THE RELATIONSHIP BETWEEN ANNUAL TREE-RING GROWTH AND PEAK POPULATION DENSITIES OF SMALL MAMMALS IN AN EASTERN APPALACHIAN FOREST

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ABSTRACT

The purpose of this study is to describe associations between the annual tree ring growth of some specific trees and the population densities of four different small mammals of the Eastern Appalachian Forest. It is hypothesized that in the year following increased tree ring growth, the small mammal population densities, of *Peromyscus maniculatus*(deer mouse), *Clethrionomys gapperi* (Red Backed Vole), *Tamius striatus* (Eastern Chipmunk), *and Glaucomys volans* (Southern Flying Squirrel), will ascend. An exception was made when comparing *Quercus rubra* and small mammals because they mast one year after increased growth, and the mammal population will respond therefore two years after increased tree ring growth. The trees that are tested included Sugar Maple (*Acer saccharum*), red oak (*Quercus rubra*), American Beech (*Fagus grandifolia*), Black Cherry (*Prunus serotina*), and the tulip poplar (*Lirodendron tulipifera*). The testing was preformed at Powdermill Biological Station, which is an Eastern Appalachian Forest located in Southwestern Pennsylvania. This site was selected because Dr. Merrit has preformed mammal trapping there for over twenty years, and his data was used in the present study. The data was analyzed with the Pearson's product moment correlation coefficient test and correlation coefficents showed little evidence of correlations. Except for *G. volans* and *T. striatus* when compared to Q. rubra. The correlation coefficients were .651979 (*G. volans*) and .70060 (*T. striatus*). The hypothesis is refuted by the information collected in this study.

Introduction

The present study is being performed to find a relationship between small mammals and the availability of food sources in their habitat. More specifically it is to observe the relationship between the annual growth of trees and small mammal population densities.

Dendrochronology is the method of scientific dating based on the analysis of tree rings. “Because the width of annular rings varies with climatic conditions, laboratory analysis of timber core samples allows scientists to reconstruct the conditions that existed when a tree's rings developed” (Encyclopedia Britannica, 2000). Tree rings leave records of the climatic conditions that occurred in that area. (Norris, 2001). Every year, each tree makes another ring, depending upon the precipitation, or the season, the band will be light or dark, thick or thin. During some years when there is a drought or deluge, this will cause the ring to be unusually thin or thick. These are called signature years and can be used to cross-reference rings, (this can help eliminate error in dating the years). Trees, in the spring, create large cells called xylem that act almost like straws. The large cells are made to handle the influx of water that occurs during the spring. In the other seasons the cells appear smaller. Trees in the same area, which are exposed to the same precipitation and sequences of wet and dry, usually share a similar pattern of annual rings (Norris, 2000).

Precipitation is very influential in our study. The amount of precipitation directly correlates to the amount of fruit a tree will produce in a given masting cycle (Piovan and Adramas, 2000). The fruits of the trees are a main staple in the small mammal diet (Guilday, 1977). Therefore the more fruit produced then the larger the amount of small mammals the environment can support (Piovan and Adramas, 2000). Precipitation not only affects the amount of fruit a tree produces, but also such biotic elements as tree ring growth. The more precipitation a tree receives the more potential the tree has to grow (Norris, 2000).

For many small mammals, trees can provide the adequate nutrition needed to make the population of that species thrive (McLaren & Petersen 1994, Halfpenny 1991). Powdermill Biological Station, in Southwestern Pennsylvania, is where all the mammal data is collected. Some of the herbivorous mammals that live at Powdermill are *Tamias striatus* (Eastern Chipmunk), *Peromyscus maniculatus (*Deer Mouse), *Clethrionomys gapperi* (Red Back Vole), and *Glaucomys volans* (Southern Flying Squirrel). The vegetation at Powdermill is thought to be sufficient enough to support many of the animals that live there. The Eastern Chipmunk mainly eats black cherries, maple seeds, hickory nuts, and the fruits of cucumber trees. It will also eat insects and other small creatures like small snakes and birds and may even resort to cannibalism. The Deer Mouse is fond of eating black cherries, hemlock cones, sycamore, maple seeds, birch, black gum and dead crayfish. The Red-back Vole eats tree leaves, acorns, beech nuts, black cherry pits, and old bones. The Southern Flying Squirrel eats oak acorns, hickory nuts, beech nuts, and an assortment of berries.

This study is performed to identify the relationship between tree ring growth (of *Acer saccharum*, *Quercus rubra*, *Fagus grandifolia*, *Lirodendron tulipifera, and Prunus serotina*) and small mammals (*P. maniculatus, G. volans, C. gapperi, and T. striatus*) population densities. It is hypothesized that in the year following increased tree ring growth, the small mammal population densities of *P. maniculatus, G. volans, C. gapperi,* *and T. striatus* will ascend. An exception was made with the Red Oak (*Q. rubra*) because they mast one year after increased growth, and the mammal population therefore will respond two years after the increased ring growth.

METHODS

Study site

The study site is located at Powdermill Biological Station (PBS), a field station of the Carnegie Museum of Natural History, in southwestern Westmoreland County in Pennsylvania. The site was chosen because of the mammal data collected there since 1979. The forest at PBS is a typical Appalachian forest and has a humid continental climate. The temperatures range from about – 31 degrees C to about 36 degrees C, with an average yearly temperature of 7 degrees C (Merritt 2001). Annual precipitation usually ranges from about 1002 to 1480 mm and averages to 1220 mm (Merritt 2001). Snow may fall from October to April, and can be heavy from October to March, while permanent snow cover may last for about two months (Merritt 2001).

