-long sandspit in Lake Erie which is recognized as a biosphere reserve by the United Nations. It is a world-renowned refuge and stopover for migrating birds in fall and spring. Waterfowl viewing is excellent in March. Its delicate dunes and marshes also teem with songbirds, spawning fish, turtles and frogs" (Ontario Parks, 2002. http://www.ontarioparks.ca/long.html).

There are two plots presently monitored near the Long Point World Biosphere Reserve, Backus and Wilson woods. Backus is Old Growth Carolinian forest whereas Wilson was logged 25 years ago and is presently a managed Carolinian forest (Craig, 2002). Monitoring in both woodlots relies on an arrangement of Artificial Cover Boards (ACOs). ACOs are typically wooden boards placed on bare soil on the forest floor.

Figure 1: ACO at Long Point World Biosphere Reserve

According to Zorn and Blazeski (2002) ACOs of any type of wood can be used provided that it is consistent over time, and the board is flat and non-layered. Initial ACO placement consists of 40 boards arranged in a 20 by 20 meter quadrant (Zorn and Blazeski, 2002). Both the Backus and Wilson plots have two sets of perimeter boards. One set in each plot was placed directly on the mineral soil and the other was placed on leaves, so that a Bias Test could one day be conducted (Craig, 2002).

The boards used in both monitoring plots are unfinished, untreated white pine. The relative sizes of the boards vary depending if the boards are on the interior or perimeter of the plot. However, the composition of different sized boards is equal in both plots to avoid any type of bias. These boards are never to be placed closer to each other than five meters or within 50 meters of the edge of the forest (Droege, 1999). There are a number of advantages and disadvantages associated with ACO sampling. See Table 1 below.

Table 1: Advantages and Disadvantages of ACO sampling

ACO AMPHIBIAN SAMPLING	
Advantages	Disadvantages
1. Standard number of cover items of standard size	1. Provides only an index of population size
2. Little between-observer variability	2. Use of artificial cover may vary among different species
3. Limited Disturbance to cover items	3. Counts may vary with local weather conditions
4. Modest investment of time and money to establish transects	4. Cover boards may be difficult to locate in habitats with fast-growing vegetation.
5. Limited training required	
6. Easy maintenance of cover items	

(Davis, 1994)

During the first three years in both plots, data collection began each year immediately after the spring thaw, through to and including the final week before winter freeze up. However, as will be discussed in the results section, during the last two years of the program, fewer months have been monitored. ACOs at each given plot are sampled once a week to avoid disturbance and trampling to the plot. At each plot a number of variables are recorded while sampling. These include: name of sampler, species and number of salamanders under each board, snout to vent length, vent to tail length and total length of each salamander, date, ACO number and disturbance to ACO (if any). Below is a picture of a *P. cinereus* specimen being measured.

Figure 2: Measuring *P. cinereus*

2.4 EMAN

EMAN has created a national network of long-term monitoring sites that strive to provide a national perspective on how Canadian ecosystems are being affected at a larger ecozone scale (Zorn and Blazeski, 2002).

"The main goal of EMAN is to improve understanding of ecosystem changes in Canada. – what is changing and why by examining integrated data and knowledge sets. The network is moving towards the ability to report on ecological changes and providing interdisciplinary and/or inter-jurisdictional assessments of ecosystem status, trends and processes on an ecozone or national basis. EMAN faces a continuing challenge to produce science-based and policy-relevant reports on ecological status and trends in a

timely fashion - better linking of science to decision-making" (Environment Canada, 2002).

The National Plethodontid Salamander Monitoring Program will provide another outlet to their expansive network of monitoring sites. This addition also provides them with another indicator from which to compare different populations at different sites across the country.

2.5 Parks Canada

Parks Canada's number one priority in the management of its parks is the maintenance or restoration of ecological integrity (Canadian National Parks Act, 2000), which by Parks Canada's (2001) definition means:

"An ecosystem has integrity when it is deemed characteristic for its natural region, including the composition and abundance of native species and biological communities, rates of change and supporting processes." In plain language, ecosystems have integrity when they have their native components (plants, animals and other organisms) and processes (such as growth and reproduction) intact".

The National Plethodontid Salamander Monitoring Program will provide Parks Canada with another tool to fulfill their priority of preserving, or where necessary restoring, ecological integrity.

3.0 OBJECTIVES

The primary objectives of this study involved the data analysis of both woodlots near Long Point. This included the population counts and the size measurements. There are also a few other associated objectives that were met over the course of the project. Below is a short list followed by detailed explanations of each of the objectives that were accomplished.

- Results of monitoring question
- Analysis of size trends
- Critical thinking about collective data
- Evaluation of National Monitoring Protocol for Plethodontid Salamanders
- Testing of protocols' data organizing and analysis tool on an excel spreadsheet

3.1 MONITORING QUESTION

The monitoring question that has been designed by EMAN for both plots near Long Point is as follows: "Is an index of population size (counts) of plethodontids changing more than +/- 15% over a 5 year period at the Long Point World Biosphere Reserve or +/- 3% per year"?

This question is to be evaluated both individually between Backus and Wilson woods and with the two combined to compare the trends. The data needs to be evaluated against the criteria in the monitoring question to reveal if there is any real significance. Therefore, it will be calculated and compared for each individual year and over the five years as a whole. Data sets can also be compared between Backus and Wilson on the basis that Backus is a representative old growth forest whereas Wilson is considered a managed forest.

3.2 Analysis of Size Trends

As previously discussed, each salamander is measured after being captured. For each amphibian, snout to vent length (SVL), vent to tail length (VTL) and total length are measured. Mathis (1990) suggested that the longer a salamander's SVL and tail length are, the healthier the salamander is. Thus SVL will be a worthwhile statistic to evaluate. For the purposes of this data set analysis all three categories will be calculated and compared for all five years individually and combined.

3.3 Critical Thinking

Beyond analyzing the data with respect to the monitoring question, between SVL and VTL, and within and between monitoring plots, other trends and possible relationships were evaluated. The excel spreadsheet provided some basic feedback, beyond this, the data was organized and thoroughly evaluated through critical thinking. It was hypothesized that there would be other important trends that could be identified beyond what the study was designed to detect and that these data would lead to a proper explanation of the overall population trends. Some of the other questions that were looked into included the following: Are bigger or more salamanders found during certain months or years? What were the conditions during these years that might have led to some of the trends? One of the means by which some of the data involving the microclimate conditions was obtained, was the Wilson Climate Tower Station, located within the Wilson woodlot. This station provided valuable daily air and soil temperatures over the first four years of the study.

3.4 Monitoring Protocol Evaluation

One of the intended design features of the National Plethodontid Salamander Monitoring Protocol is that it is set up to assist volunteers from high schools, universities and the general community to implement monitoring stations of their own. However, to ensure that this is feasible, the protocol must be easy to understand while ensuring that no important details are left out. If it does not meet these criteria, then there is a good chance that monitoring plots or designs will be set up incorrectly thus invalidating the data obtained from the results. The protocol is nearly complete and required some feedback to ensure it would in fact be understandable to the public. Aside from personal observations and some additional points by Greg Michalenko, Ted Cheskey of the Wrigley's corner Outdoor Education Center provided some feedback. The outdoor education center was selected because they have likely had experience organizing community events and may understand what is unclear about the protocol.

3.5 Testing Excel Spreadsheet

The excel spreadsheet designed by Paul Zorn from Parks Canada, is designed to accept data from other terrestrial ACO salamander monitoring programs. The idea is to create a template that can allow data input from any plethodontid monitoring study to be analyzed in the exact same format. However, the sheet had previously not been tested for any practical use involving real monitoring studies. As such, this study operated as a pilot study from which the kinks and flaws of the spreadsheet were assessed and mitigated.

4.0 SIGNIFICANCE

Although there have been a number of initiatives to start monitoring programs across the country, in too many instances the data sets collected are never analyzed. This renders all the work that went into the monitoring program virtually useless. Data sets are few, scattered, research-rather than monitoring-oriented, and largely unpublished, consequently providing almost no help in detailing regional status. (Droege *et al*., 1997). Statistics are very important to sample based monitoring. They enable us to make management decisions even when there is only access to part of the information (Elzinga *et al., 2001).* Without proper analysis the very trends that monitoring programs are initiated to detect go unnoticed.

Sampling Backus woods near Long Point World Biosphere Reserve

An increasing or stable number of salamanders indicates that the forest's balance of invertebrates, leaf litter, moisture, pH, debris, burrows, and other habitat features were positive, while declines would signal shifts opposite to the needs of the species and their ecosystem.

"Hopefully such declines would adequately forewarn us to begin searching for the root causes and take action to reverse the damage. Given their longevity and low fecundity, as well as the stability of a forest soil environment, changes in salamander populations are much more likely to represent significant environmental changes than any other group of North American amphibians" (Droege et al., 1997).

5.0 RESULTS

5.1 LITERATURE REVIEW

5.1.1 Impacts on Populations and Distribution

The purpose of this portion of the literature review was to gain an understanding of what factors can cause fluctuations in *P. cinereus* populations and distribution on the forest floor. By gaining a broad understanding of these various impacts and important behavioural characteristics, there is a greater opportunity to identify certain cause-effect relationships when analyzing the data.

