How are white squirrels able to survive in a forest?

J.C. Hodge[1*]
[1]Blue Ridge Community College, 100 College Dr., Flat Rock, NC, 28731-1690

Abstract

The white squirrels' (Sciurus carolinensis) causes of success in a predatory environment and causes of the apparent population equilibrium with gray squirrels are mysteries. White squirrels of Brevard, NC are thought to be a color variant of the Eastern gray squirrels. White and gray squirrels were observed from 2001 to May 2010. The squirrel population in the observation area has changed from predominantly gray to predominantly white. The observations suggest white squirrels have many physical and culture characteristics that differ from gray squirrels. These characteristics favor white squirrels over gray in a substantial feral and stray cat (Felis catus) predation and human environment. That Brevard white squirrels may be at an evolutionary branching point is suggested.

White squirrels; prey preference; evolutionary dynamics

1 INTRODUCTION

Because white pelage is much more noticeable to predators in a forested environment, the cause of the success of the white variant is a mystery. Human protection may be part of the answer.

White squirrel colonies exist in various places in the eastern US (Glesener 2010). The white squirrels of Brevard, North Carolina are distinct from other white squirrel variants. The white squirrels of Brevard have dark eyes, a dark patch on their head, a wide shoulder patch called a saddle, and a dorsal stripe. The dorsal strip occasionally extends the length of the tail. The white squirrels are postulated to be a color morph of the Eastern gray squirrel. However, no head patch has been observed in normal gray variants. Also, a seasonal variation of head patches ranging from gray to pure black has been observed. The inheritance pattern of the two morphs is unknown. The white and gray morphs appear to segregate as separate Mendelian units (Glesener 2001a).

The only other colonies of Brevard type white squirrels are in the southeastern US, particularly in Florida. These colonies appear to have a direct

*E-mail:jc_hodgeblueridge.edu

connection to the Brevard white squirrel (Glesener 2010). Other white squirrel colonies are true albino or white with dark eyes but without the head patch, saddle, or dorsal stripe.

Local folklore holds that white squirrels in Brevard originated from islands off Hawaii or from China and were brought to Florida by a circus. The Brevard white squirrel descended from a single pair trapped in northern Florida and released in Brevard in 1951. The Hawaii or China origin story may have been invented to enhance the appeal of the folklore. Since release, the Brevard white squirrel has increased in abundance and disbursed over a wide area from Cashiers to Hendersonville, a span of approximately 50 miles. Admiring humans may have assisted this distribution.

Periodic sample censuses are conducted (Glesener 2001a,b). This census investigates the relative abundance of white to total squirrel population (hereinafter "Ratio") in an approximate three-mile radius centered on downtown Brevard. The census methods would miss or underestimate some effects such as environmental factors, how far squirrels will travel for a sudden large availability of food, daily activity variance, culture characteristics, and characteristics with short survival times.

Glesener (2001a) reported the Ratio had remained relatively constant at between 21% and 25% for several years. Since then, the census has found the Ratio may be increasing. The April 2010 census found an estimate Ratio of 36.7%, the highest on record, and a 12-year average Ratio of 27.4%. However, Glesener (2010) noted this change in the Ratio might be caused by changes in the count protocol. Also, the error bars indicate the recent Ratio increase may not be significant. Glesener (2010) is confident that the white squirrel population is doing well and that the Ratio appears stable. This is another part of the white squirrel mystery.

Glesener (2010) noted variation among the census sectors of both the total number of squirrels and the Ratio. This suggests that environment affects the Ratio in addition to the number of squirrels in a sector. Notably, the highest Ratio (88.9%) and low overall squirrel abundance were observed on the Brevard College campus. The Brevard College campus has several buildings with moderate, open, and grass covered grounds and sparsely placed trees.

Brevard has a large stray cat population that is considered a nuisance. The cats hunt and kill squirrels.

