

**Abiotic factors and effects of forest edges on red-backed salamander  
populations**

**Abstract**

Red-backed salamanders were observed to see how they colonized the forest edges of northern forests. By quantifying the surrounding abiotic factors, we predicted favorable abiotic factors. We set up 27 artificial habitats in a cedar swamp, mature hardwood forest, and a plot that was burned in 1936 at the forest edge, middle and interior. Soil and air temperature, light intensity, humidity, soil moisture, pH and percent understory cover were measured. Observing the population of salamanders under the artificial logs and surrounding natural habitat, we obtained significant results that salamanders did not choose to populate the forest edge. All abiotic measurements were different between forests, but air temperature, humidity, and percent soil moisture were predictors of salamander densities. Low air temperature, high humidity, and moderate levels of percent soil moisture was favored by red-backed salamanders and lead to more dense populations in the mature hardwood forest. No abiotic factors had significant trends varying from the forest edge to interior. In all forests, we did find salamanders inhabited forest edges less than the interior of forests.

## Introduction

In the wake of human expansion, natural forests are being dissected into smaller areas. On the perimeters of the natural forests, known as the forest edges, abiotic factors differ due to clear cuts, large sun spots or roads characteristic of the edges (Marsh et. al 2004). Differing abiotic factors include higher light intensity, low soil moisture, smaller organic layers and little vegetation cover on the forest edges compared to the interior of the forest (Marsh 2007). Forest edge effects pose a problem because small populations and decreased species diversity that are associated with edges. The change in abiotic factors contribute to a physical barrier that are difficult to cross for many species, in particular the terrestrial red-backed salamander which requires low intensity of light and high moisture to survive (Gibbs 1997).

The red-backed salamander, *Plethodon cinereus*, prefers moist habitats that shelter small invertebrates for consumption. This habitat is where red-backed salamanders lay their eggs in the spring and is found under logs and rocks in the Northern hardwood forests of Michigan. Salamanders do not have lungs, and rely on osmosis through their skin for oxygen. The skin is therefore responsive to moisture and pH of the surrounding soil. As a result, the red-backed salamander is sensitive to changes in the abiotic factors associated with forest edge, such as pH, temperature, light and moisture (Hawksley-Lescault and Wyman 1987). If these gradients are large enough, they can separate populations of red-backed salamanders at the forest edges.

Many curious about forest edges and the differing abiotic factors associated with the edges have investigated red-backed salamanders. Gibbs (1997) discovered that soil moisture and light intensity were more ideal for salamanders in the interior of the forest, and therefore saw a decreased population at the edge. Moisture was also the significant predictor of salamander population density in Beckman and Marsh's (2004) study in which the soil moisture and population density increased in the interior of the forest. Soil pH was also observed to affect salamander densities, being optimal for salamanders between 6.2 and 7.2 (Heatwole 1960). At more acidic pHs, *P. cinereus* experienced decreased fecundity and difficulty absorbing nutrients (Hawksley-Lescault 1987).

Due to varying abiotic factors, different forests are expected to contain different salamander population densities. Light intensity, soil moisture, and pH were measured by Heatwole (1962) and were discovered to be more favorable by the salamanders in late successional forests than early successional. Comparing forests, increased humidity, decreased temperature and decreased light were found in mature forests that were also associated positively with salamander densities (DeGraff and Yamasaki 2001).

Our goal was to study the effects of forest edges on red-backed salamanders. By selecting three forest types of cedar swamp (Resse's Swamp), mature hardwood forest (Colonial Point) and younger hardwood forest (burn plot), consistent trends of decreased salamander populations near the edge of forests were predicted. At each edge, we predicted increasing light

intensity and declining soil moisture to explain the lower population of salamanders there. Abiotic factors such as relative humidity, air and soil temperature, pH, light intensity, soil moisture and percent of ground cover by forbs were hypothesized to differ between forests. Since differing habitats will harbor different densities of salamanders, we believe the mature hardwood forest will be most conducive to high populations of red-backed salamanders because the pH, light intensity, and air temperature will be favored.