5.1.2 Effects of Silvicultural Practices and Edges

Within the literature there is extensive research on different environmental factors that influence *P. cinereus* distribution. Due to their lack of lungs, their skin must remain constantly moist or they lose the ability to transfer oxygen. When moving on the surface they can become dehydrated even when the air is saturated with moisture (Feder, 1983). Logging, insect defoliation, development, and canopy fires all can reduce population levels indirectly through loss of soil moisture, exposure to sun, or the compaction and disruption of soils (Welsh and Droege 2001, DeMaynadier 1995). In direct contrast, salamanders achieve their highest densities in ancient or undisturbed forests (Herbeck & Larsen, 1999; DeMaynadier & Hunter, 1998; Meier *et al.,* 1996; Welsh, 1990; Herrington & Larsen, 1985; Blymer & McGinnes, 1977).

Previous studies have shown that factors such as temperature, moisture, and available cover have an effect on plethodontid salamanders (Heatwole, 1962; Spotila, 1972; Feder & Pough, 1975; Jaeger 1972, 1979, 1980; Feder, 1983; Feder & Londos, 1984; DeMaynadier & Hunter, 1998; Herbeck & Larsen, 1999). Regeneration or 'selective' cutting reduces microhabitats for salamanders because temperatures increase and surface moisture decreases with the elimination of forest canopy (Bury, 1983; Ash, 1988; Raphael, 1988; Welsh, 1990; Petranka et al., 1994; Ash, 1997; Herbeck & Larsen, 1999; Blymer & McGinnes, 1977; Messere and Ducey, 1998).

Some of these studies have found *P. cinereus* to be greatly affected by fragmented edges and the loss of mature undisturbed forests. For instance, Herbeck and Larsen (1999) found that Redback salamander densities were much higher and more stable in mature forests than second growth forests, and even significantly lower in regeneration-cut sites. DeMaynadier and Hunter (1998) found *P. cinereus* to be the most sensitive of 15 amphibians in their study of edge effects and clear cutting. They found 71.4% of the captures to be under closed-canopy conditions opposed to open canopy conditions along the edge. They also recognized that there were more immature animals observed in recently harvested areas, which suggests that open-canopy sites may serve as a habitat for non-breeding salamanders that are constantly pressured out of one habitat to another and excluded from mature forest territories (Mathis, 1990). This conclusion emphasizes that the smaller populations of Redback's along the edges may also be less healthy.

Although most of the literature supports the notion that mature, unmanaged forests can sustain the highest numbers of *P. cinereus,* some research had conflicting findings. Some found in comparison to other salamander and amphibians, that *P. cinereus* was affected the least by silvicultural and edge effects. Gibbs (1998) also found that amphibians might be especially prone to local extinction resulting from human–caused transformation and fragmentation of their habitats. However, his field surveys revealed that *P. cinereus* was one of two species most resistant to habitat fragmentation. Similarly, Messere and Ducey (1998) found that there was no effect on the floor distribution of *P. cinereus* in relation to canopy gaps following selective logging. This is especially contradictory to other reports because the data were collected the first year after selective logging, which, according to other reports, is the same time that the greatest impact on *P. cinereus* occurs.

5.1.3 Influence of Cover Item

Consistent with the other studies that cite ground moisture as an important factor in *P. cinereus* distribution, Jaeger (1979) researched an important implication. He looked at the behaviour of the salamanders during dry and moist periods on the forest floor. He believes that during dry periods, cover objects on the forest floor become important moisture refuges for terrestrial salamanders. “Foraging is probably restricted to areas under and bordering these objects” (Jaeger, 1972, Pp. 542). He found that during spring surveys, salamanders were clumped together in groups far more often than during drier periods in the summer. He suggests that the aggression and territoriality demonstrated by Plethodontidae (see Thurow, 1976), in relation to food and shelter, may be the cause of the spacing, and as such it is likely that the fitness of the salamander is partly determined by its ability to defend an optimal area, such as a cover object.

Other studies also look at salamander health and size in correlation with cover item size (Jaeger, 1972,1979, 1980, 1988; Roudebush & Taylor, 1987; Mathis, 1990, 1991; Gabor, 1995; Moore et al., 1998). Moore et al. (1998) revealed that *P. cinereus* weight and length was greatest under bigger cover items. Resource quality may have an impact on the distribution and abundance of individuals in an area (Mares & Lacher, 1987). This is consistent with Mathis (1990), who found that larger cover boards yield larger snout to vent length (SVL) salamanders. In this study Mathis found that soil temperatures beneath large cover objects were significantly cooler than the temperatures of soil beneath small cover objects and soil located at random points beneath the litter.

This is significantly correlated to Jaeger’s studies (1972,1980) that state that during dry periods cover objects become an important foraging location and that food is a periodically limiting resource for *P. cinereus*. She also contradicted Jaeger (1982), that larger specimens are superior competitors to small ones in contests over resources. However, Gabor (1995) found that where sunlight heats cover objects on the forest floor, salamanders prefer larger cover objects. On the other hand, where direct sunlight does not heat cover objects, bigger salamanders do not select cover objects based on their sizes but instead by the quality and quantity of food around them.

5.2 Protocol Feedback

The National Monitoring Protocol for Plethodontid salamanders has exceptional potential to produce significant results on plethodontid salamander populations across the country. Once results have accumulated nationally, EMAN will be able to compare and identify any consistent trends at a national level or ecozone scale, as is identified in their mandate. Clearly, this protocol is a step in the right direction and it will be important for EMAN to address the results on a more holistic watershed level rather than across superficial political boundaries. The literature clearly supports plethodontid salamanders for use as indicator species and any trends found within these species will often represent what is happening at the greater ecosystem level. These results should also be compared with other indicator species monitoring programs, such as aquatic amphibian monitoring programs, like Frog Watch.

This protocol will also be a valuable tool for Parks Canada whose present mandate indicates preserving ecological integrity as an important goal. This monitoring protocol along with other monitoring programs will be a crucial proactive step towards moving this goal from paper into action. Once sufficient information is retrieved, trends can be compared across all levels of parks to evaluate the state of ecological integrity in parks and in the case of any significant population trends, figure out what is the cause of the trend. This information should also be used when parks revise their management plans every five years. Specifically, it can be used in park zoning and in visitor management issues.

One of the protocol's most important requirements is to ensure that both community and school groups are able to set up and conduct the monitoring program. The information in the protocol is well researched and should ensure quality-monitoring programs across the country. Whether or not some of the statistical analysis and other more complicated sections of the protocol may be too difficult for the general public to properly comprehend is unclear. The Excel protocol analysis section should suffice for any general trends occurring in the populations and if any further analysis is required, it should be conducted by either EMAN or Parks Canada, or at the least guided by them to ensure accuracy.

Ted Chesky of the Wrigley's Corner Outdoor Education Center of the Waterloo Regional District School Board provided some additional suggestions and concerns he had about the protocol.

- The boards should be spaced further apart to reduce interactions between territorial salamanders.
- Concern was raised as to whether the boards can last for the extended period required for long term monitoring.

- Further concern was raised about vandalism to plots set up in public locations rather than provincial or national parks, where the plot would be more susceptible to interference.
- Animal interference with the board, in particular in more urban areas where pest species such as raccoons are more common, could create problems.
- It was felt that two to three people would not suffice in handling all the responsibilities required to monitor the plot, and that this might be deceiving to potential monitors.

The Microsoft Excel template was designed to provide a location for data input after the monitoring information had been collected. The five years of monitoring data from both Backus and Wilson were slated into the template to test its effectiveness. The instructions were helpful, but it will be important that contact information is provided for anyone using the template to ask questions and ensure they are inputting their data properly. When inputting the Long Point data there were a couple of misunderstandings encountered. Namely, the year has to entered beside every monitoring value, the name entered for the species of salamander needs to be the same for every set of data, the years were not sorting in numerical order and some of the graphs were not displaying the respective values. With some assistance from Paul Zorn, the author of the template, these problems were mitigated effectively. Paul will now take this information and find ways to ensure these problems are clearly addressed for future users of the template.

According to Palys (1997), a good monitoring question must address a specific, researchable question in a particular setting at a given time. The monitoring question for these two plots is appropriately designed because it quantifies what is significant, includes where the question applies to, reveals the specific variable to be evaluated and addresses the time over which the study will be conducted (Kay, 2001).

Although a fifteen percent change in population would certainly indicate a significant change, because *P. cinereus* populations are usually so stable, ten percent might also indicate a significant change. However, after researching the issue and analyzing the data, it has become clear that external conditions (such as the weather) can skew the population data over a five-year period without a negative change actually occurring in the populations. This is largely due to salamanders moving in between different locations based on factors such as temperature and moisture levels. As such, fifteen percent is a realistic number over a five-year period. A ten-year period however, should suffice in reducing any external influencing factors, at which point a ten percent change in the population would likely indicate that something significant was occurring. See the recommendations section at the end of the report for further input.

5.3 DISCUSSION AND ANALYSIS

5.3.1 Monthly Population Trends

Figures 3 and 4 represent the monthly averages of salamanders found per day each month for Backus and Wilson woodlots respectively. Only the months that were sampled consistently over the five-year period were plotted here. In the Backus woodlot five months were sampled in all five years, whereas in Wilson only four were. See Appendix 3.

Both woodlots share similar monthly averages of salamanders per day. Clear trends are noticeable in both graphs, namely, there is a higher per day average in April that slopes downwards in May and then in most years increases in September and then falls again in October. In Backus Woods October and September produced more salamanders per sampling day than any other month. In the Wilson tract, September produced the most, then April followed closely by October.