Neither a white dominant model nor white recessive model describes the apparent Ratio equilibrium (Glesener 2001a). This inconsistency between calculations of gene frequency and census observations suggests the existence of some undetected pleiotropic effect. White squirrels and gray squirrels freely interbreed and have mixed litters. Current wisdom holds that the offspring of mixed mating are either white or gray, but not blends. Glesener (2001a) postulated a gene frequency model to explain the apparent Ratio equilibrium.

This paper suggests that there is a constellation of characteristics including genetic traits, culture, and behavioral traits that allow the Brevard white squirrel to have a higher fitness than the gray squirrel in a highly predatory environment. The white squirrel is white, is cautious, is more agile, has a smaller

body structure, and has a shorter and less bushy tail. The gray squirrel is gray, is more aggressive, is less agile, has a slightly larger body structure, and has a longer and bushier tail. White squirrels and gray squirrels have different cultures. Individual survival requires all the characteristics of the variant be present. That is, the mixing of culture and pelage characteristics within an individual is selected against. Indeed, the highly predatory environment such as in the high stray cat population of Brevard is necessary for the white squirrel to be more fit. The cats introduce a prey preference than causes a stable Ratio.

In section 2, the observations are described The Discussion and conclusion is in section 3.

2 Observations

A bird feeder was installed in 2001 on the east side of 16 Hosta Lane, Brevard, North Carolina 28712 to feed and watch birds. This site was approximately one mile outside Brevard city limits and was outside the squirrel census zone. This feeder has become a squirrel feeder. The food was sunflower seeds. The feeder was suspended approximately 1.5 meters above the ground and one meter from a tree, which was at the edge of a sharply declining slope of approximately 40 degrees. Food dropped to an area of approximately one meter diameter on the ground (hereinafter "Food Area"). The feeder was located approximately three meters from a sliding glass door. The "Feeding Volume" included the feeder, the Food Area, and three meters distant from the feeder. The "Feeding Area" was on the ground within three meters of the Food Area.

Other than stocking the feeder and being close, I did not interfere or interact with the critters. Several patterns and characteristics of white squirrels and gray squirrels have been qualitatively noted.

Distinguishing individuals by their gray pattern determined the number of white squirrels. The number of gray squirrels was determined by distinguishing individuals by their body and tail size. The maximum number that was seen simultaneously within a week determined the number of chipmunks (Tamias striatus) visiting.

Initially, one white squirrel visited once or twice per week. Up to ten gray squirrels visited the Feeding Volume daily. One to two chipmunks visited the Feeding Volume daily.

The number of chipmunks visiting has cycled between none and six. The number of stray and feral cats (herein simply "cats") cycled between none and two. Domestic cats were discounted because they were too fat and slow to be a serious threat to the squirrels. However, they did harass squirrels. The cat cycle lagged the chipmunk cycle by approximately two weeks after I saw four chipmunks. Domesticated dogs were running loose in the area - a situation that may not be present in Brevard city. Also, hen hawks (Accipiter cooperii) and, occasionally, Red-tailed Hawks (Buteo jamaicens) frequently appeared in the sky and trees.

The daily visit count of eight or nine white squirrels has existed since 2007.

Eight active drays were within an 80-meter radius in the summer of 2009 (Rowe 2009). This was the same number of human houses in this area. This implied approximately 2.8 squirrels per forested acre. Because food was supplied daily, perhaps this was a squirrel culture limit rather than a mast limit. A neighbor also feeds squirrels. When he left for more than a day, over 18 white squirrels visited daily. Therefore, squirrels routinely traveled 80 meters to a food supply and 160 meters when food was scarce. Apparently, a constant and copious mast supply bred more white squirrels not bigger white squirrels. That is, smaller size was an advantage because the group culture structure can be more effective with more individuals for a given food supply.

By May '10, an average of one to three male gray squirrels visited approximately twice per week. Five female and six male white squirrels visited daily. Up to six white squirrels within the viewing area were seen simultaneously daily. Twice in 2008, in Jan. '09, and in Mar. '10 nine white squirrels were seen simultaneously.