### **Methods**

The study locations were Resse's Swamp, Colonial Point, and an early successional forest that was burned in 1936. All locations fell within a ten-mile radius of the University of Michigan's biological station in Northern Michigan. At each sample site, we set up three parallel transects running 30m into the forest that were 10m apart. Artificial salamander habitats at 3m from the road, or forest edge, and at another 15m into the forest were placed. The final artificial habitats were placed at 30m into the forest, assuming this was the interior. The artificial habitats were used to control factors such as area under which salamanders could inhabit and location of the habitat. Artificial habitats at each location were comprised of two logs that were approximately 40cm long and 10cm thick and soaked in lake water for 24 hours to provide a moist habitat for salamanders. In all, 27 sites of artificial salamander habitat were placed with 9 artificial habitats at the forest edge, 9 at the middle, and 9 at the interior at three separate forests.

At all 27 artificial habitats the temperature of the air at 1m above the soil and the temperature of the soil about 5cm below the horizon was determined. We also used a pH meter to evaluate pH and a digital meter to measure light intensity at each site. By using a soil corer to obtain soil, we weighed wet and dry mass of soil samples, and percent soil moisture was quantified. A hydrometer calculated percent humidity while we estimated the percent of understory cover to the nearest 5% by observation.

Since salamanders require time to colonize, the sites were returned to one week after artificial habitat placement. At dawn and the afternoon, we checked under the artificial logs and natural red-backed salamander habitat was also searched on five separate occasions. Each forest varied in amount of natural habitat, so we attempted to overturn as much as possible in each forest. Once a salamander was discovered, the place it was found, the length of the salamander and the morphology (red or black) was recorded. If salamanders were found under natural habitat, we assumed the abiotic factors were similar to the closest artificial habitat and noted the nearest site. No abiotic measurements were taken specifically at natural habitats, but the natural habitats were no more than 7m away from the noted artificial habitat.

To statistically analyze data, two-way ANOVA tests were used to examine the relationship between forests (Resse's swamp, Colonial Point and the burned plot) the location of each site (forest edge, middle, and interior) and the interaction between the sites and habitats for example the cedar swamp edge and burned plot edge. Regression analyses were completed to determine

the differences in abiotic factors and red-backed salamander presence or absence. Regression analyses were completed for each abiotic factor, totaling 7 analyses in all.

## Results

Physically finding salamanders varied by day and time searched. Although salamanders colonized some artificial habitats, salamanders were more densely populated under natural habitats. Therefore, we analyzed data from a single day, morning and afternoon, in which no artificial habitats were inhabited but 43 red-backed salamanders were discovered under natural habitats. After the morning collection, it rained and therefore more salamanders were found.

The results show significantly higher populations of salamanders in Colonial Point, followed by the burned plot, and Resse's Swamp had the least ( Fig. 3). All abiotic factors differed between forests types (Fig. 1). Percent soil moisture was greatest in the cedar swamp and lowest in the burned plot ( Fig. 5). We discovered pH in the burned plot was lowest and greatest at the cedar swamp, with a mean pH near 8 (Fig. 6). Light intensity was lowest colonial point and the burned plot had the highest light intensity (Fig. 4) The burned plot also had the most understory cover and colonial point the least (Fig 9). Air temperature was coolest in colonial point and warmest in the burned plot (Fig. 8).

A 2-way ANOVA showed that the location from the edge of the forest significantly influences salamander population. Salamanders preferred locations farther from the edge ( $t= 3.7$ ,  $df= 2$ ,  $p< .04$ ). There was no significant interaction between the location of the salamander and the forest in which it was found (Fig. 1). No abiotic factors were significantly different at all forest edges, yet the soil temperatures increased marginally near the edge (Fig. 1).

On a microhabitat scale, pH, soil temperature, and light intensity were not found to be significant predictors of salamander densities. High levels of percent humidity were a preference for red-backed salamanders ( $t= 9.8$ ,  $df=1$ ,  $p< .004$ ). Air temperature was significantly related to salamander densities, seeing a preference for lower air temperatures ( $t= 5.7$ ,  $df= 1$ ,  $p< .02$ ). We also found moderate percent soil moisture to be marginally significant when predicting red-backed salamander populations ( $t= -1.86$ ,  $df= 1$ ,  $p< .07$ ).

