THE USE OF BIOLOGICAL CONTROLS FOR VECTOR-BORNE DISEASES: THE CASE OF GUINEA FOWL AND LYME DISEASE

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Abstract. Hundreds of viruses, bacteria, and protozoa require a parasitic arthropod for transmission between vertebrate hosts. The failure of many conventional methods of vector-borne disease control has lead modern research to consider biological control methods. Lyme disease is a potentially debilitating condition that has caused many people to seek an effective means of protecting themselves from ticks; the primary vector of the disease. Reducing the chance of encountering a tick is an effective, and thus popular, mode of protection. Using guinea fowl to eat ticks is a widely accepted biological control method used in backyards; however, no sound scientific research has examined the role of guinea fowl in reducing the risk of Lyme disease. Nymphal, blacklegged ticks pose the greatest risk to human health in the northeastern United States, due to their high infection prevalence and small size. This study assessed what effect, if any, guinea fowl have on the density of nymphal and adult ticks in backyards. This was achieved by determining the difference between the density of ticks in yards that have had guinea fowl for at least one year and nearby yards that served as matched controls. Statistical analyses revealed no significant effect of guinea fowl on nymphal densities (Wilcoxon z-value=1.26, p=0.21) but a significant reduction in adult densities on lawns with guinea fowl (Wilcoxon z-value= 2.03, p=.043). This study poses two possible scenarios for the effective reduction of adult tick abundances by guinea fowl: the Predation Hypothesis and Aggressive Exclusion Hypothesis. There was no apparent correlation between the density of adults and the density of nymphs found in yards. Therefore, although the presence of guinea fowl reduces adult tick numbers, this does not appear to have an effect on nymphal tick abundance, the primary vector for Lyme disease transmission. Based on these findings, guinea fowl are not an effective biological-control for Lyme disease vectors.

INTRODUCTION

Viral, bacterial, and protozoan transmission by arthropod vectors continues to have substantially devastating effects on human health in temperate and tropical regions around the world. Methods to combat vector-borne diseases have included vaccinations and treatments but historically, vector control has been the most widespread method of choice. Reduction of parasitic, arthropod populations decreases the chance of a blood meal being taken from a human and for that reason, is critical in reducing the risk of disease transmission. Some diseases, such as Trypanosomiasis, depend entirely on this method, since no effective alternative has been found (Petney 1997). Reducing disease vector abundance has not been as effective for many other serious diseases. Malaria and dysentery, transmitted by mosquitoes and flies respectively, are two examples in which insecticides and breeding habitat destruction were the primary methods used (Molyneux, 1998). However, the evolution of chemical resistant mutants and anthropological disturbance recreating breeding grounds and altering community composition, led to the reemergence of disease vectors. Not surprisingly, disease epidemics were soon to follow. Current, epidemiologic research focuses on potential biologic controls as an alternative method of suppressing vector-borne disease transmission (Sharma 1995).

Lyme is a vector-borne disease caused by the bacterium, *Borrelia burgdorferi*, and transmitted in the northeastern United States by the blacklegged tick, *Ixodes scapularis*. It is a potentially debilitating illness that can lead to arthritic and neurological disorders (Ostfeld 1997). The highest concentration of Lyme disease can be found in the northeastern United States and some of the highest in Dutchess County, New York (Allan et al. 2003; Ostfeld 1997). Widespread use of traditional disease-vector controls has been impossible for blacklegged ticks, because no insecticide is species-specific enough and reproduction usually occurs on the white-tailed deer (*Odocoileus virginianus*), so eliminating their breeding habitat is not an option. Recommendations to reduce Lyme disease risk when entering forests include: wearing light-colored clothing and insect repellent, avoiding areas of exceptionally high risk, and performing thorough tick checks upon leaving a forested setting (Ostfeld 1997; Sonenshine and Mather, 1994). However, many people are interested in protecting themselves from ticks in their own backyard without having to depend on covering exposed skin during the hot summer months or resorting to frequent use of chemical deterrents near their homes.