Figure 3: Backus monthly averages

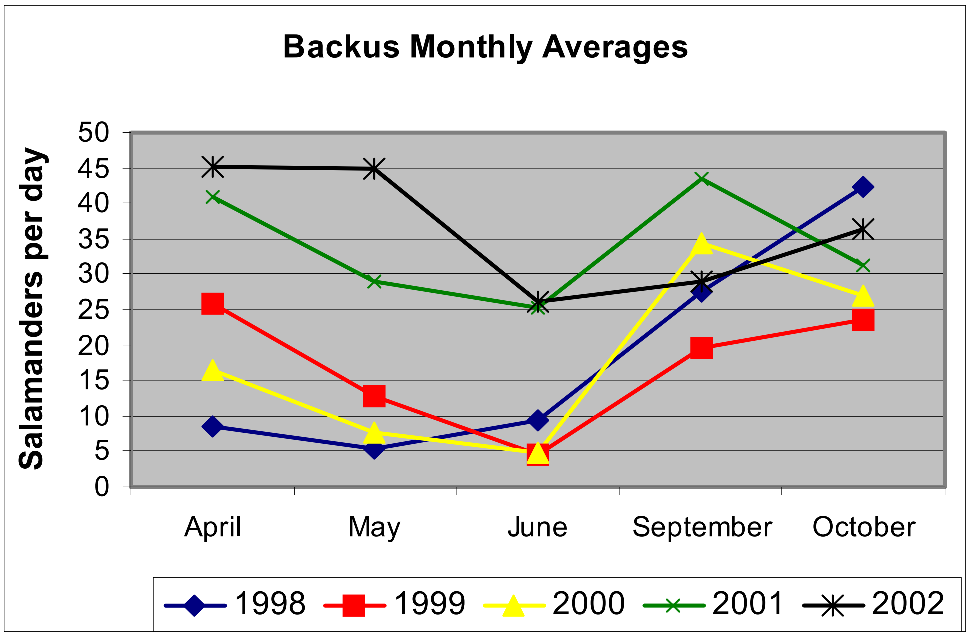
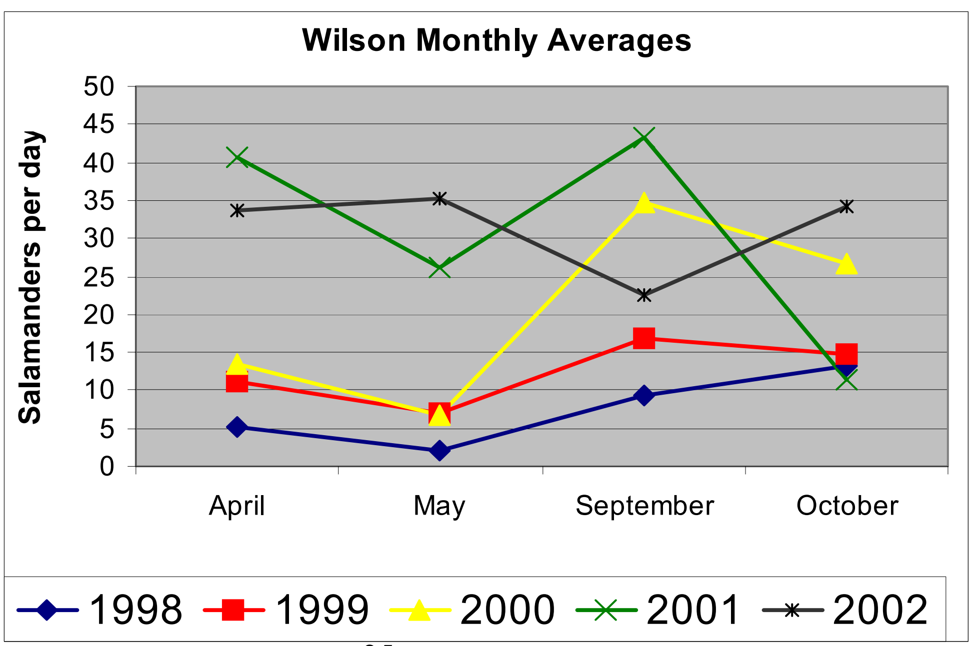


Figure 4: Wilson monthly averages

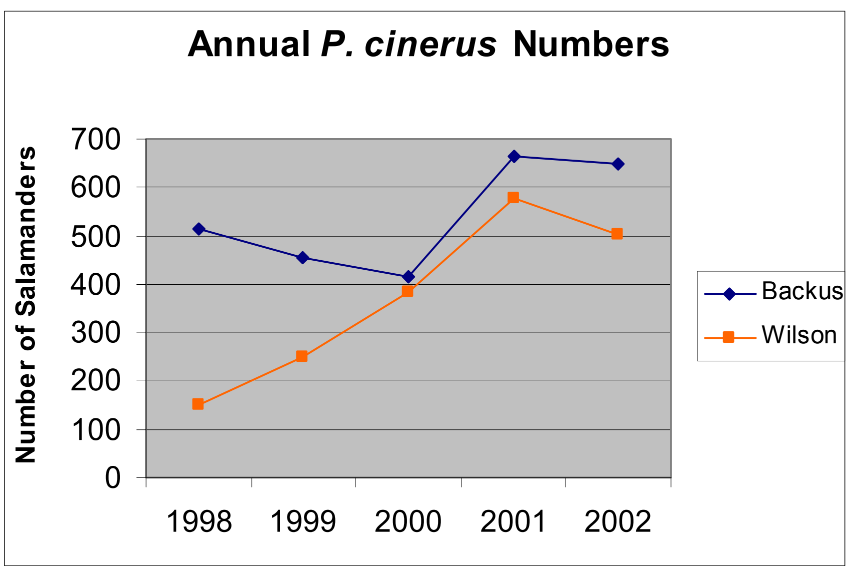


In the Backus woodlot, June had the fewest salamanders sampled per day in every year but 1998. April and May were considerably lower than September and October in 1998 in both Backus and Wilson. This is somewhat of an oddity when compared to the other years. One hypothesis that may account for this is that the cover boards did not have enough time to become suitable as salamander habitat because they were initially placed in the woodlots in August of 1997 (Craig, 2003). Since the boards should have approximately one year to sit in the forest and become more suitable to salamanders (Zorn and Blazeski, 2002), it is conceivable that during April and May of 1998 the ACOs were not yet attracting many salamanders.

5.3.2 Annual Population Trends

The five years of population data is calculated by the excel spreadsheet, however, it was also calculated independently to ensure accuracy. The results were similar in both calculations, which indicates that the excel spreadsheet calculated the proper numbers and that the data being presented here is accurate. The excel spreadsheet and the initial population trend calculations for this analysis focused on the overall salamanders found per year. See Figure 5 for the graphical results and Appendix 1 for the actual numbers.

Figure 5: Overall Annual Salamander Numbers.



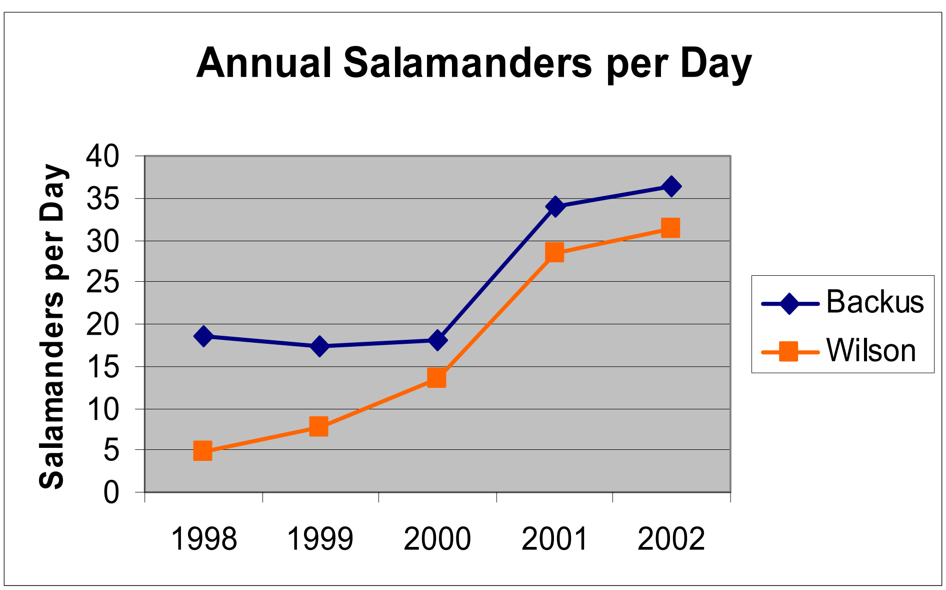
When analyzing the populations in this manner there are some consistent trends between both plots. There is clearly an overall increase over the years and both increase from 2000 to 2001 and decrease from 2001 to 2002. However, there are also some differences between the two woodlots. The numbers of salamanders found in Backus actually decreased from 1998 to 2000 whereas the numbers in Wilson increased all five years. The overall change in salamanders over all five years also varied greatly between the two woodlots. Both increased greater than the fifteen percent change, which was posed in the monitoring question, however, Backus just surpassed it, whereas Wilson was much greater.

However, when evaluating the data, it became clear that certain years had more overall sample days in them than others. Upon calculating these numbers for both woodlots, it became evident that in each year the number of sample days had in fact decreased for both years. For example, in 1998 there were 39 and 38 sample days in Backus and Wilson respectively. These numbers decreased each year until 2002 where there were only 17 and 16 sample days in Backus and Wilson respectively. See Appendix 2 for information that is more detailed. This is largely because as each year passed fewer days were sampled during the warmer summer months, with a greater focus being left on the fall and spring months. In both Wilson and Backus, April and May followed by September and October were the most frequently sampled months over the five years. See Appendix 2. According to Craig (2003) the lack of summer months sampled as the study progressed was due to the decreasing number of salamanders being found. See Appendix 3.