The researchers also used Dr. Joe Merritt's PBS mammal population data that he has collected over the past twenty years. There are one hundred stations on the trapping grid at PBS, which are arranged in a ten by ten fashion, with each station ten meters apart. Each station has a chimney containing two large Sherman live traps. Every third station has a large Sherman live trap attached to a tree, mainly for capturing flying squirrels.

Dominant canopy trees studied and sampled were American Beech, Sugar Maple, Yellow Poplar, Red Oak, and Black Cherry. In the study tree cores collected from July 14 to July 17, 2003 were used.

Mammal Trapping

The data used in this study lasted from 1979 to 1999. Dr. Merritt's mammal trapping periods lasted four days at a time, every two weeks. The traps were checked twice a day, morning and mid-afternoon, and refilled with sunflower seeds, which were used as bait for the small mammals. When the mammal was caught, it was identified by species, sexed, and weighed with a Pesola spring scale. Each new mammal was marked and recaptured mammals were identified by ear tag number. In addition to ear tagging, if the mammal did not have pinnae, like shrews, it was marked and identified through toe clipping.

Dendrochronology

Dendrochronology is the study of climate changes and past events by comparing the annual ring growth of trees. During data collection, Black Cherry, American Beech, Yellow Poplar, Red Oak, and Sugar Maple tree cores were collected with increment borers. Two cores were taken from each tree and four trees from each species were cored to ensure that the trees were correctly representing environmental and climatic conditions over the past twenty years. The cores were then put into straws that were labeled according to tree number and species. The diameter at breast height was taken using DBH tape and the height was taken using a clinometer. The tree cores were then glued to wood paneling for a good cross-section view of the annual tree rings. They were sanded so that they had a flat surface which enabled them to be viewed easily with a dissecting microscope. The dissecting microscope was used to measure in millimeters how far apart each tree ring is, which showed how much the tree grew each year. As a common practice, this study used a signature year to cross-reference some of the trees with rings that were harder to view. The signature year used was 1988, a year marked by drought.

Statistical Analysis

The number of xylem cells deposited in the spring and summer is dependent on the amount of precipitation during that year. This causes variation among ring widths throughout the life of a tree. In addition, as a tree ages, the annual ring circumference increases. Therefore, the ring width areas need to be adjusted in order to be used in comparisons during scientific investigations. The ring-width index (RWI) is used to account for this variation. Also, each tree is exposed to different environmental and climatic conditions. Different factors exist for each tree such as soil, slope, wind, precipitation, and light. To standardize this, the RWI is used. The width of every yearly ring was measured and then divided by the mean of all the years. RWI is equal to the ring width per year divided by the mean of all ring widths of all the years.

The data had to be staggered because the hypothesis stated that mammal populations increase the year following increased tree ring growth. Therefore, tree data from 1980 is aligned with mammal data from 1981. After the tree rings were analyzed, a linear regression was applied to the Annual peak mammal populations and the tree-ring mean RWI for each year.

The Pearson Product Moment Correlation Coefficient test was applied to the data to express the strength of relationship between the two variables, species of mammals and species of trees.

RESULTS

	P. maniculatus	*T. striatus*	*C. gapperi*	*G. volans*
A. saccharum	-.22376	.16920	-.2539	N/A
Q. rubra	N/A	.70060	N/A	.651979
F. grandifolia	.100994	.15668	.30556	.02709
P. serotina	.412641	.60624	.28162	.383735
L. tulipifera	.4762	N/A	.05339	N/A