## **Discussion**

As predicted, red-backed salamander densities were higher in Colonial Point followed by the burned forest and Reese's Swamp, respectively. As our hypothesis predicted, all seven abiotic factors measured were significantly different between forests also. Our results indicate that humidity, air temperature and percent soil moisture affect the red-backed salamander densities in Northern Michigan while soil temperature, light intensity, pH and percent of understory cover did not affect salamander densities.

Percent soil moisture was greatest in Resse's Swamp, and contradictory to our hypotheses that high soil moisture indicated high populations of salamanders. Although light intensity was not a significant predictor of salamanders in our study, the highest density of salamanders were found in Colonial Point where the light intensity was least. Just as in Heatwole's (1962) study, our mature hardwood forest contained more salamanders than the burned forest, but his significant predictor was that deciduous leaf litter was preferred over pine by red-backed salamanders. Even though we did not find pH to be a determining factor in our study, others have shown that salamanders prefer a pH between 6.2 and 7.2 (Heatwole 1960). Since the pH Resse's Swamp was considerable more basic at mean of 7.9, red-backed salamanders could have been affected negatively.

Salamanders preferred high humidity, low air temperatures, and moderate percent soil moisture, which matched conditions at Colonial Point best of the three forests. Soil temperature, pH, and light intensity and percent understory cover were not predictors of salamander populations. This agrees with Heatwole (1962) who found temperature and soil moisture to be dependent factors of salamander densities, but unlike in that he found percent cover an indicator also. Light intensity was surprisingly not an indicator of salamander populations, but other studies suggest that this may be due to soil moisture and temperature being the predominant factors (Sugalski and Claussen 1997).

In relation to red-backed salamanders and how they approach the forest edge, we found the same trend of avoiding forest edge habitat in all forests.

This means, even though they preferred the mature hardwood forest to the cedar swamp, they did not inhabit near the edge in either. Curiously, we found no expected trends of higher light intensity and lower soil moisture at the edges in all forests to explain the decreasing salamander populations at the forest edge. Running roads, or edges, through the salamander's natural habitat separates the salamander populations, which has been demonstrated to increase genetic drift and decrease genetic diversity within a population (Gibbs 1998).

When examining the relationship between forest edges and red-backed salamander populations, we concluded that salamanders avoided the forest edge. The reason for this trend is unclear, but perhaps our hypothesis of light intensity and soil moisture being significant was incorrect and a significant abiotic factor was simply not measured. Light intensity, especially, is variable with the time of day and we collected salamanders in the morning and afternoon. The entire study was performed in two weeks and longer periods and more sampling may result in more significant data. Our transects were extended 30m into the forest and therefore we may have obtained a more drastic difference in abiotic factors if we had went deeper into the forests, like Beckman and Marsh (2004) whose edge studies went up to 80m into the forest. Another possible explanation is there were varying amounts of fallen logs near the edge of the forest and between forests, yet no estimates of potential salamander habitats were recorded. For example, there may have been less

natural habitats available near the edge compared to the interior and therefore the data would be skewed toward the interior.

Nonetheless, red-backed salamanders avoid the edges of forests. While we were able to predict salamander densities by three abiotic factors: humidity, air temperature and percent soil moisture. All of the indicating factors of salamander densities differed between forest, and therefore we found different salamander densities between forests also.

### Tables and Graphs

Dependent Variable	Independent Variable	df	F	p
Total	Location	2, 18	3.779661	0.04261
	Forest	2, 18	10.38983	0.001
	Location * Forest	4, 18	1.059322	0.40502
pH	Location	2, 18	0.550729	0.585941
	Forest	2, 18	24.6982	6.91E-06
	Location * Forest	4, 18	2.645639	0.067492
% soil moisture	Forest	2, 18	18.3447	4.53E-05
	Location	2, 18	0.267434	0.768329
	Forest * Location	4, 18	0.357743	0.835296
soil temperature	Forest	2, 18	70.08824	3.2E-09
	Location	2, 18	3.294118	0.060382
	Forest * Location	4, 18	1.485294	0.248202
air temperature	Forest	2, 18	73.25932	2.25E-09
	Location	2, 18	0.56352	0.578926
	Forest * Location	4, 18	1.399184	0.274141
% cover	Forest	2, 18	8.580041	0.002415
	Location	2, 18	0.156155	0.856573
	Forest * Location	4, 18	0.388847	0.813825
light intensity	Forest	2, 18	9.12122	0.001839
	Location	2, 18	0.380301	0.68902
	Forest * Location	4, 18	0.331217	0.853333
humidity	Location	2, 18	1.277027	0.302953
	Forest	2, 18	44.83784	1.02E-07
	Location * Forest	4, 18	2.847973	0.054386

Fig. 1: All ANOVA tests between abiotic factors and location, forest, and location combined with forest. Also included is the total number of salamanders and location, forest, and location combined with forest.