Using guinea fowl, which eat insects, to reduce tick numbers in backyards and, subsequently, Lyme disease risk, is an increasingly popular tactic. Unpublished data by Crowe revealed ticks in the stomachs of three guinea fowl (Duffy et al. 1992). These findings spurred Duffy et al. (1992) to conduct a study which assessed the effect of guinea fowl on blacklegged tick densities in lawns. The study's results revealed that the presence of guinea fowl decrease adult blacklegged tick numbers. Duffy et al.'s (1992) study was limited in its ability to assess guinea fowl's effects on tick numbers and subsequently Lyme risk and further studies have not been conducted (Ostfeld 1997). Duffy et al. (1992) found a total of fifteen ticks, which is an inadequate sample size to analyze statistically. In addition the study was conducted on two lawns in Suffolk County, New York, thus it had poor replication. Despite the study's limitations, it has prompted a number of homeowners to acquire guinea fowl with the intention of reducing the risk of Lyme exposure in their yard. An aspect of this study will reevaluate Duffy et al.'s (1992) claim, by assessing the effect of guinea foul on adult tick abundance in lawns.

Duffy et al.'s (1992) research had additional limitations to assessing guinea fowl impact on Lyme disease risk, because they only assessed the effect of guinea fowl on adult tick numbers (Duffy et al. 1992). Ticks in the adult life stage are much less likely to transmit Lyme disease to humans than the nymphal life stage, because their larger size makes them more easily perceptible to those who have been bitten (Ostfeld et al. 1996). As a result, the nymphal life stage is the only stage used to assess Lyme disease risk and as a result the potential impact of guinea fowl on nymphal ticks has greater implications for human health than guinea fowl's impacts on adult ticks (Figure 1) (Falco and Fish 1989, Ostfeld et al. 1996). In addition, adult tick size, most likely, allows them to be more easily detected by guinea fowl; therefore it is not suitable to simply extrapolate Duffy et al.'s (1992) conclusions to nymphal ticks. This study will directly assess the effect of guinea fowl on nymphal tick abundance.

It is unlikely that a reduction in adult densities will reduce the number of nymphs in a backyard because this habitat is not conducive to completing the lifecycle of a blacklegged tick. Three vertebrate hosts are required to successfully complete this parasitic, tick's two year, life-cycle (Figure 1) (Ostfeld et al. 1996; Ostfeld 1997; Allan et al., 2003; LoGiudice et al. 2003). Once a tick enters a lawn, its chances of encountering a host are greatly reduced. If the tick does attach to a host, it is likely to be transported back out of the yard before it feeds to repletion several days later, and drops off. This is to be expected because wildlife hosts are more active in wooded habitats than human's lawns. If the tick is able to find a host in the yard (a household pet for example) and remain in the yard after feeding, it is unlikely the tick would survive all life stages within the lawn's harsh environment. Ticks require moderate temperatures and adequate moisture especially during quiescent periods between molts. A mowed lawn is much drier than the tick's natural habitats making them more susceptible to desiccation. Therefore, it is most probable that a host-seeking nymph (life-stage of primary health concern) on a lawn was transported there as a larva and did not emerge from eggs laid in the lawn two autumns prior. If guinea fowl do, in fact, decrease adult ticks on a lawn, it is unlikely an impact would be detected on nymphal abundance, unless guinea fowl can find and consume nymphs as well. Since no scientific assessment of this question has been addressed, this study will evaluate any correlations in nymphal and adult tick abundance on lawn.