Figure 1. Correlation coefficient of each mammal with each tree

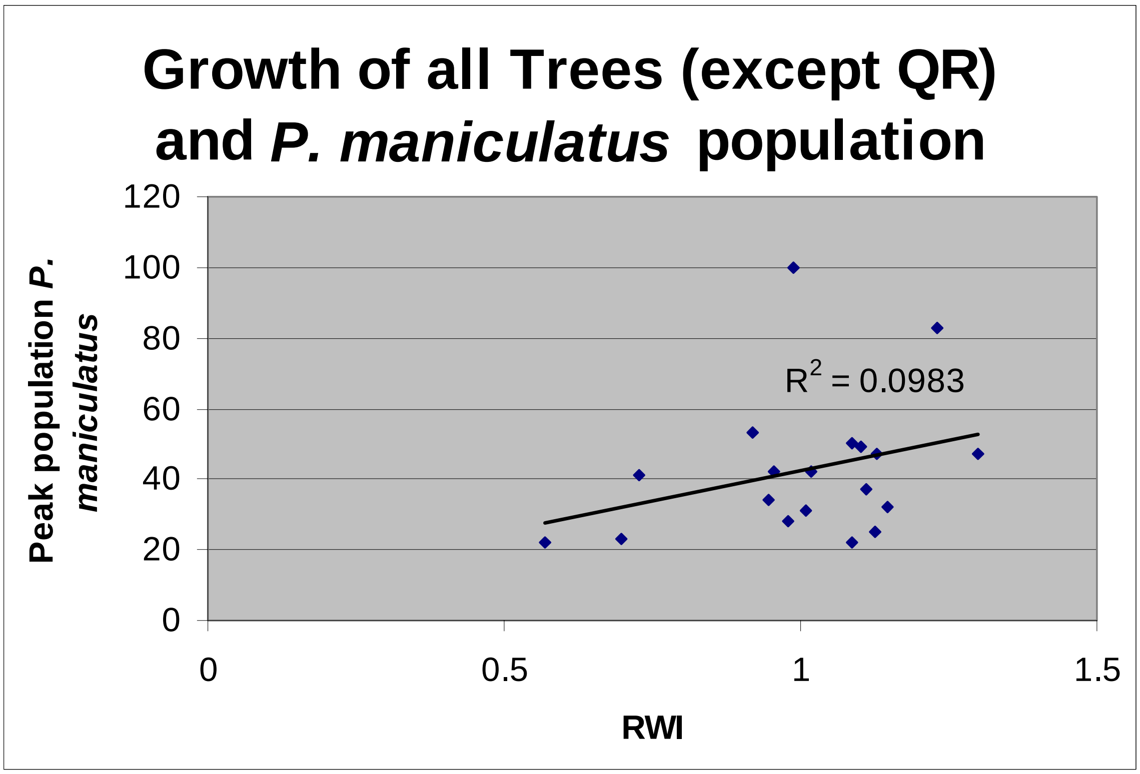

Figure 2. Relationship between all trees and *P. maniculatus*

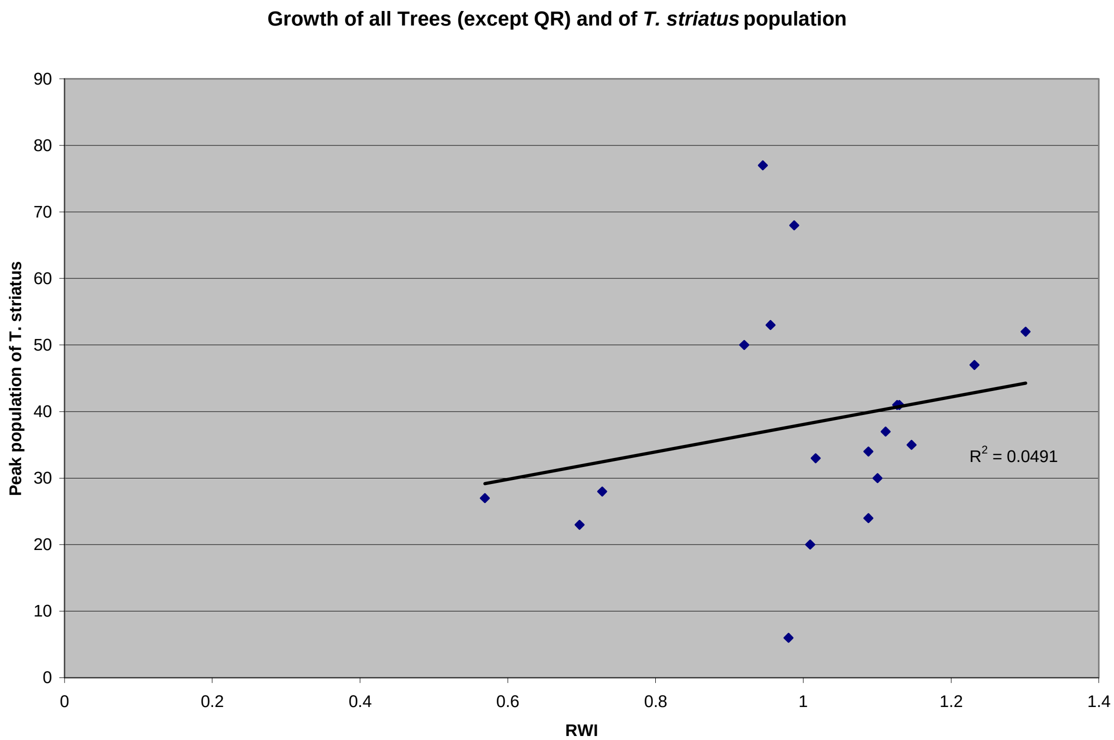

Figure 3. Relationship between all trees and *T. striatus*

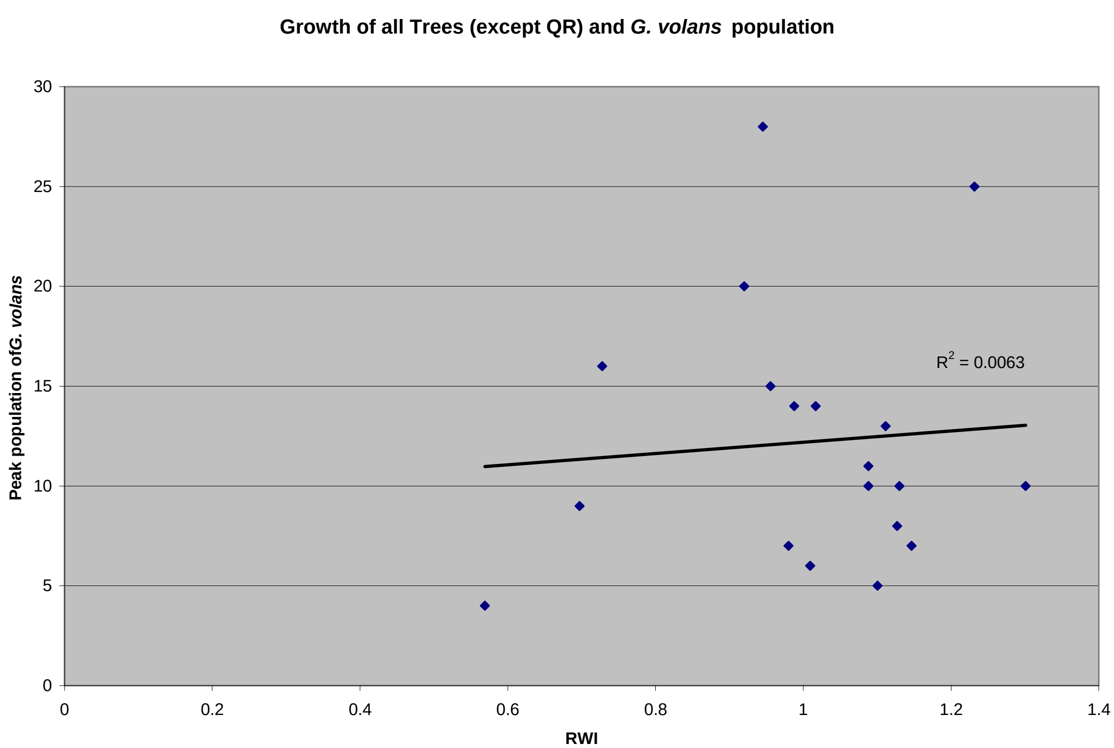

Figure 4. Relationship between all trees and *G. volans*

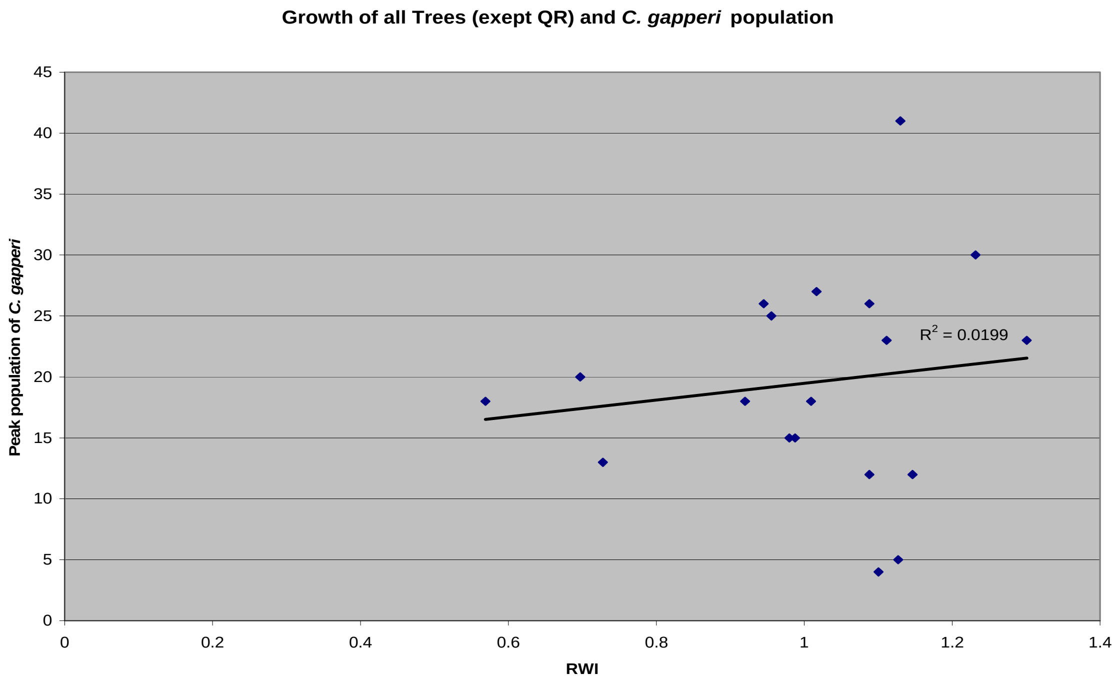