The larger gray squirrels had a larger body size, a longer stride, a longer tail, and a wider, bushier tail than the largest white squirrel. The medium sized gray squirrels also had longer and bushier tails than most white squirrels. The larger white squirrels chased and caught the smaller gray squirrels. The medium and larger sized gray squirrels chased all white squirrels. However, a gray squirrel catching a white squirrel has not been observed. Usually, the white squirrel gained at least a half-meter after a three-meter chase. Among squirrels, the squirrel with the larger tail size chased the squirrel with the smaller tail.

The feeder usually emptied each day. The limit of view in the forest during summer was approximately 50 meters. After the feeder was refilled, from five minutes to two hours (to normal feeding time) elapsed before the first squirrel arrived. The time lag was dependent on when the feeder was refilled and which morph arrived first. The shortest time to first squirrel was just after sunrise, around midday and late afternoon. If the feeder was refilled between these times such as at 10 AM and if the first squirrel to visit was a gray squirrel, the next squirrel arrived an average of 40 minutes later. Up to two hours may elapse before the next squirrel arrived occasionally occured. Other squirrels in the trees between 20 meters and 50 meters did not come to the Feeding Volume.

If the first squirrel was a white squirrel, the next one to four squirrels arrived within 20 minutes. Other squirrels in the trees between 20 meters and 50 meters did come to the Feeding Volume.

The definition of a "dominant" squirrel in a group was refined in 2009 to mean high in the pecking order, only. Physical fights ultimately determined pecking order. However, tail size appeared to substitute for fighting.

The definition of an "aggressive" cultural characteristic was refined to mean a squirrel behavior wherein the squirrel either did not tolerate other squirrels within a half-meter radius when feeding or left the Feeding Area when other squirrels were present which applied to squirrels low in the pecking order.

The definition of a "cautious" cultural characteristic was refined to mean a squirrel behavior wherein the squirrel was tolerant of others in the Feeding Area. A cautious, dominant squirrel in the Feeding Area chased other squirrels

for a short distance if they approached within a half-meter or tolerated the others in the Feeding Area. Other characteristics included more wariness than aggressive squirrels of new things, of new noises, and of being too close to a place where it could not see such as corners. For example, the cautious squirrel slowly approached a new dead stick in the Feeding Area whereas the aggressive squirrel usually did not approach or investigate. When startled, the cautious squirrels climbed higher and returned slower than the aggressive squirrels.

The set of squirrels that were aggressive and the set of squirrels that were cautious were mutually exclusive sets. Each squirrel was in one of these sets. A dominant squirrel could be either cautious or aggressive. Likewise, a squirrel low in the pecking order could be either cautious or aggressive.

As long as there were three or less squirrels on the ground, the cautious, dominant squirrel can maintain the half-meter feeding radius. More than three gray squirrels within the Food Area have not been witnessed. More than three and up to six white squirrels in the Food Area simultaneously occurred frequently. The squirrels lower in the pecking order occasionally tested the more dominant squirrel. If there were three or less squirrels in the half-meter zone, the cautious, dominant squirrel attempted to chase or fight. This chasing was little more than a threat if the chased squirrel left or was a chase of less than four meters. That is, the cautious, dominant squirrel asserted dominance then quit.

Occasionally two cautious squirrels shared the feeder. If there were three cautious squirrels in the Feeding Volume, there was a little chasing but they soon settled into an acceptable eating arrangement. A less dominant, cautious gray squirrel was tolerated in the Food Area by dominant, cautious, white squirrels. Two to four cautious squirrels could be on the ground within half-meter of each other feeding. If there were six or more cautious squirrels in the Feeding Volume, one or more would settle on a tree branch and wait.

The aggressive squirrel attempted to chase others in the Food Area. If the other was a more dominant squirrel, a physical fight ensued. The aggressive squirrel was often injured. Another response of aggressive squirrels was to visit the Feeding Area alone at times when others were usually absent. This was an opportunity for predators.