I hypothesize that, a decrease in densities at either life stage, associated with guinea fowl presence will indicate guinea fowl are effectively foraging and controlling ticks on lawns. If data reveal an increase in tick densities on lawns, it may indicate that guinea fowl are acting as a host for ticks allowing them to more easily complete their lifecycle within a backyard setting. Alternatively, an increase in nymphs may indicate that feeding guineas attract white-footed mice (*Peromyscus leucopus*), which are known to carry high larval burdens and are the most competent *B. burgdorferi* reservoir. This would result in more nymphs and higher Lyme infection prevalence on the lawn the following year (Ostfeld et al. 1996; Shaw et al. 2003). The same alternative mechanism applies to an increase adults, except the eastern chipmunk *(Tamias striatus)*, would most likely be the primary cause, since they are the nymphal stage, primary host (Shaw et al. 2003). If there is no effect on densities, at one or both life stages, from foraging guinea fowl, then they may not interact with that particular life stage. Alternatively, a combination of the above mentioned mechanisms leading to density increases and decreases may result in no net effect. If guinea fowl do not reduce nymphal densities, but support Duffy's conclusion by reducing adults, and a correlation is found between abundances in these two life stages, then an indirect impact of guinea fowl on nymphal ticks, by consuming adult ticks may be adequate to significantly reduce the risk of Lyme disease transmission. This study will seek to determine what effect persistent foraging by guinea fowl have on nymphal and adult densities on lawns to assess their usefulness as a local, biological control for Lyme disease.

METHODS

The effect of guinea fowl presence on tick densities was evaluated using 20, paired lawns in Dutchess County, New York (Figure 2). Ten treatment sites were chosen by fulfilling the following criteria: guinea fowl had been in the lawns for over one year, no use of alternative tick control methods, and no or very little activity by other fowl. Each treatment yard was paired with a control yard located within one kilometer but not adjacent, to insure no spillover guinea fowl activity. Control yards fulfilled the same criteria as treatment yards, except no guinea fowl were present. Treatment and control sites were in similar landscapes, and each yard pair had similar domestic pet activity, to ensure the same consistent movement in and out of surrounding forests, onto the lawn.

Sampling on each site involved dragging a one meter squared, white cloth for 50 to 100 meters within two meters of the yard's edge, 50 to 100 meters within the yard's interior, and 50 meters along the forest edge. The dragging technique has proven to be reliable for sampling nymphal abundance (Falco & Fish 1992; Ostfeld et al. 1995; Allan et al. 2003). Sampling at each site occurred once a week for three weeks during the nymphal peak (June 20, 2004 – July 10, 2004) and adult peak (October 16, 2000 - October 31, 2004) and only on days when the grass was dry, and had not been mowed recently (Ostfeld 1997). Comparative densities of nymphs and adults found on control versus treatment lawns were determined using a Wilcoxon Signed Ranks Test.

Nymphs were kept alive, in separate vials, for each yard's exterior, interior, and edge, to be tested for the presence of *B. burgdorferi* using a fluorescent antibody technique. Ticks were placed in separate Eppendorf tubes, washed with ethanol (70%) and rinsed twice with distilled water. One-hundred micro liters of phosphate-buffered saline solution (PBS) (pH 7.4) was added before crushing each tick with a plastic grinding tool, used only once to avoid contamination. Five micro liters of suspension from each tube was placed into each of three wells on a mutiwell test slide. After air drying each slide was fixed in cold acetone for ten minutes and allowed to air dry once again. Seven micro liters of fluorescent-antibody conjugate was pipetted into each well and incubated at 37°C for forty five minutes. Slides were then washed twice in PBS for ten minutes and rinsed in distilled water for two minutes. Lastly, slides were mounted in fluorescent-antibody mounting medium with a coverslip to be examined under an Olympus BH-2 binocular at 400x magnification. After systematic scanning of the wells each tick was classified as positive or negative for *B. burgdorferi*. The difference in infection prevalence of nymphs found in control versus experimental lawns was analyzed using a Chi-Square Test.

RESULTS

After sampling 20 yards in Dutchess County, New York once a week for three weeks I found a total of 41 nymphal, blacklegged ticks (*Ixodes scapularis*). A Wilcoxon Signed Ranks Test revealed that in two out of ten instances the treatment yard had a higher density than the paired control yard. Six times a control yard had a higher density than the treatment, and two times the densities were equal (Table 1). Statistical analysis revealed that the density of nymphs found in treatment lawns, which contained guinea fowl, did not differ significantly from control lawns, which had no guinea fowl (Wilcoxon z-value = 1.26, p=0.21) (Figure 3).