Figure 5. Relationship between all trees and *C. gapperi*

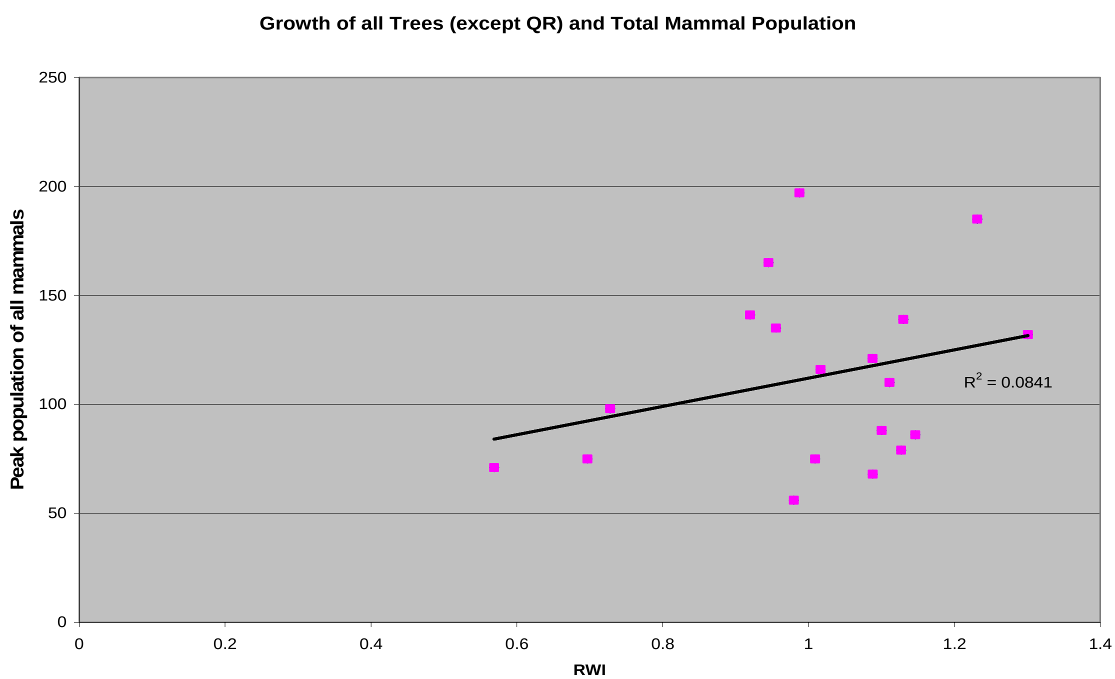

Figure 6. Relationship between all trees and all mammals

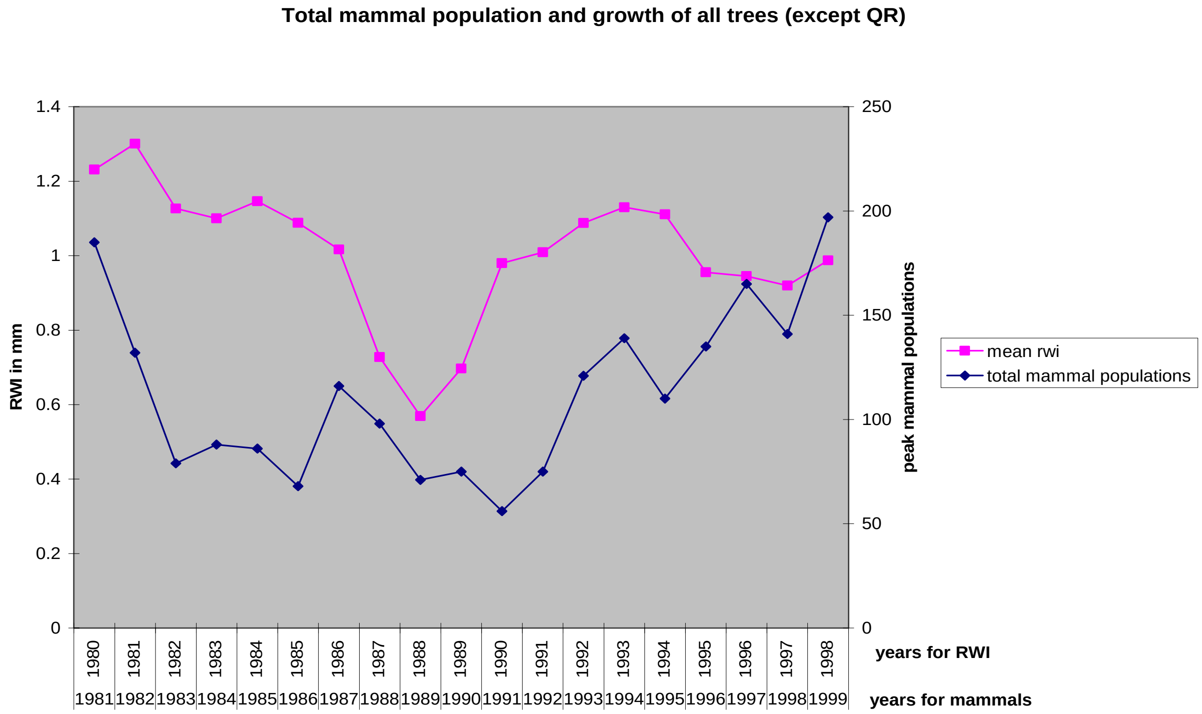

Figure 7. Total mammal population and growth of tree rings

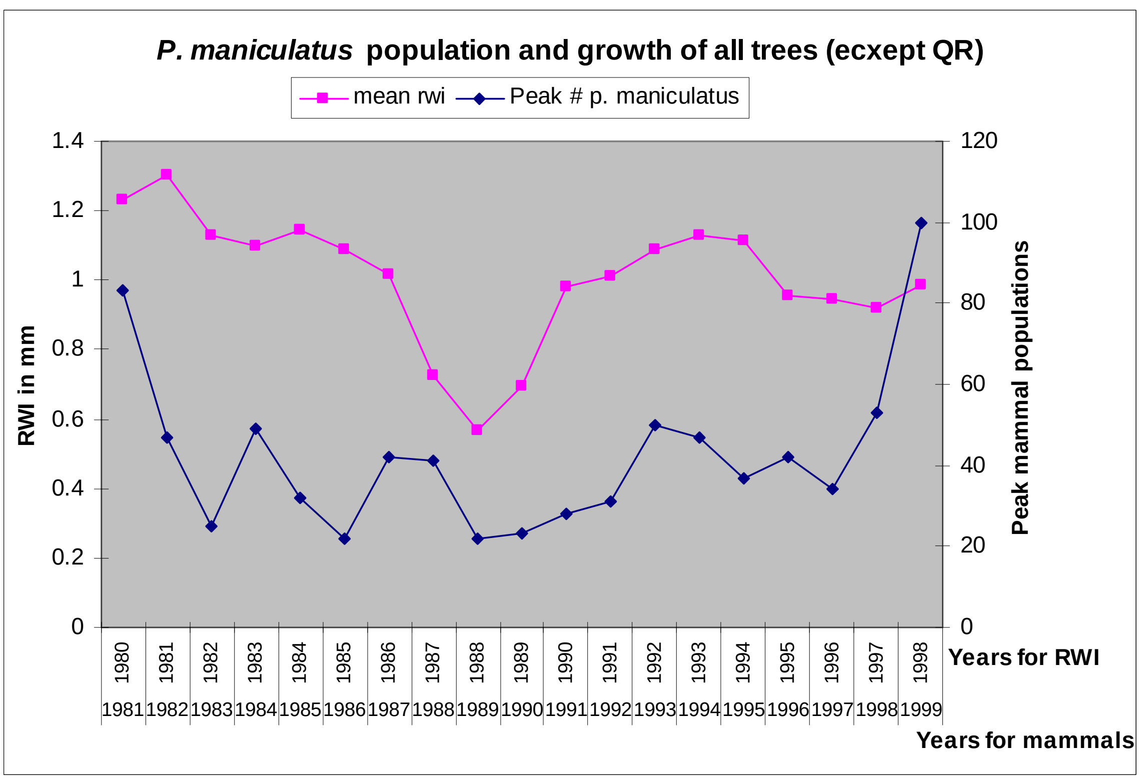

Figure 8. *P. maniculatus* population and ring growth of all trees