When four or more squirrels were in the Feeding Area, one then another tested the aggressive squirrel's half-meter feeding radius nearly constantly. Eventually, the aggressive squirrel appeared to loose its temper and started chasing the unlucky one of its harassers for several tens of meters. During this chase, which may last a half-minute or more, one or more of the other squirrels invaded the Food Area. When the aggressive squirrel returned, it chased another one of the invaders. This process continued for a few cycles. The aggressive squirrel then retreated to an overlooking branch and waited for the larger number of squirrels to leave. As the aggressive squirrel gains experience, it left the area without the long chase. That is, it was intolerant of others feeding nearby. Further, if an experienced, aggressive squirrel visits when squabbling white squirrels were on the ground, the aggressive squirrel left the area. Dominant squirrels tend to feed on the feeder. When a dominant squirrel was on the

feeder, aggressive squirrels fed on the ground.

Aggressive behavior in a group carried a huge energy price. However, such energy expenditure may have a return if the mast was scarce.

The landscape around the house before a recent remodeling provided two ambush areas for cats that were easily monitored. One was the Feeding Area and one was in the front of the house. The forest around the house provided many other ambush sites. The one in front was a carport. A cat would often hide under the car by the car wheel. When a gray squirrel or chipmunk crossed in front of the house to travel from the Feed Volume to the forest on the other side of the house, they usually traveled close to the house, which was a shorter distance than crossing away from the house. The white squirrels traveled at least five meters from the carport and usually across the narrow part of the driveway. Since monitoring started in 2004, over 30 dead gray squirrels and no dead white squirrels were found within one meter of the carport with a distinguishing bite in the back of its neck.

Cats were frequently seen killing and carrying away chipmunks at the ambush site near the feeder. One white and two gray aggressive squirrels were seen killed in the Feeding Area. They were alone and on the ground. Cautious squirrels had also been seen alone on the ground. However, cautious squirrels were more wary than aggressive squirrels. They sensed the cat approaching before the cat came within striking distance.

Between 2005 and 2009 squirrel road kill between my house and approximately one mile toward Brevard was counted during visits to Brevard. The road was well traveled with forest on both sides of the road. This area seems to have had more white squirrels than gray squirrels in 2005, 2006, and 2007. However, the road kill count averaged 14 gray squirrels and two white squirrels per year. The annual road kill count averaged two gray squirrels and two white squirrels per year in 2008 and 2009 when the white squirrel ratio was high. Because road kill was quickly disposed and because counts were taken only one to four times per week, these counts were likely underestimates of actual road kill.

The nearest, squirrel-supporting tree from the feeder tree was over two meters distant. The white squirrels occasionally jumped this distance rather than travel a longer route. No gray squirrel has been seen jumping this distance. When a gray squirrel was chasing a white squirrel, the white squirrel frequently climbed the tree one to three meters and jumped to another tree approximately one meter away. The gray squirrel did not follow. If the squirrel chasing was a white squirrel, it would frequently follow at this height. However, if the chased white squirrel ascended to over five meters, the chasing white squirrel would follow only infrequently.

If a cat approached, white and gray squirrels emitted a chattering, went up trees, and left the area for at least 15 minutes.

The hen hawks tended to glide toward the feeder from the east. A squirrel feeding on the feeder could not see the hawk approach from this direction. One to three times per week a hawk perched in the forest overlooking a one-lane road. The cautious squirrels stopped feeding and watched. Infrequently, the hawk perched in a tree overlooking a flight path that was an attack path for

the Feeding Area. Two to four times per year, the hawk was seen diving on the Feeding Area. White squirrels in the Feeder Volume emitted a higher rate of chatter than for a cat. Most, but not all, white squirrels scurried under bushes rather than climb trees. White squirrels on the feeder rapidly descended and went under the bushes. Gray squirrels climbed trees. Hen hawks have been known to attack prey in trees. The squirrels returned in two to 10 minutes. The white squirrels apparently had differing signals and behavior for danger-from-above and danger-from-the-ground. The gray squirrels did not.

A unique male squirrel started visiting in the early summer of 2005. It had the body but not tail of gray squirrels and mostly gray hair with white on its head, neck, and side. It was a blend, one of two noted during the observation period. It was an aggressive squirrel. This squirrel stopped visiting by mid summer.