The fact that fewer days were sampled over different years has significant implications for evaluating the population counts. Only looking at the actual number of salamanders found per year such as Figure 5 can be misleading if an unequal effort was put into sampling each year. Instead, it is more accurate to evaluate population trends based on the level of effort that was exerted into sampling the populations each year and erroneous to only look at the overall count regardless of days sampled. Therefore, the analysis of annual population counts for this report will be based on the number of salamanders found per day and as mentioned in the protocol evaluation section, this needs to be addressed in the excel spreadsheet setup.

Once the population counts were evaluated on a salamander per day basis, the trends altered. However, since certain years sampled different months than others, the only way to get a comparable number was to evaluate how many salamanders were found per day based on the months that were sampled consistently for each year. Figure 6 below graphs the population counts based on a per day average for the consistently sampled months.

Figure 6: Annual Counts of Salamanders Found per Day



Evaluating the populations on a per day format produced a number of variances from the overall salamanders per year calculations. The monitoring question results varied a considerable amount when evaluated in the per day format. In Wilson woods the population counts per day increased from 4.8 salamanders a day to 31.44, whereas Backus increased from 18.6 salamanders per day to 36.3. Clearly, both monitoring plots greatly exceeded the fifteen percent suggested in the monitoring question.

The decline in salamanders found from 2001 to 2002 in Figure 5 is actually an increase when evaluated this way. However, it is worth noting that the increase in salamanders sampled between 2001 and 2002, was the smallest increase between years in the entire sampling frame. It also marked the smallest increase between years in Wilson and a considerably smaller increase than the previous 2000 to 2001 increase evident in Backus. This may suggest that the populations have begun to level off in both populations in comparison to the considerable changes that occurred in previous years. However, only continued monitoring in the future will be able to determine if that is the truth.

It has also become evident that the populations have effectively increased every year since the beginning of the sampling frame in 1998 for Wilson and that with the exception of the first three relatively similar years at Backus, it too has been increasing. In both woodlots, the most significant increase occurred between the year 2000 and 2001. The average number of salamanders found in Backus per day jumped from 18.9 to 33.1 and Wilson jumped from 13.55 to 28.46.

The large increase over these two years was the focus of the population count analysis, as it marked the most significant change over all five years in both woodlots. There are a number of possible explanations for the sudden increase in this period and why the overall large population increases, some of which may overlap with each other. One hypothesis worth considering is that the study area actually provided enough additional cover to act as an artifact in attracting salamanders. The monitoring plot may produce higher counts of salamanders than a randomly sampled area elsewhere in the forest because the monitoring plot has become more attractive to *P. cinereus* specimens and attracted and retained a larger than average population. Since salamanders are territorial, once an ideal cover item is found (an ACO), they are likely to remain at that spot and defend it against intruders.

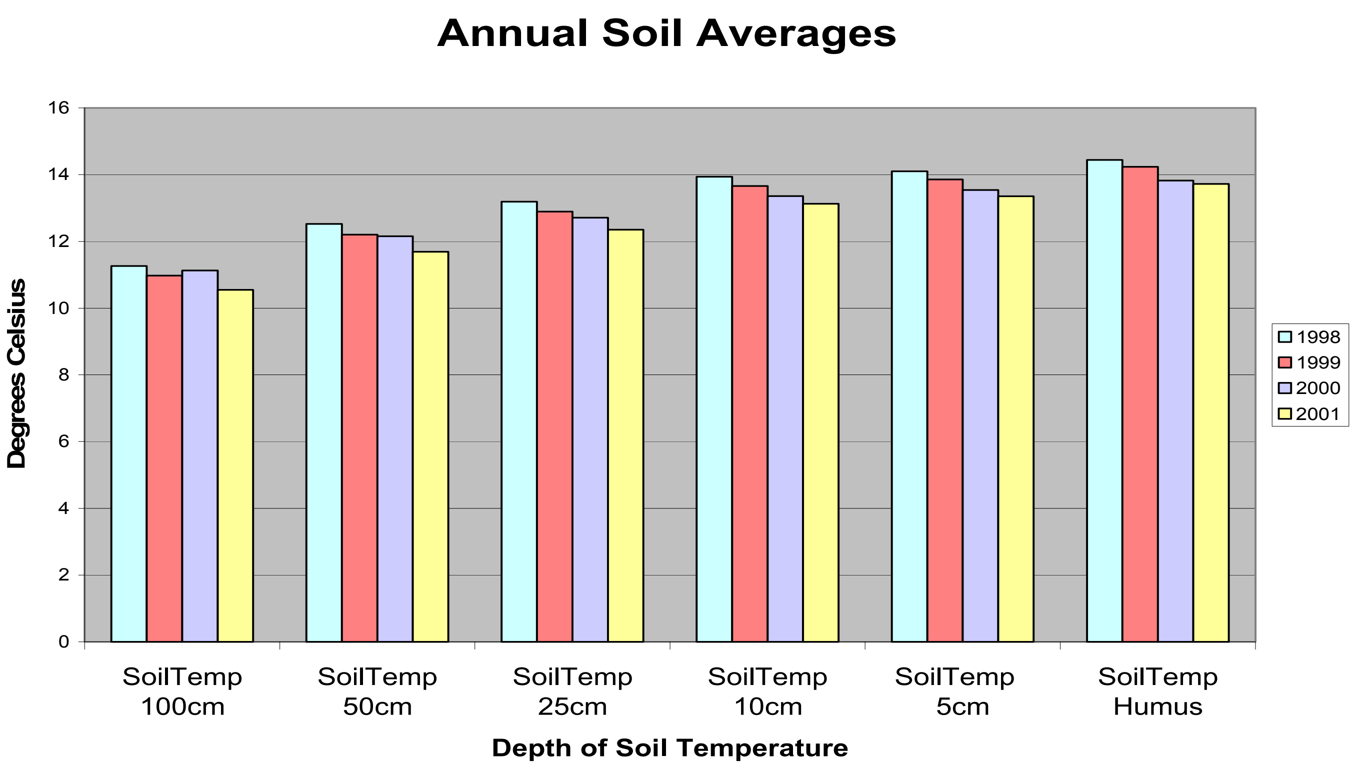
This may lead to an accumulation of salamanders over time, which is further supporter by Jaeger, Kalavarsky and Shimizu (1982) whose research found on average, in seventy-four percent of all encounters between defending and intruding *P. cinereus*, the defender expelled the intruder. Furthermore, resource quality may have an impact on the distribution and abundance of individuals in an area (Mares & Lacher, 1987; Stamps & Buechner, 1985) and on the intensity of agonistic behaviour associated with defense of resources (Itzkowitz, 1979). Mathis (1990) found that *P. cinereus* compete for high quality resources such as ACOs, because they "represent discrete, defendable patches, one consequence of this competition may be territoriality" (pg.169).

This however, may not be the only reason for the overall or sudden increase in populations over the five-year period. Another hypothesis relates to the fact that the past two sampling seasons have been hotter and drier than normal. During warmer and drier periods, *P. cinereus* often behave differently. Jaeger (1972, 1980) demonstrated that food is a periodically limiting resource for *P. cinereus.* During wet periods, salamanders forage in the leaf litter where invertebrate prey is abundant, but during dry periods the salamanders are restricted to patches of moisture beneath rocks, logs, and in this case ACOs. Large salamanders may therefore increase their net rate of energy gain by utilizing microhabitats that allow for minimum energy expenditure during these warm periods (Mathis, 1990).

This hypothesis may seem false, since in the years where the summer months were sampled, the numbers were often much lower than spring or fall numbers. However, as stated by Jaeger it is at these times that the salamanders show up most in the cover boards because they are limited to them for moisture and foraging whereas wetter cooler years may have made the salamanders less dependent on the cover boards to keep moist, in any season. Since this hypothesis can apply to any season, a warmer fall or spring should cause more salamanders to occur under ACOs than during cooler ones. It is therefore possible that this is the reason for the larger counts over the years. Why the salamanders are fewer in number in the even warmer and often drier summer months, may be because at this temperature the salamanders go deeper in the soil or seek cover in larger, better moisture retaining cover objects such as logs or stumps (Francis, 2003, Heatwole, 1962; Jaeger, 1972, 1980).

Another interesting piece of information to consider is the changing levels of soil temperature over the five-year period. Over all five years, the soil temperatures retrieved from the Wilson Climate Tower, located within the Wilson woodlot near the monitoring plot, decreased annually at –50cm, -25cm, -10cm, -5cm, and even at the humus level. See Figure 7. The decreasing trend over the five years directly correlates with the Wilson tract population counts per day over all five years, the correlation being, in every year the soil temperature decreased, the *P. cinereus* specimens sampled per day increased. It would be interesting and useful to know if the Backus woods population counts followed a similar trend, which would mean that during the first three years the soil temperatures remained relatively constant, and in the final two years, they decreased.

Figure 7: Annual Soil Temperatures



There is also a possibility that this had something to do with the logging that occurred at Wilson 25 years ago. Since logging occurred here it is possible that the canopy cover in the Wilson tract is more immature than Backus, and that the annual decrease in soil temperature relates to an annual gradual increase in canopy cover. This may also account for the Wilson population counts being lower than the Backus counts in every year of sampling. This might identify why there was such a significant difference in the counts over the first two years and considerably less in the final three.