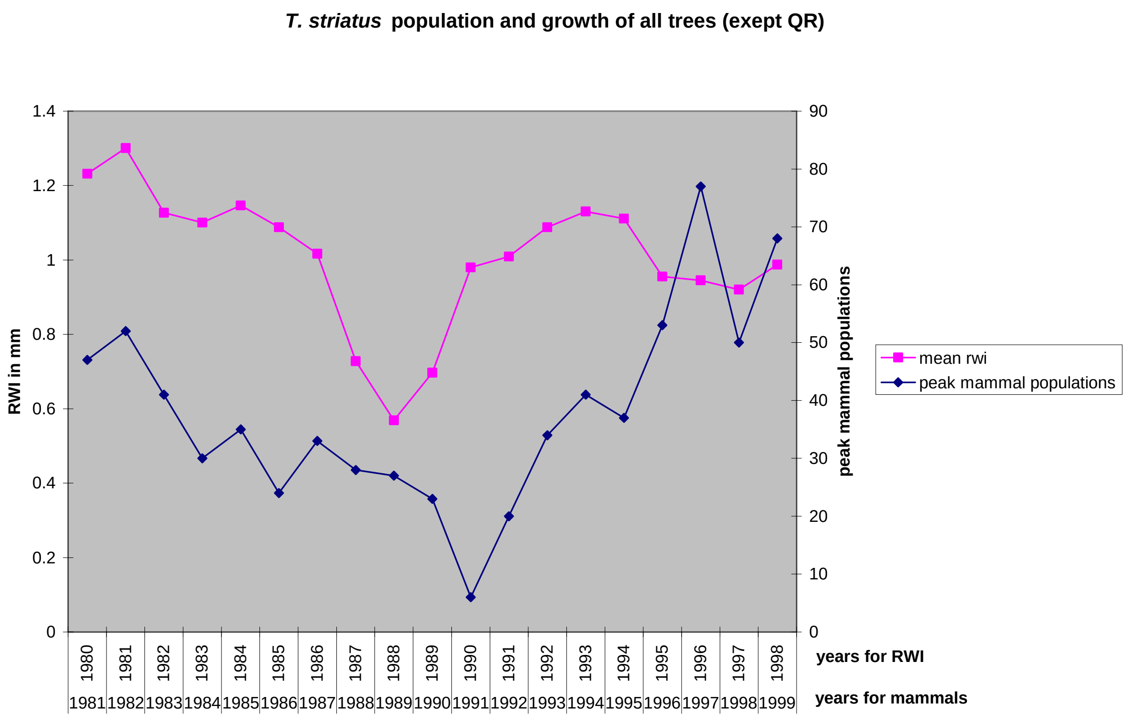

Figure 9.*T. striatus* population and ring growth of all trees

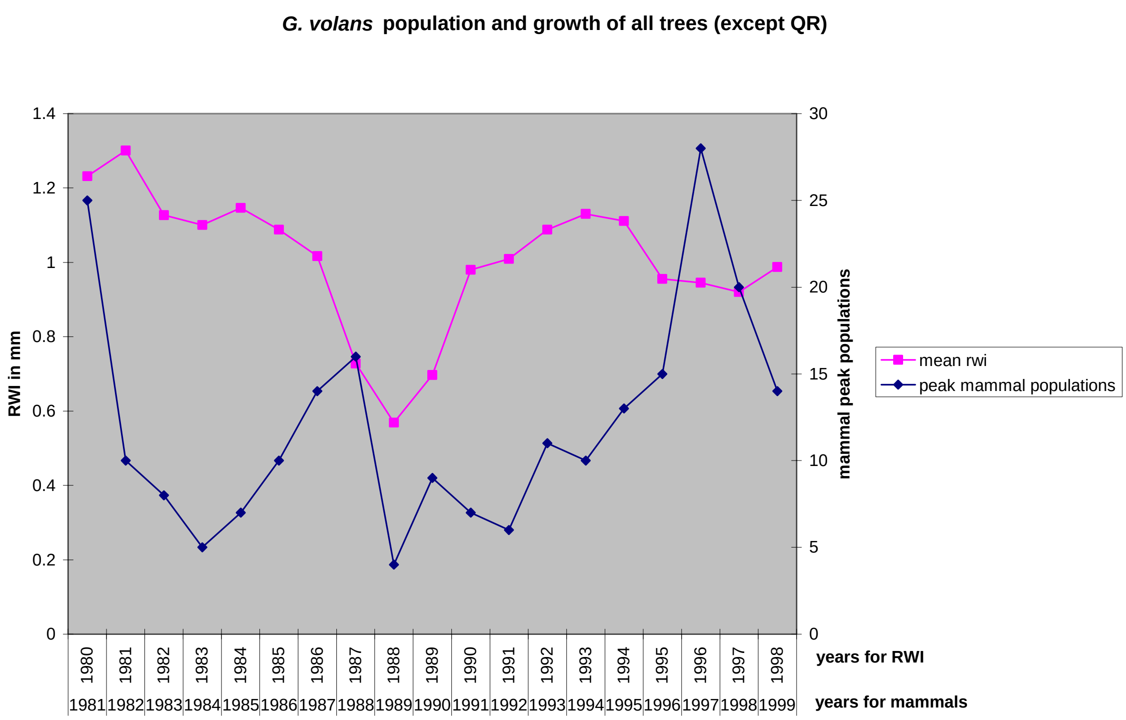

Figure 10.*G. volans* population and ring growth of all trees

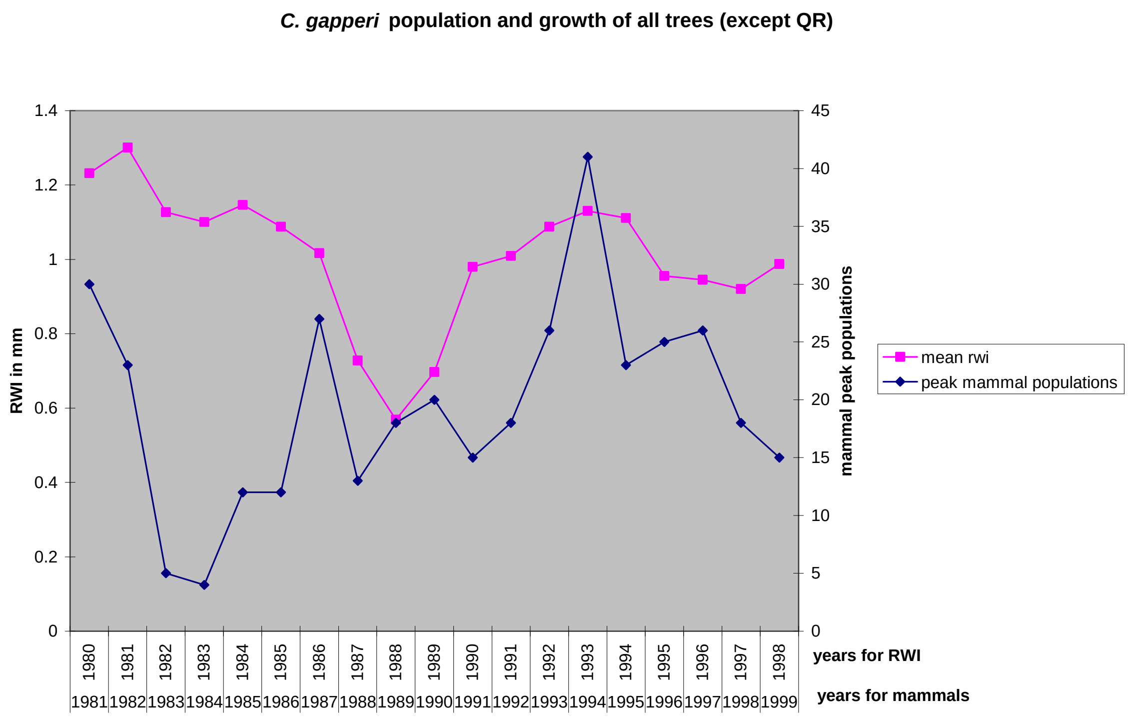

Figure 11.*C. gapperi* population and ring growth of all trees

Figure 1. shows the Pearson's product moment correlation coefficient for mammal/tree comparisons. Figure 2 shows the correlation between all trees (except *Q. rubra*) in the study site and *P. maniculatus*. This graph is a regression analysis and shows a weak correlation because the correlation coefficient is 0.31348523. For it to be a strong correlation then the coefficient is close to one. Figure 3 shows the correlation of all tress (except *Q. rubra*) in the study site and *T. striatus.* This graph is a regression analysis and shows a positive relationship with little evidence of a correlation because the correlation coefficient is 0.221583014. Figure 4 shows the correlation of all tress (except *Q. rubra*) in the study site and *G. volans.* This graph is a regression analysis and shows a positive relationship with little evidence of a correlation because the correlation coefficient is