Each year one or two younger, white squirrel(s) with variation visited. Some had difficulties or limited abilities. One such white squirrel appeared normal except for a behavioral trait difference in the summer of 2009. Being young and small, other white squirrels would chase it from the feed. It would position itself in a tree close the food and give the danger-from-below call. The other white squirrels scampered up the trees and soon left. The false caller would then eat. After a few weeks and when the false caller had given a warning, the other white squirrels looked but did not leave. A few weeks later, an incident occurred wherein the false caller was on the ground eating and one other white squirrel was on the feeder. The white squirrel on the feeder was gathering seeds and then went to the top of the feeder to eat. Suddenly, the white squirrel on the feeder left the area unusually rapidly without calling. Within two minutes a cat attacked the false caller. The false caller escaped. Within two weeks, the false caller stopped visiting. This was the only squirrel during the observation period with this characteristic.

An aggressive, female white squirrel with a white tail except for distinguishing dark fur at the end of its tail was in a fight with a larger white squirrel in May '09. This aggressive squirrel limped away. The next day this squirrel had a swollen right front paw. A week later, it was missing its right front paw. Its tail became thin. It ate only when other squirrels were absent. It survived through 2009 and became stronger with a bushier tail. By May '10 it could chase smaller white squirrels and maintained its aggressive personality.

As of May '10, two of the 11 white squirrel daily visitors were aggressive. Usually none or one aggressive white squirrel was seen in a season. Both aggressive white squirrels were in the middle of the pecking order. Two of the three male, gray squirrel weekly visitors were aggressive. Both were at the top of the pecking order. The cautious gray squirrel was near the bottom of the pecking order.

A black and white, stray cat remained near the house in the summer of 2009 . Usually the stray cats left when the number of chipmunks declined. By Nov. '09 there were no chipmunks noted in the Feeder Area or around the house, which was unusual. This cat was seen with an injured right front leg in early Nov. '09. This cat was last seen in mid Nov. '09. Since then, no feral or stray

cats have been seen.

3 Discussion and conclusion

The gray squirrels evolved in a wild, forested environment. The gray camouflage allowed the dominant squirrels with increased mating opportunity to be aggressive. The white pelage is very noticeable in the forest. Therefore, developing a cautious characteristic with a white pelage seems plausible a posteriori. Further, developing the cultural characteristic of tolerance in larger groups in a concentrated mast supply seems plausible. Also, a smaller size would allow survival of more individuals for limited mast and for years of low mast availability. All these changes are difficult to explain in a step-by-step evolutionary model in an environment that has selected the gray squirrel.

A human involvement in the selection process is a simpler explanation. Because the initial record was of a circus, the white squirrels may have been selectively bred for the white trait. Selective breeding for wider white underbelly within an enclosure may have also bred for less aggressiveness, more caution, and willingness to feed in larger groups. The foreign origin folklore may have been a circus promotion embellishment. Further, the white squirrel's slighter body, more agility, with more developed speech such as the noted warning sounds and, perhaps, a more developed culture structure such as indicated by the number of squirrels around the feeder simultaneously may be their key to survival in an area of substantial predation.

The present observations suggest a different dynamic of the Ratio than gene frequency of only a pelage trait. The varying Ratio among count sectors (Glesener 2010) and the present observation of a changed Ratio upon the introduction of the feeder and the removal of a cat kill zone suggest the Ratio is environment dependent. Post et al. (2000) studied the dynamics of two noninteracting pray populations in an environment where the predator kills in response to pray frequency. They found that although chaos is possible in food webs, pray preference reduces the potential for chaos. The pray preference may be exercised by the pray. The cautious behavior reduces the cats' opportunity and aggressive behavior may trigger the cats' kill response. This predator-pray dynamic may result in a stable Ratio. Berezovskaya et al. (2009, and references therein) argued that evolution should favor heterogeneous settings including Allee effects. Doebeli & Ispolatov (2010) demonstrated that evolutionary diversity could occur after the population reaches a continuous stable strategy such as demonstrated by a stable Ratio in a stable environment.

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