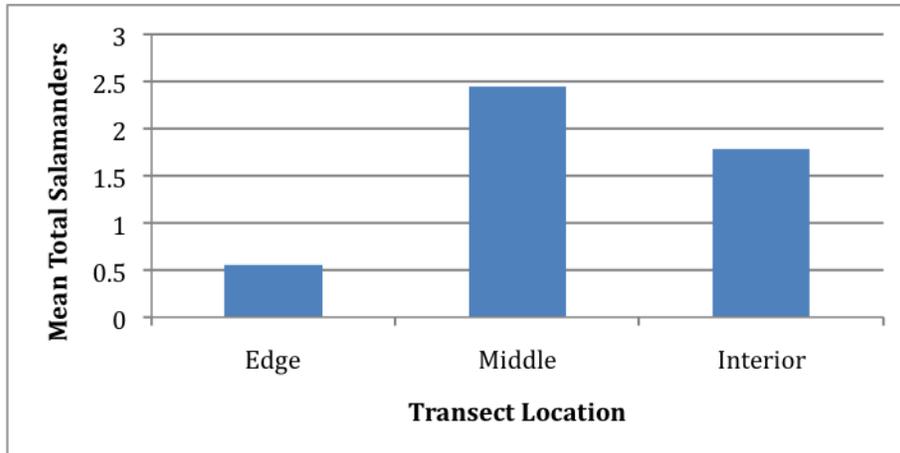


Fig. 2: The mean number of salamanders found at the forest edge, middle, and interior ( $F= 3.8$ ,  $df= 2,18$ ,  $p=.04$ )

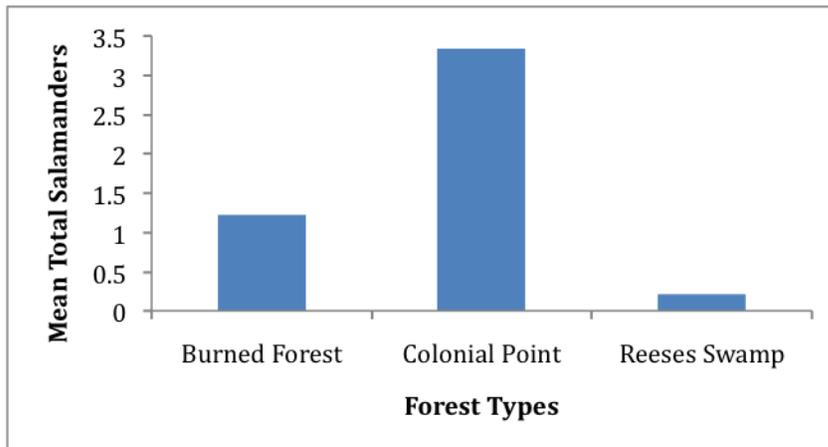


Fig. 3: The mean number of salamanders found at the burned forest, Colonial Point, and Resse's Swamp ( $F= 10.4$ ,  $df= 2,18$ ,  $p=.001$ )