According to Welsh and Droege "Most species of woodland salamanders studies appear to reach their peak abundance in late seral stage of old-growth forests and yield depressed population counts following cutting of forest or in earlier success ional habitats" (2001, pg.562). However, they also noted that Brooks (1999) found that Massachusetts forests that were logged twelve to twenty-one years prior to being studied produced no difference in counts of *P. cinereus* and presumed that those sites had returned to full cover. Since Wilson was logged over twenty-five years ago, it may have already achieved full canopy cover and the effects of logging may have not played any role in the population counts exhibited by this study. However, all too often science is unable to entirely predict what is occurring at an ecosystem level. For instance, the logging may have caused a decrease in good cover objects or changed the soil chemistry. As a result, the long-term effects of logging will not be ruled out as a hypothesis as to why the Wilson population count is lower.

Other miscellaneous reasons may also play a part in the increasing numbers over the years. Beyond the warmth and dryness of both the 2001 and 2002 summers, locations of the actual boards should be considered in the evaluation of the populations. For example, boards placed along different contours in the forest will accumulate different amounts of moisture, which may directly relate to how many salamanders are found under the boards. Heatwole (1962, pg.471) found “that in the early, wet part of the season salamanders were commonly encountered in sample plots both in depressions and on level topography. As drying progressed, salamanders disappeared from level sites but were still present in depressions”. However, the random placement of the ACOs in both woodlots should ensure that a relatively equal amount of boards covered these different moisture regimes.

Finally, it is important to stress that the increases exhibited by populations in both woodlots do not necessarily ensure that both ecosystems are healthy. Often this type of population fluctuation in one species represents a misbalance in the ecosystem, perhaps through another species population decreasing. One example that comes to mind is the decreasing Jefferson salamander populations in the areas (Craig, 2002). The decreasing numbers of Jefferson salamanders may decrease the competition for food or habitat for Red-back salamanders. This of course is not a good thing for the ecosystem, as it may represent bad wetland conditions because the Jefferson salamander requires them for the reproductive phase of their lifecycle, unlike the Red-back. Another example might be an increase in the *P. cinereus* food source populations, which is beyond the scope of this study, but might have played a factor in the increasing populations in both woodlots.

5.3.3 Monthly Length Averages

The monthly length averages were calculated by averaging the length of all salamanders caught in the same month over the five years of data gathering. The monthly salamander length averages were relatively consistent from month to month within each year and over both woodlots. See Figures 8 and 9. However, one thing worth noting is the differences displayed in the summer month averages between Backus and Wilson woods. In the Wilson woodlot, salamanders found in July had a larger average length than any other month, and August was comparable to any of the other months with high averages. In the Backus woodlot on the other hand, July and August were the two months with the smallest overall length averages. See Appendix 4.

Figure 8: Backus Monthly Length Averages

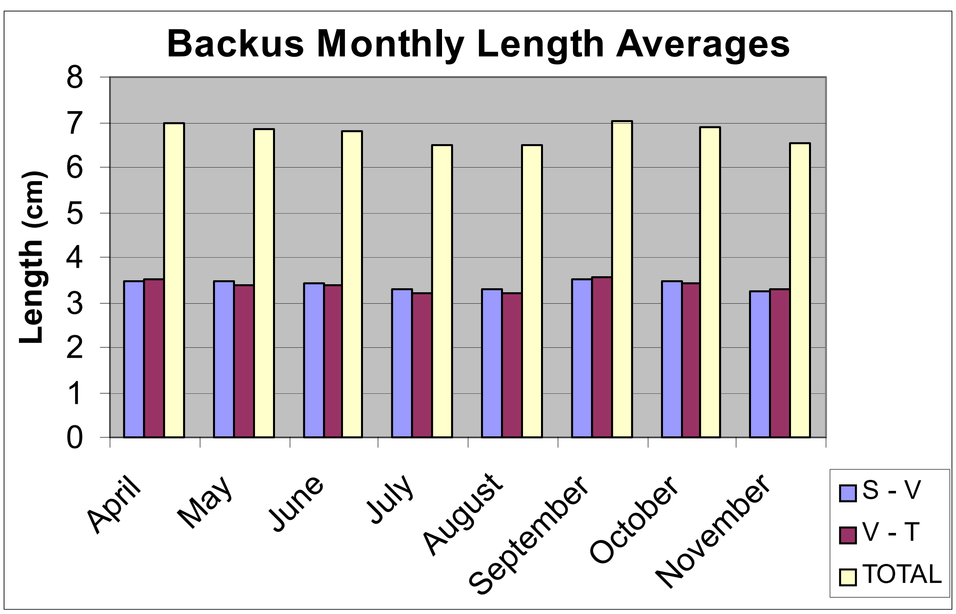
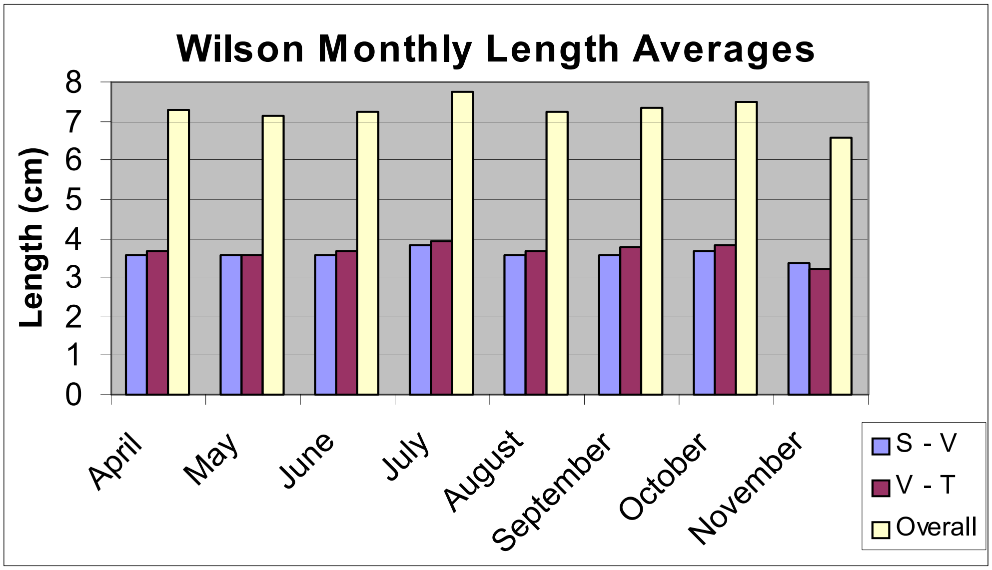


Figure 9: Wilson Monthly Length Averages



The trends discovered may indicate that the logging of the Wilson tract has resulted in weaker canopy cover, which may have caused a microclimate slightly warmer than the one at Backus. As a result, the salamanders in the Wilson woodlot may be more restricted to the ACOs for cover, whereas the cooler conditions in the Backus woodlot could provide more options for the salamanders to forage. This effect could be enhanced, because as mentioned in the literature review, bigger salamanders are often better able to defend optimal territory.

5.3.4 Annual Length Averages

Similar to the yearly counts of salamanders found per day, the yearly length averages have also been consistently going up annually. The only exceptions occurred in 2002, where the averages were smaller than 2001, and in Backus woods where 2000 was actually smaller than 1999. See Figures 10 and 11. Aside from those exceptions, the annual size averages increased every year. The 1998 size averages in both Backus and

Wilson were greatly smaller than any of the other years. This may be another sign that the ACOs were not yet very suitable habitat for most salamanders, because as mentioned before, bigger salamanders are often able to defend better habitat.