After sampling the same twenty yards (with the exception of one control, which acquired guinea fowl between summer and fall) once a week for three weeks I found a total of 70 adult, blacklegged ticks (*Ixodes scapularis*). A Wilcoxon Signed Ranks Test revealed that in one out of ten instances the treatment yard had a higher density than the paired control yard. Six times a control yard had a higher density than the treatment, and there times the densities were equal (Table 2). Statistical analysis revealed that the density of adults found in treatments lawn, which contained guinea fowl, differed significantly from control lawns, which had no guinea fowl (Wilcoxon z-value = 2.03, p=.043) (Figure 4). No apparent correlation was detected between the number of nymphs found in the summer and the number of adults found in the fall across the twenty yards sampled (Figure 5).

Thirty-nine nymphs were analyzed for the presence of *B. burgdorferi*, the bacterium that causes Lyme disease (two nymphs were unable to be analyzed). The results of the Chi-Square test performed showed the difference between the nymphal infection prevalence in yards with guinea fowl was not significantly different from yards without guinea fowl, $\chi^2(1, N = 39) = 3.84$, $p = 0.20$ (Figure 6).

DISCUSSION

Lyme is a vector-borne disease, which traditional methods of control are impractical for because no species-specific enough pesticide exits and reproduction occurs on mammals consequently their breeding habitat is a permanent fixture in the environment. Lyme disease is caused by the bacterium, *Borrelia burgdorferi*, and transmitted in the northeastern United States by the blacklegged tick, *Ixodes scapularis* (Ostfeld 1997). Using guinea fowl, which are believed to eat ticks, to reduce the abundance of this parasitic arthropod and, consequently, Lyme disease risk, has become an increasingly popular tactic on homeowners' lawns (Ostfeld 1997). However, only one study has analyzed the effect of guinea fowl on tick abundance. Although the study supports the use of guinea fowl for tick control, it has serious flaws in its methodology and only examines ticks in the adult life stage (Duffy et al. 1992). Nymphal blacklegged ticks are the prime risk to human health; therefore this study assessed the effect of guinea fowl on ticks in the nymphal life stage on lawns in Dutchess County, a Lyme endemic region, and reevaluated Duffy's claims of a significant reduction in adult numbers with guinea fowl foraging (Allan et al. 2003; Ostfeld et al. 1996; Ostfeld 1997).

The average number of nymphs I found per yard, from sampling once a week for three weeks was only between .002 and .005 ticks per meter squared (Table 1). This means, that walking one kilometer, in a lawn with ticks at similar densities to those I found, one would only encounter three to four ticks. Conversely, someone walking the same distance through a forest in Dutchess County, during the same time of year, would encounter approximately 750 nymphal ticks (Ostfeld, unpublished data). This indicates that yards are an extremely low risk habitat for Lyme transmission by nymhpal blacklegged ticks, which supports earlier findings (Maupin et al. 1991).

A Wilcoxon Signed Ranks Test was used to determine if a statistical difference existed between the number of nymphs found in each treatment yard which contained guinea fowl, and its paired control yard, which did not. The results revealed that there was not a statistically significant difference in nymphal density between treatment and control lawns (Wilcoxon z-value = 1.26, p=0.21) (Figure 3). This discovery, is of the utmost importance because it reveals that regardless of the mechanisms that lead to no effect, and regardless of the effects on adult numbers, guinea fowl do not appear to have a significant effect on numbers of blacklegged ticks, at the life stage most likely to transmit Lyme to humans.