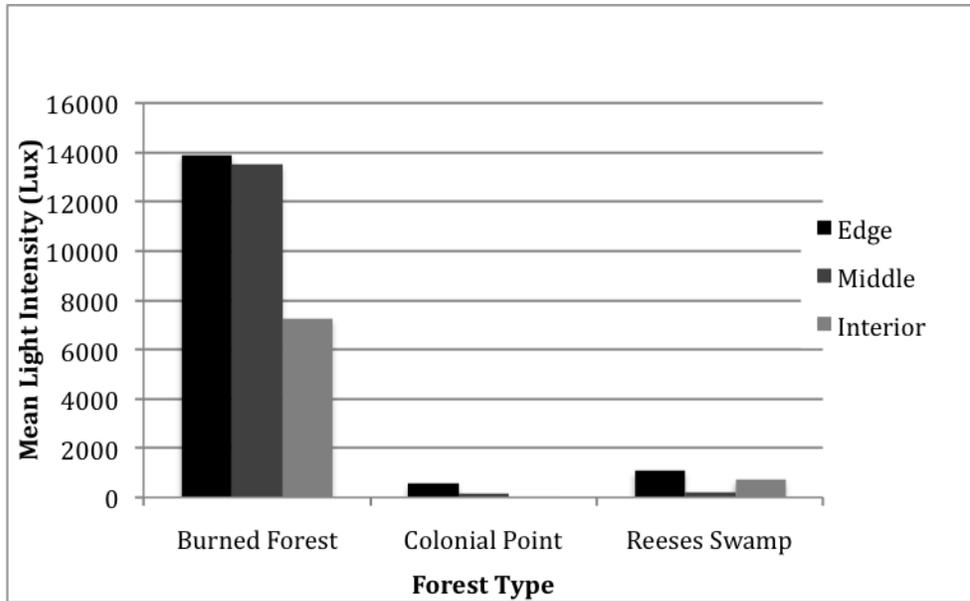


Fig. 4: Comparison of the mean light intensity and the forest type ( $F=9.1$ ,  $df= 2, 18$ ,  $p= 0.001$ ) and light intensity varying between the edge, middle, and interior ( $F=0.38$ ,  $df= 2, 18$ ,  $p= 0.689$ ).

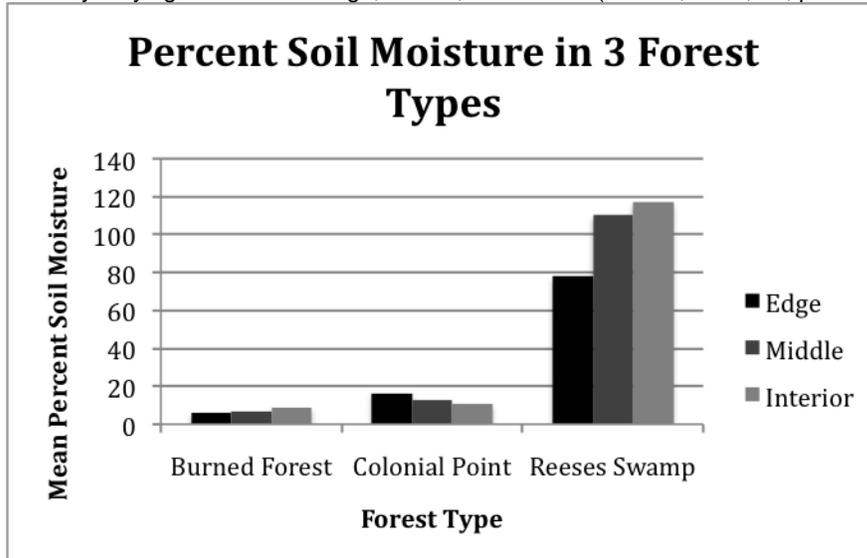


Fig. 5: Comparison of the mean percent soil moisture and the forest type ( $F=18.3$ ,  $df= 2, 18$ ,  $p= .001$ ) and percent soil moisture varying between the edge, middle, and interior ( $F=0.26$ ,  $df= 2, 18$ ,  $p= 0.768$ ).