Figure 10: Annual Length Averages for Backus

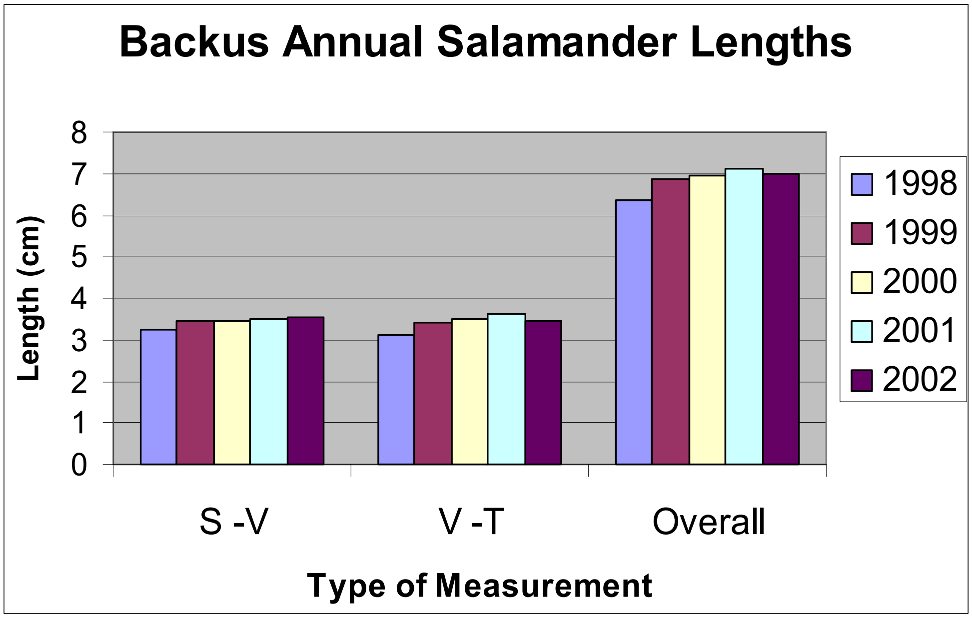
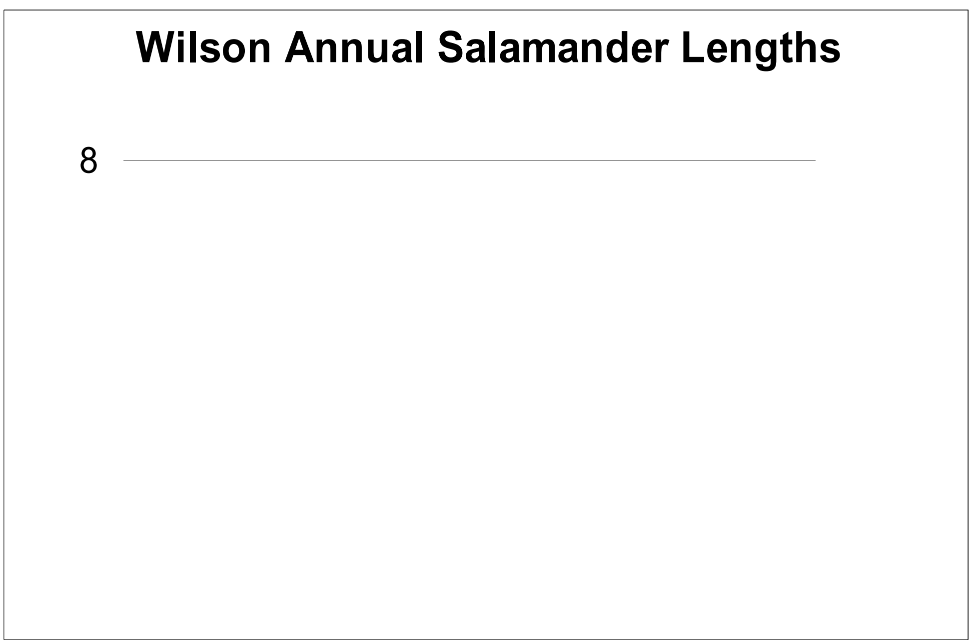


Figure 11: Annual Length Averages for Wilson



Since Wilson was logged 25 years ago and *P. cinereus* are usually more abundant and healthier in mature woodlots, it was presumed that the Backus woods salamanders would be larger. However, this was not the case. Instead, with the exception of vent-tail length in 1999, Wilson's length averages were bigger in every category of snout-vent length, vent-tail length and overall length in every single year. This was surprising considering the historical logging that occurred in Wilson.

Gabor (1995) found that larger boards produce larger and healthier specimens, only where direct sunlight shines on the boards. When the sun is able to shine directly on a cover object through a canopy gap or forest edge, having a bigger board would help retain the moisture better. However, he found that in areas where the sunlight did not directly heat the cover objects on the forest floor, bigger salamanders selected the objects not based on their size but rather based on the quantity and quality of food around them. This is important because although Wilson was logged 25 years ago, there is now likely enough canopy cover to avoid extended periods of direct sunlight, as is the case in Backus. As a result, salamanders in the area may be selecting the cover boards that have the best quality and quantity of food around them.

Based on the artifact theory discussed in section 5.3.2, it is also worth considering that the monitoring plot has provided enough additional cover to act as an artifact in attracting salamanders. The monitoring plot may produce higher counts of salamanders than if an area was randomly sampled elsewhere in the forest because, as previously discussed, it is possible that the area has become more attractive to salamanders, which may have attracted and retained a population with greater numbers of salamanders than an average area in the forest. This could have implications for the average size found in the plot compared to the forest in general. This is because the area may have better, if not more habitat per square meter than other locations within the forest. As a result, once a more dominant or healthy salamander finds the area, it may remain in the area if there is an adequate and stable food source to retain it. This may be significant in raising the overall average size of salamanders because, as discussed, the fitness of salamanders is partly determined by its ability to defend an optimal area, such as a cover object.

Jaeger, Kalvarsky and Shimizu (1982) concluded that, on average, 74% of the time the defending salamander expels the intruding one. Since the larger healthier salamanders are supposedly able to defend an optimal area, it is conceivable that over the years these larger salamanders have slowly gathered and accumulated in the sampling plot, and in the process have slowly displaced smaller unhealthier salamanders in a survival of the fittest fashion. If this is true, it could have significant implications for the actual health of the population in the forest as a whole. If the monitoring results are demonstrating a larger, healthier and denser population at an ideal habitat location than is representative in the rest of the forest, the results could be slightly skewed. Since the monitoring efforts at the Wilson tract produced larger overall size averages, it may be that in other locations in the woods, such as forest edges and other less ideal areas, the salamanders are less healthy and smaller.

Another issue worth investigating is demonstrated by the results of Mathis (1991), who conducted a study looking at the rate at which salamanders were recaptured.

Although her monitoring technique was a pitfall technique, opposed to the use of ACOs, the data she obtained should still be relevant to this study, because the salamanders that were recaptured were inhabiting the same area for extended periods of time, such as is hypothesized by the artifact theory. Of the 227 captures during Mathis' study, fifty-one percent of the individuals were recaptured at lease once, and were therefore presumed to be territorial. What is important to note about this study, is that the SVL of salamanders with multiple captures tended to be greater than that of salamanders captured only once.

This supports the notion that there may be an overall smaller and unhealthier population that is constantly on the move and is not sampled as often as the healthier population that may be sampled on a consistent basis. Mathis also added that presumed territorial salamander's tails comprised a mean of forty-three percent of total body length, while the salamanders that were presumed to be denied from ideal habitat tails accounted for a mean of only thirty-nine point three percent. This is even more significant considering that tail length and weight are often reflective of the overall salamander's health (Mathis, 1991).

It is however, important to note that even if the artifact theory is a reality, that the monitoring plot should still provide valuable information on the condition of the forest, especially if observed beyond the initial five years. Even if more and healthier red-backs were concentrated in the monitoring plot, if the overall forest population was declining or becoming less healthy, the salamanders in the plot would still likely reflect the trend through decreased numbers within the plot over the monitoring years. One implication of this is that a small decrease or increase in the monitoring plot may actually be representing a much larger change in the forest as a whole, especially if much of the forest surrounding the monitoring plot has been logged, developed, fragmented or heavily used by humans. This of course can be very difficult to identify with only one monitoring plot in the woodlot. Appendix 6 is a guideline that can be used to implement a monitoring design that would help answer some of the unknowns of ACO sampling and perhaps more importantly, identify the impacts caused by both edge effects and silvicultural practices on *P. cinereus*.

5.3.5 ACOs with Two or More Salamanders under them

Upon evaluating the data, it became noticeable that on a number of occasions in every month there were ACOs that had more than one salamander under them at once. See Appendix 5. Jaeger (1972) first hypothesized that *P. cinereus* individuals show a more clumped distribution, in relation to cover objects (rocks and wood) in the spring than in the summer. His rationale was that spatial disputes (Thurow, 1976) "will begin early in the spring, after salamanders surface from their wintering retreats, and that spatial distributions will be established by summer" (Jaeger, 1979, pg. 90). He found that in the spring, salamanders that just surfaced from over wintering were frequently found in groups of 2-7 under cover objects. These groupings decreased significantly in frequency by summer, even though the surface density of salamanders did not change significantly between seasons (Jaeger, 1979, pg.91).

This hypothesis is not widely discussed in much of the literature so it was worthwhile to take the data from both Backus and Wilson woods and evaluate if it supports or rejects Jaeger's theory. It also provides some insight into *P. cinereus* distribution within the monitoring plot. As demonstrated by Figures 12 and 13, the trends exhibited by the number of ACOs found with two or more salamanders under it per day are very similar to those demonstrated in the annual salamander per day averages. Both woodlots have the dramatic increase from the year 2000 to 2001 and in both cases the years 2001 and 2002 are much larger than the rest of the years. In the Wilson tract, 1998 is extremely low and there is then a gradual increase thereafter. Whereas in the Backus woodlot, the first three years are relatively constant in their counts, before the large jump in 2001.