An analysis of nymphal infection prevalence on treatment versus control lawns revealed no statistically significant difference, $\chi^2(1, N = 39) = 3.84$, $p = 0.20$ (Figure 6). This test was conducted in an attempt to determine if the lack of significant difference found in nymph densities is a result of no interactions, or a combination of mechanisms resulting in no net effect. This data indicates that guinea fowl presence is unlikely to attract higher numbers of white-footed mice, than occur on control lawns. Given that increased mouse activity does not appear to be a mechanism at work, guinea fowl acting as hosts for blacklegged ticks is the only other method proposed that could lead to increased nymphal densities. A study conducted by Ostfeld and Lewis (1999) determined that turkeys are poor hosts for juvenile blacklegged ticks, which suggests that guinea fowl may also be poor hosts. If, in fact, they are poor hosts, then no mechanisms exist to increase nymph densities. This would mean if guinea fowl were decreasing densities, by finding and consuming nymphs, then a detectable difference would have existed between control and experimental lawns. This evidence leads me to believe that guinea fowl are unlikely to interact with nymphal blacklegged ticks; however, an investigation of guinea fowl's competency as a host is required to definitively conclude that this is true.

The most pertinent findings from this portion of data, collected in this study, indicate that guinea fowl do not interact with nymphal blacklegged ticks. However, it is important to note that the data reveals a trend towards a decrease in nymphal abundance on lawns with guinea fowl (Figure 3). Although statistically this difference was not significant, the sample size was small and consequently has little power. A power analysis was performed and revealed that the same study repeated with 27 pairs of yards, would yield a statistically significant difference if the trends that existed in the ten pairs of yards I sampled remained the same. There is also a trend toward a higher prevalence of infected nymphs in lawns with guinea fowl although, again, it was not a statistically significant difference (Figure 6). A repeat of this study with more yards may, very well, indicate statistical significance. This would be an extremely important finding because it would mean that even if guinea fowl could eat nymphs and reduce their numbers, they may also bring white-footed mice into the yard, resulting in more nymphs with a higher infection prevalence.

Duffy et al.'s (1992) study used a very small sample size, of only 15 adult ticks, for analysis. Analysis of adult tick abundance in my study was performed with 70 ticks, which is more than four and one half times the amount Duffy et al. (1992) used. In addition, Duffy et al.'s (1992) research was performed on two lawns; this study was conducted using twenty. Consequently, the amount of power in this study is significantly stronger. My results supported Duffy et al.'s (1992) findings: there were significantly lower densities of adults found on lawns with guinea fowl (Wilcoxon z-value = 2.03, p=.043) (Figure 4). Since both studies supported this conclusion, a great deal of confidence can be put in it. However, most importantly, there is no clear correlation between adult tick numbers and the number of nymphs on a lawn (Figure 5). This suggests that, despite the ability of guinea fowl to significantly reduce adult numbers, there is no latent effect whereby ticks in the nymphal life-stage are subsequently reduced. Since the nymphal life-stage is the primary cause of Lyme transmission, this solidifies the claim that guinea fowl do not appear to be an effective biological control for Lyme disease (Ostfeld 1997).

I have proposed the Predation Hypothesis to explain the significant decrease in adult ticks on treatment lawns. This hypothesis supports the mechanism suggested by Duffy et al. (1992). The Predation Hypothesis suggests that guinea fowl and ticks interact in the final life-stage when adult ticks seek their terminal host, at which time they are found and eaten by foraging guinea fowl (Figure 7). However, I have developed an alternative mechanism through which adult tick abundance may be reduced called the Aggressive Exclusion Hypothesis. This hypothesis was spurred by work done by Ostfeld et al. (1995) in which the abundance of ticks was said to be determined by the habitat associations of their hosts since ticks are only capable of moving minimal distances on their own. The Aggressive Exclusion Hypothesis postulates that guinea fowl are not interacting with adult ticks but rather the primary hosts that serve as vessels to transport them into lawns as feeding nymphs; the eastern chipmunk (Figure 8). From both personal observation and Duffy et al.'s (1992) study, I found that guinea fowl are territorial and extremely noisy birds. Guinea fowl and chipmunks are diurnal and, consequently, active during the same time of the day. The hostile nature of guinea fowl may deter chipmunks from choosing to forage in lawns that guinea fowl inhabit. This could lead to fewer nymphs being dropped on lawns to molt into host-seeking adults that fall. The white-footed mouse is nocturnal and, consequently, active when guinea fowl are sleeping. Therefore, in the context of this hypothesis, mice would be expected to forage indiscriminately on treatment and control lawns. The white-footed mouse is the primary host for larval ticks; therefore this would subsequently lead to similar abundances of host-seeking nymphs on treatment and control lawns. For this reason, the Aggressive Exclusion Hypothesis also offers an alternative explanation for the lack of a significant difference in nymphal abundances between treatment and control lawns other than nymphs are too small for detection.