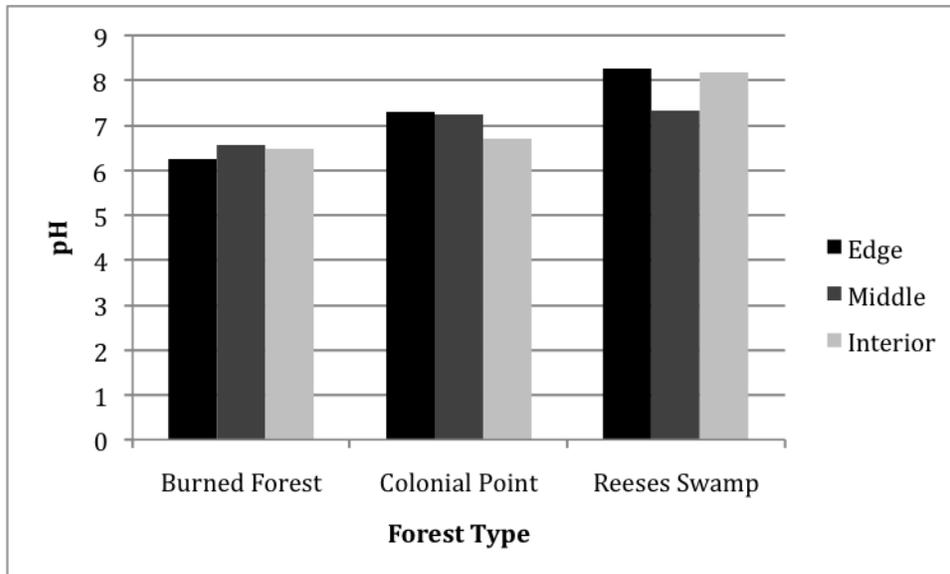


Fig. 6: Comparison of the mean pH and the forest type ( $F=24.7$ ,  $df= 2, 18$ ,  $p= .001$ ) and pH varying between the edge, middle, and interior ( $F=0.551$ ,  $df= 2, 18$ ,  $p= 0.585$ ).

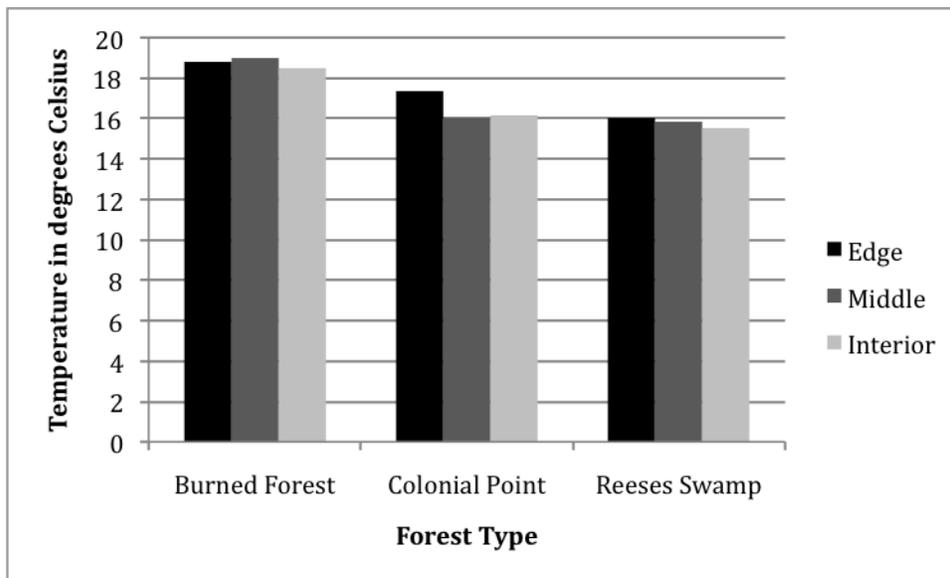


Fig. 7: Comparison of the mean soil temperature and the forest type ( $F= 70.1$ ,  $df= 2, 18$ ,  $p= .001$ ) and soil temperature varying between the edge, middle, and interior ( $F=0.551$ ,  $df= 2, 18$ ,  $p= 0.060$ ).