0.079419301. Figure 5 shows the correlation of all tress (except *Q. rubra*) in the study site and *C. gapperi.* This graph is a regression analysis and shows a positive relationship with little evidence of a correlation because the correlation coefficient is 0.141201611. Figure 6 shows the correlation of all tress (except *Q. rubra*) in the study site and all four mammal species studied. This graph is a regression analysis and shows a positive relationship with little evidence of a correlation because the correlation coefficient is 0.290016526. Figure 7 through 11 shows the mean RWI of all tree species and annual peak population densities of each mammal species in the study: *P. maniculatus, T. striatus, C. gapperi, and G. volans* for the years of 1980 - 1999. In all of these graphs the trend of peak populations and tree growth appear to be similar, especially in figure 9.

CONCLUSIONS AND DISCUSSION

The hypothesis of the present study states that in the year following increased tree ring growth, the small mammal population densities of *Peromyscus maniculatus, Glaucomys volans, Clethrionomys gapperi, and Tamias striatus* will ascend. An exception was made with Red Oak (*Quercus rubra*) because they mast one year after increased tree ring growth, and the mammal population will therefore respond two years after the increased tree ring growth. The hypothesis is rejected, although some correlations are found.

Most of the relationships found are not very strong, with a range of -.25 to .4. There are no strong relationships between the four mammals and *Fagus grandifolia*. The Sugar Maple shows negative correlations (see figure 1), though not strong ones, with *P. maniculatus* and *C. gapperi*, and a very low positive correlation with *T. striatus*. There is a stronger relationship, .7, between Red Oak, *T. striatus,* and *G. volans*. The acorn of the Red Oak is a staple for both *T. striatus* and *G. volans*. The relationship between *P. serotina* and *T. striatus* is .6. This strong relationship could be because Black Cherry is another valuable food source for *T. striatus*.

It appears that the most evident period of time, where figures 7-11 graphically represent a relationship between mammal populations and tree ring growth, is in the years 1988 to 1989. 1988 is used in this study as a signature year, due to the drought conditions of that summer. Tree ring growth drops from 1987 to 1988 and mammal populations also drop from 1988 to 1989, showing that the drought may have impacted the mammal population. Then from 1989 to 1990 the RWI increases, but from 1990 to 1991 the mammal population decreases with the exception of P. maniculatus. This could be because after the drought the separate mammal species (*G. volans, C. gapperi, and T. striatus*) died off. Then because of the lower population, there would be more food available for the next generation of mammals, which would cause the population to swell. The *P. maniculatus* may not have died off because it might not heavily depend upon seeds from trees as much as other species.

In figures 7-11, there are some other trends found that are the same among some of the graphs. For example, in figure 9 the RWI increases from 1980 to 1981 then decreases from 1981 to 1982 while the *T. striatus* population increases from 1981 to 1982 and decreases from 1982 to 1983. Next, figure 10 shows that from 1981 to 1983 the RWI decreases and then increases from 1983 to 1984 while the *G. volans* population from 1982 to 1984 decreases and then increases from 1984 to 1985. In figure 11, the RWI decreased from 1981 to 1983 and then increased from 1983 to 1984 while the *C. gapperi* population decreased from 1982 to 1984 and then increased from 1984 to 1985. Red Oak is not included in the graphs because it masts the year after increased tree ring growth and would affect the mammals two years after increased tree ring growth.

There are some limitations in the present study, which include the fact that only a few weeks were allotted for field study and a few more for data analysis. Next, if the predator-prey relationship was studied, the researchers would have known if a drop in population was due to a high predation rate for that year. There are also nonliving factors that affect the population of small mammals and trees, such as amount of sunlight, amount of precipitation, temperature, and environmental disasters. The only trees cored were from inside the grid and only three or four trees of species were sampled. The grid was also small (only one hectare in area) and only one site was tested.

If different sites were sampled and more cores were taken from trees, there would be a better representation of the kind of forest at Powdermill. Also, if a larger area was sampled, the data may have better represented the forest. If the climate was monitored more closely along with the data, a correlation might have been found between weather and mammal population densities. An overabundance of food may cause the small mammal populations to be unresponsive to fluctuations in tree ring growth because there would be so much food that a decrease in masting would not affect their populace. Also, it might be helpful to monitor the predation rate on the small mammals along with the population densities of the mammals that are preyed upon.

If all of the Eastern Appalachian forests within this climatic region were studied, would you find the same results? Could predator prey relationships affect the population density? Does disease affect the population density? Does the position of the tree within the forest structure affect its masting? Would a dominant canopy tree produce more seeds than an intermediate tree in the forest structure? Also, would one find a pattern of peak mammal populations in each season? Would forests with less food availability show a higher correlation between masting and mammal population?

The findings of this study are significant because they show that tree rings do not accurately describe the fluctuations in the population of small mammals. There must be other factors influencing the small mammal populations if mammals have a low correlation with tree ring growth. One might be able to study what other factors affect mammal population. This technique of using tree rings to describe small mammal populations may be more applicable in a forest where resources are scarce and therefore further research could be performed to contribute to the scientific knowledge of forest ecology.

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