Figure 12: Annual Averages of ACO's with 2+ Salamanders for Backus

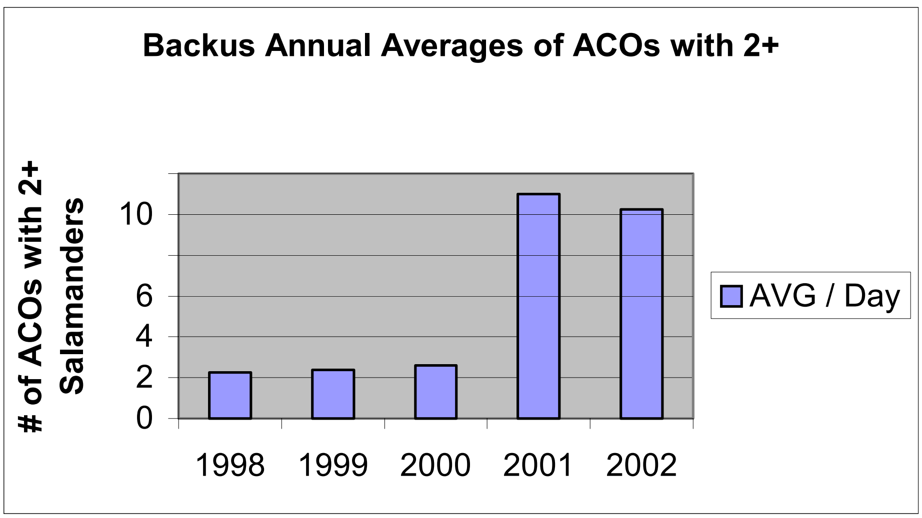
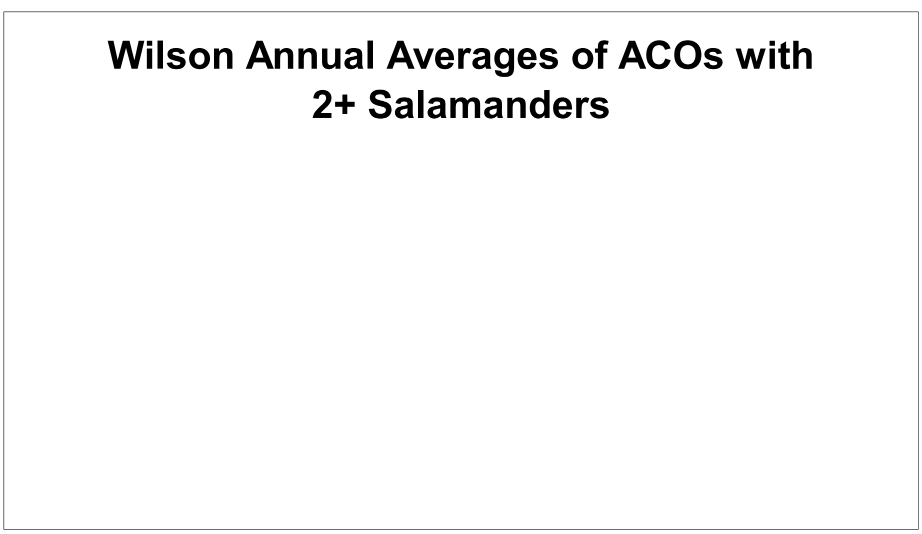


Figure 13: Annual Averages of ACO's with 2+ Salamanders for Wilson



In regards to Jaeger's theory, the data for both woodlots seem to support it. As is demonstrated by Figures 14 and 15, the spring occurrences of ACOs with two or more salamanders under them is much higher than the summer occurrences. If Jaeger's theory is correct, the salamanders in both woodlots were clumped together under the ACOs because they had not yet established their territories. Once the summer has arrived each year, certain salamanders have claimed their ACO and are less tolerant of sharing their boards with any other salamander. According to much of the literature the salamanders that have claimed their territory under the boards, are most often larger and healthier. This supports some of the earlier analysis evaluating the monthly and annual length averages of salamanders found in both Backus and Wilson woodlots.

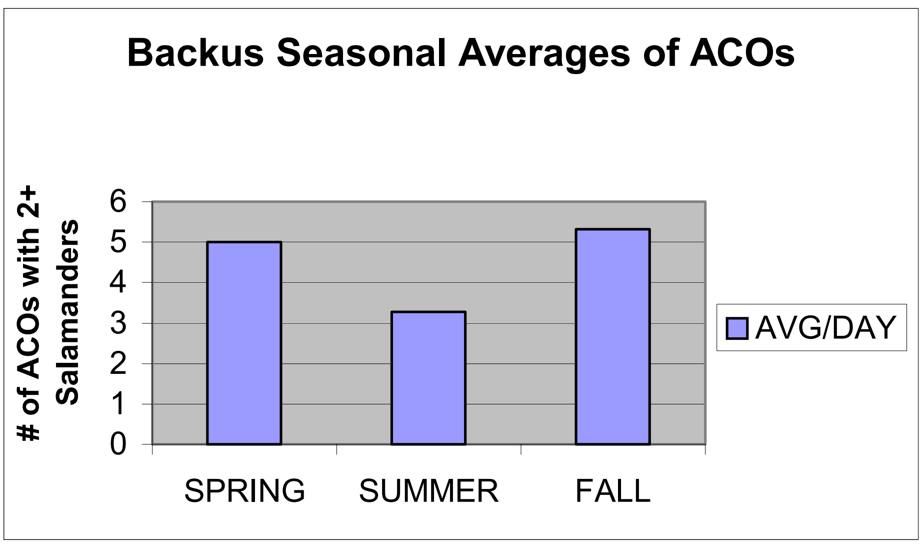


Figure 14: Seasonal Average of ACO's with 2+ Salamanders for Backus

Figure 15: Seasonal Average of ACO's with 2+ Salamanders for Wilson

One element that was not considered in Jaeger's hypothesis was that of how clumped the salamanders are in the fall season. In this study, the fall season portrayed very similar characteristics to that of the spring season. Considering that *P. cinereus* mating can occur in both the spring and fall (Froom, 1982), it is likely that these activities play at least a part in accounting for the higher rates of salamanders found under the same ACO. Another factor that may contribute to the seasonal differences in clumped distribution is the fact that Red-backed salamanders have also shown examples of kin selection behavior. When foraging is very stressful due to dry conditions, adults holding territories will sometimes allow juveniles access to their territories. Kin can be recognized through olfactory communication, and this juvenile access is generally relegated to kin. (Horne and Jaeger 1988; Jaeger et al. 1995; Simons et al. 1997). However, since the eggs hatch in the summer, it is unlikely that this has any significant impact on the clumped distribution differences.

6.0 CONSERVATION ISSUES

- Logging, either selective or clear cut, can have serious implications for Red-back populations. The implications of clear cutting are obvious and very dangerous to any *P. cinereus* population. Once the forest is void of any trees, the microclimate and complex processes that maintain the salamander's delicate home are destroyed. Selective cutting may also cause significant problems to *P. cinereus* populations. It can result in canopy gaps, which might cause moisture and microclimate regimes to be altered (see section 5.1.2). If direct sunlight shines on cover objects, it has been postulated that only big cover items will work, especially in extreme conditions. This results in increased competition and inevitably higher stress levels in individuals. Furthermore, depending on the degree of logging, there may be increased fragmentation and edge effects, all of which have been recognized as causing a host of negative environmental problems. Furthermore, when there are increased canopy gaps caused by selective logging and an increased temperature caused by global, a host of cumulative impacts may occur. One of many examples is the Herbeck and Larsen (1999) study. They found that in old growth woods (older than 120 years) there were 1205 red-backed salamanders per hectare, in second growth woods (70 – 80 years old) there were and in regeneration cut sites (less than 5 years old) there were none.

- If global warming becomes a reality, many species' home ranges may be altered. Southern populations of *P. cinereus* may find the temperatures too warm or the vegetation types not to their liking and as a result the overall home range of *P. cinereus* may shift or even become smaller. Even in populations that are still able to tolerate the warmer conditions, there may be a decrease in the overall health of the salamander population. These trends are very difficult to recognize and are one of the many reasons that it is important to monitor on a larger national scale.

- Finally, red-backed salamander habitat is rather pervasive, and they are common in most of their range. However, they could be affected by high levels of soil acidity through human-induced factors such as acid rain. More specifically, red-backs and any other Plethodontidae species are very sensitive to air pollution and any other source of contamination that would affect them while breathing through their skin.

7.0 RECOMMENDATIONS

- Identifying salamander gender in the future might provide an overall more complete picture of what is going on in both of the monitoring plots. Furthermore, it might shed some more light on clumped distribution of the salamanders during the spring and fall.

- Since the month of June was sampled in all five years at the Backus woodlot, and in four of the five years in Wilson, and the numbers per day are still relatively high, sampling in June should be considered. July or August might also be sampled in future years despite present low numbers, because having data from a full range of seasons should provide for a more complete data set.

- Trends and results derived from the National Monitoring Protocol for Plethodontid Salamanders must be evaluated with results from other monitoring protocols to ensure that the full range of environments is encompassed in evaluations of present conditions. For instance, Plethodontid salamanders are terrestrial, so their population trends would not be reflective of any kind of aquatic system health. EMAN is presently doing this by monitoring a wide range of species.

- Parks Canada should implement this monitoring protocol in as many parks as possible with known *P. cinereus* populations and then compare the results so as to produce a broader set of trends. The data developed from the protocol should also be used in the revision of park management plans, specifically, park zoning and visitor management.

- When a monitoring project is being conducted by a community based or other amateur groups any complex analysis within and between different monitoring plots should be completed or at least double checked by professionals at EMAN to ensure accurate results and that there are no errors in the analysis.

- In the Microsoft Excel protocol, the data analysis must evaluate the annual population trends based on how many salamanders were found per actual sampling day, not just the overall number found over the year. Otherwise, it must be clear to monitoring bodies that the exact same numbers of sampling days are to be conducted each year to ensure reliable data. This may also have ramifications for the actual monitoring question as well.

- The monitoring protocol outlines what might occur if there is a negative population curve, but not if there is a positive one. Although, the latter is often more desirable, significant increases may actually be a result of something else in the ecosystem being out of kilter. By suggesting some implications and more importantly causes of positive trends, the protocol may be able to utilize personal observations from those conducting the monitoring who are out in the field sampling the most.

- There is no monitoring question for the snout to vent length or vent to tail length. There needs to be a monitoring question similar to the one asked about the annual population counts.

- Spatially Explicit Sampling should be investigated as a form of analysis for the monitoring plots. This will enable one to look at the specifics of the plots, such as which boards or areas in the plot produce the most salamanders and at what size.

- The guidelines provided in Appendix 6 would produce a greater understanding on the effects of edges and open canopies on salamander distributions and populations. It would also produce some insight into understanding *P. cinereus* habitat preferences and territoriality issues. This information could be useful in determining if the monitoring plots located on the interior of the forest truly represent the entire range of the populations throughout the entire forest.