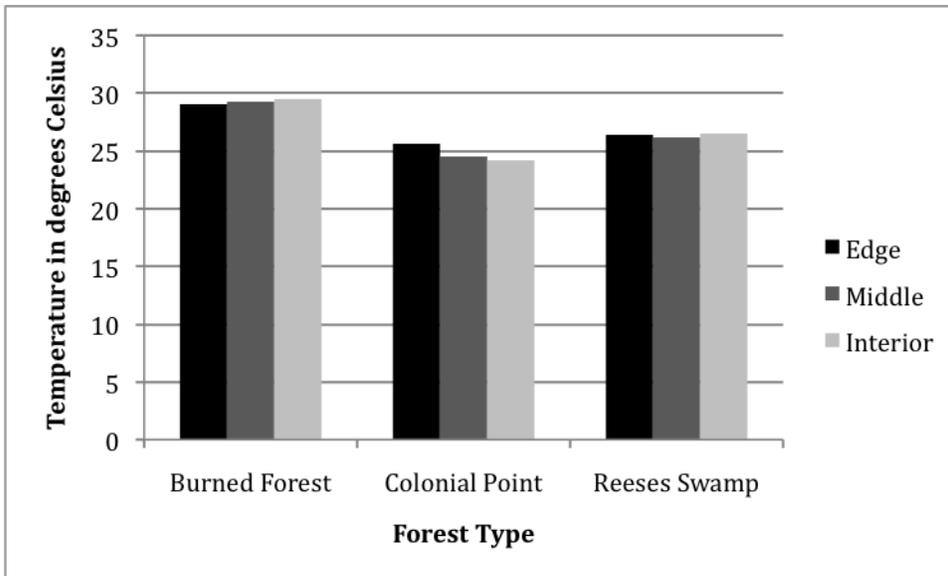


Fig. 8: Comparison of the mean air temperature and the forest type ( $F= 73.2$ ,  $df= 2, 18$ ,  $p= .001$ ) and air temperature varying between the edge, middle, and interior ( $F=0.563$ ,  $df= 2, 18$ ,  $p= 0.579$ ).

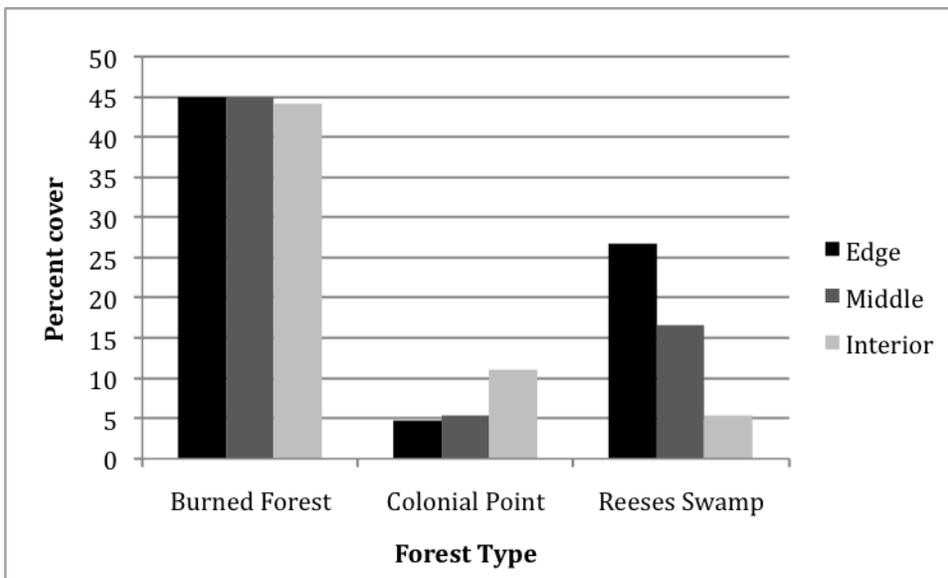


Fig. 9: Comparison of the mean percent understory cover and the forest type ( $F= 8.5$ ,  $df= 2, 18$ ,  $p= .002$ ) and percent understory cover varying between the edge, middle, and interior ( $F=0.156$ ,  $df= 2, 18$ ,  $p= 0.856$ ).

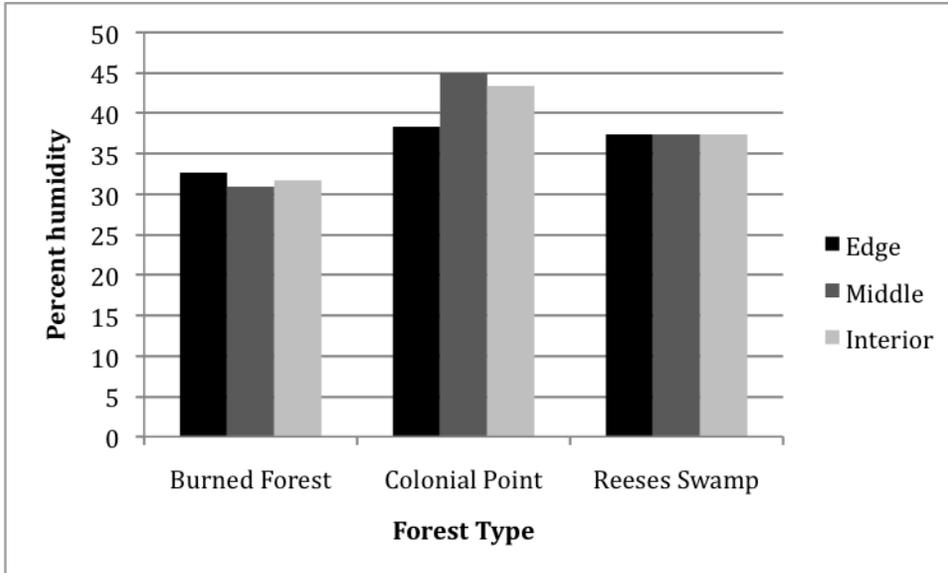


Fig. 10: Comparison of the mean percent humidity and the forest type ( $F = 44.8$ ,  $df = 2, 18$ ,  $p = .001$ ) and percent humidity varying between the edge, middle, and interior ( $F = 1.28$ ,  $df = 2, 18$ ,  $p = 0.302$ ).

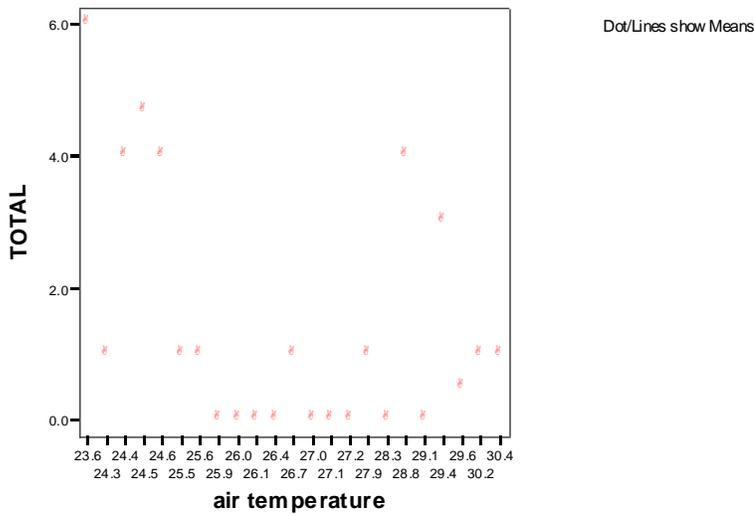


Fig. 12: The linear regression of air temperature versus total salamanders present ( $t = 5.7$ ,  $df = 1$ ,  $p = 0.02$ )

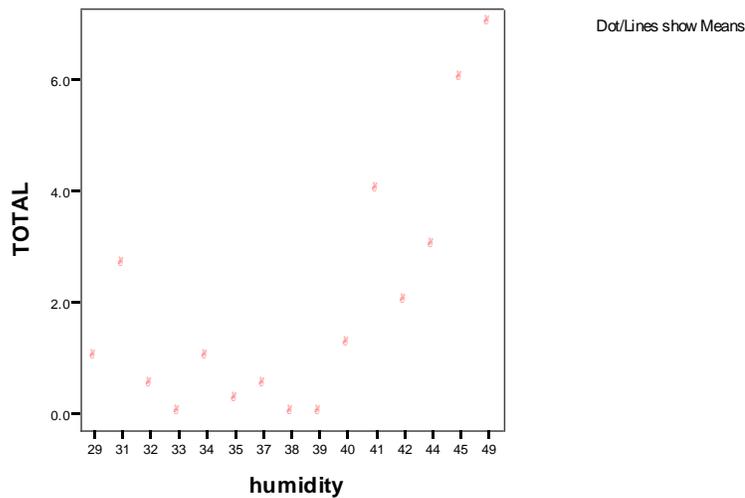


Fig. 13: The linear regression of humidity versus total salamanders present ( $t=9.8$ ,  $df=1$ ,  $p=0.004$ )

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