8.0 CONCLUSIONS

The results for both Backus and Wilson woodlots are positive, as the annual population counts and size averages have increased. The population counts have increased so much that in both woodlots they are above the fifteen percent increase figure suggested in the monitoring question. This suggests that there are healthy populations of *P. cinereus* in both woods. However, it may also reflect a shift or decrease in another species population, such as food and habitat competitors or their food sources themselves. Other variables are also possibilities, such as the changing weather conditions that impacted the plots over the years. Warmer and drier seasons have the ability to restrict red-backs under ACOs to escape dry conditions in the leaf litter. Salamanders were found to be more clumped in their distribution during the spring and fall months. This may reflect the theory that by the summer the larger, healthier salamanders have out-competed smaller less healthy salamanders, forcing them out of optimal territory.

The theory that there are enough boards to act as an artifact in attracting and retaining larger salamanders is conceivable based on the data. It is however, important to note that even if the artifact theory is a reality, that data produced by the monitoring plot are still reliable and valuable. Regardless of how many salamanders the plot was attracting and retaining, especially in hot dry weather where they are restricted to ACOs for cover, if the forest's population is on the decline, it will be reflected within the plot. As discussed, an implication of this is that a small change in the monitoring plot may actually be representing a much larger change in the forest as a whole, especially if much of the forest surrounding the monitoring plot has been logged, developed, fragmented or heavily used by humans. Although the plot is representative of the forest as a whole, it still only covers an index of the overall populations. Therefore, it is important to take precaution in evaluating exactly what is happening in a plot, since what is happening is not known for sure.

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10.0 Appendix

Appendix # 1
Actual Monthly and Annual Salamander Counts in Backus and Wilson Wood

BACKUS TRACT MONTHLY AND YEARLY COUNTS

MONTH	1998	1999	2000	2001	2002	TOTAL
March	9	NA	21	NA	NA	30
April	34	103	83	204	181	605
May	27	64	23	116	180	410
June	37	18	19	76	26	176
July	37	12	30	NA	NA	79
August	57	40	27	NA	NA	124
September	110	78	69	174	116	547
October	127	118	108	94	145	592
November	74	21	35	NA	NA	130
December	3	NA	NA	NA	NA	3
TOTAL	515	454	415	664	648	2696

WILSON TRACT MONTHLY AND ANNUAL COUNTS

MONTH	1998	1999	2000	2001	2002	TOTAL
March	0	N.A.	18	N.A.	N.A.	18
April	21	45	68	204	135	473
May	10	35	20	105	141	311
June	4	7	16	62	N.A.	89
July	3	3	11	N.A.	N.A.	17
August	10	19	13	N.A.	N.A.	42
September	37	67	104	173	90	471
October	40	59	107	34	137	377
November	24	15	27	N.A.	N.A.	66
December	0	N.A.	N.A	N.A.	N.A.	0
TOTAL	149	250	384	578	503	1864

Appendix # 2
Actual days sampled in Backus and Wilson Woods

BACKUS TRACT - DAYS SAMPLED

MONTH	1998	1999	2000	2001	2002	TOTAL
March	3	0	1	0	0	4
April	4	4	5	5	4	22
May	5	5	3	4	4	21
June	4	4	4	3	1	16
July	4	3	5	0	0	12
August	5	5	2	0	0	12
September	4	4	2	4	4	18
October	3	5	4	3	4	19
November	5	3	2	0	0	10
December	2	0	0	0	0	2
TOTAL	39	33	28	19	17	136

WILSON TRACT - DAYS SAMPLED

MONTH	1998	1999	2000	2001	2002	TOTAL
March	2	0	1	0	0	3
April	4	4	5	5	4	22
May	5	5	3	4	4	21
June	4	4	4	3	0	15
July	4	3	4	0	0	11
August	5	5	2	0	0	12
September	4	4	3	4	4	19
October	3	4	4	3	4	18
November	5	3	2	0	0	10
December	2	0	0	0	0	2
TOTAL	38	32	28	19	16	133

Appendix # 3
Salamanders Per Day Averages for Backus and Wilson Woods

WILSON TRACT - SALAMANDERS FOUND PER ACTUAL SAMPLING DAY

	1998	1999	2000	2001	2002
April	5.25	11.25	13.60	40.80	33.75
May	2.00	7.00	6.67	26.25	35.25
June	1.00	1.75	4.00	20.67	N.A.
July	0.75	1.00	2.75	N.A.	N.A.
August	2.00	3.80	6.50	N.A.	N.A.
September	9.25	16.75	34.67	43.25	22.50
October	13.33	14.75	26.75	11.33	34.25
November	4.80	5.00	13.50	N.A.	N.A.

WILSON TRACT – FOUR MONTHS CONSIDERED IN EVALUATION

MONTH	1998	1999	2000	2001	2002	AVERAGE
April	5.25	11.25	13.60	40.80	33.75	20.93
May	2.00	7.00	6.67	26.25	35.25	15.43
September	9.25	16.75	34.67	43.25	22.50	25.28
October	13.33	14.75	26.75	11.33	34.25	20.08
AVERAGE	7.46	12.44	20.42	30.41	31.44	

BACKUS TRACT - SALAMANDERS FOUND PER ACTUAL SAMPLING DAY

MONTH	1998	1999	2000	2001	2002
April	8.50	25.75	16.60	40.80	45.25
May	5.40	12.80	7.67	29.00	45.00
June	9.25	4.50	4.75	25.33	26.00
July	9.25	3.00	6.00	NA	NA
August	11.40	8.00	13.50	NA	NA
September	27.50	19.50	34.50	43.50	29.00
October	42.33	23.60	27.00	31.33	36.25
November	14.80	7.00	11.67	NA	NA

BACKUS TRACT – FIVE MONTHS CONSIDERED IN EVALUATION

MONTH	1998	1999	2000	2001	2002	AVERAGE
April	8.50	25.75	16.60	40.80	45.25	27.38
May	5.40	12.80	7.67	29.00	45.00	19.97
June	9.25	4.50	4.75	25.33	26.00	13.97
September	27.50	19.50	34.50	43.50	29.00	30.80
October	42.33	23.60	27.00	31.33	36.25	32.10
AVERAGE	18.60	17.23	18.10	33.99	36.30	

Appendix # 4
Overall Monthly Length Averages

BACKUS TRACT OVERALL MONTHLY AVERAGES

MONTH	S - V	V - T	TOTAL
April	3.47	3.51	6.98
May	3.48	3.36	6.84
June	3.43	3.37	6.80
July	3.29	3.20	6.49
August	3.30	3.19	6.49
September	3.49	3.55	7.04
October	3.47	3.43	6.90
November	3.24	3.30	6.54

WILSON TRACT OVERALL MONTHLY AVERAGES

MONTH	S - V	V - T	Overall
April	3.59	3.68	7.27
May	3.55	3.57	7.12
June	3.58	3.65	7.23
July	3.81	3.93	7.74
August	3.59	3.67	7.26
September	3.59	3.76	7.35
October	3.69	3.81	7.50
November	3.37	3.22	6.59

Appendix # 5
ACOs with 2+ salamanders

Backus Annual and Seasonal Numbers of Salamanders Found Under the Same ACO

YEAR	SPRING	SUMMER	FALL	TOTAL
1998	4	34	48	86
1999	42	16	21	79
2000	24	15	36	75
2001	103	56	50	209
2002	117	10	47	174
TOTAL	290	131	202	623

Backus Sample Days per Season and Year

YEAR	SPRING	SUMMER	FALL	TOTAL
1998	14	13	11	38
1999	12	12	9	33
2000	12	10	7	29
2001	11	3	5	19
2002	9	2	6	17
TOTAL	58	40	38	136

Backus Averages per Day of Salamanders Found Under the Same ACO

YEAR	SPRING	SUMMER	FALL
1998	0.29	2.62	4.36
1999	3.5	1.33	2.33
2000	2	1.5	5.14
2001	9.36	18.67	10
2002	13	5	7.83

Backus Annual Averages of Salamanders Found Under the Same ACO

YEAR	AVG/DAY
1998	2.26
1999	2.39
2000	2.59
2001	11.00
2002	10.24

Backus Seasonal Averages of Salamanders Found Under the Same ACO (Over 5 year period)

SEASON	AVG/DAY
SPRING	5
SUMMER	3.28
FALL	5.32

Wilson Annual and Seasonal Numbers of Salamanders Found Under the Same ACO

YEAR	SPRING	SUMMER	FALL	TOTAL
1998	2	2	4	8
1999	2	0	22	24
2000	18	24	40	82
2001	89	50	23	162
2002	68	13	24	105
TOTAL	179	89	113	381

Wilson Sample Days per Season and Year

YEAR	SPRING	SUMMER	FALL	TOTAL
1998	12	13	9	34

1999	12	12	8	32
2000	12	9	7	28
2001	11	3	5	19
2002	8	2	6	16
TOTAL	55	39	35	129

Wilson Averages per Day of Salamanders Found Under the Same ACO

YEAR	SPRING	SUMMER	FALL
1998	1.67	0.15	0.44
1999	0.17	0.00	2.75
2000	1.50	4.44	5.71
2001	8.09	16.67	4.60
2002	8.50	6.50	4.00

Wilson Annual Averages of Salamanders Found Under the Same ACO

YEAR	AVG / DAY
1998	0.24
1999	0.75
2000	2.93
2001	8.53
2002	6.56

Wilson Seasonal Averages of Salamanders Found Under the Same ACO (Over 5 year period)

SEASON	AVG / DAY
SPRING	3.25
SUMMER	2.28
FALL	3.23