A future experiment to examine if guinea fowl are capable of finding and consuming adult ticks would be necessary to test the Predation Hypothesis. Although Crowe (unpublished data) found ticks in the stomach of three guinea fowl, that finding may not have been a result of active foraging by guinea fowl for ticks. In addition, Crowe conducts work in southern Africa, and it is doubtful the arthropods he found are as small as the blacklegged tick. A behavioral study which looked at guinea fowl interactions with chipmunks versus mice would be necessary to test the Aggressive Exclusion Hypothesis. In addition, a study which looked at chipmunk versus mice behavior at forest edges could offer an explanation for the higher numbers of adults on lawns. If, for instance, mice are less likely to venture into an open lawn, then the total number of host-seeking nymphs would be lower than adults, if chipmunks were bolder in similar instances.

It is important to note that this study was not originally designed to detect a correlation between nymph and adult life stages, thus given the lifecycle of a blacklegged tick. One year is not an adequate amount of time for a reduction in adult numbers to impact nymph numbers (Figure 1). However, with the exception of one lawn, that has been removed from the graph, all treatment yards have had guinea fowl for at least two years (Figure 5). It would be worthwhile to conduct a study that is specifically constructed to detect a correlation in nymphal and adult abundances in a backyard setting. This study also did no control for the number of guinea fowl on each lawn, as treatment sites were limited. The density of guinea fowl may very well be an important factor to take into consideration when assessing their potential as a method for biological control.

This study exemplifies the importance of understanding the impact of potential biological control methods at all stages of a parasitic arthropods life cycle. In addition, evaluation of the impact a method of biological control may have on the abundance of wildlife hosts, which facilitate the spread of disease vectors is essential.

ACKNOWLEDGEMENTS

This work was supported by a grant from the National Science Foundation (NSF) Research Experiences for Undergraduates (REU) program (Grant No. DBI-244101). This is a contribution to the program of the Cary Institute of Ecosystem Studies.

Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Science Foundation.

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APPENDIX

TABLE 1. A table of the densities (ticks/meter squared) of nymphal blacklegged ticks (*Ixodes scapularis*) found after sampling ten paired yards with guinea fowl (treatment) and without guinea fowl (control) once a week, for three weeks. Densities between treatment and control yards were not significantly different (Wilcoxon z-value = 1.26, p=0.21).

Pair	Treatment	Control
1	0.010	0.025
2	0.003	0.000
3	0.001	0.002
4	0.000	0.000
5	0.003	0.004
6	0.000	0.003
7	0.000	0.010
8	0.000	0.001
9	0.000	0.000
10	0.005	0.003
mean	0.002	0.005

TABLE 2. A table of the densities (ticks/meter squared) of adult blacklegged ticks (*Ixodes scapularis*) found after sampling ten paired yards with guinea fowl (treatment) and without guinea fowl (control) once a week, for three weeks. Densities between treatment and control yards were significantly different (Wilcoxon z-value =2.03, p=.043).

Pair	Treatment	Control
1	0.008	0.013
2	0.005	0.012
3	0.000	0.003
4	0.002	0.002
5	0.000	0.001
6	0.008	0.009
7	0.005	0.011
8	0.013	0.012
9	0.000	0.000
10	0.000	0.000
mean	0.004	0.006

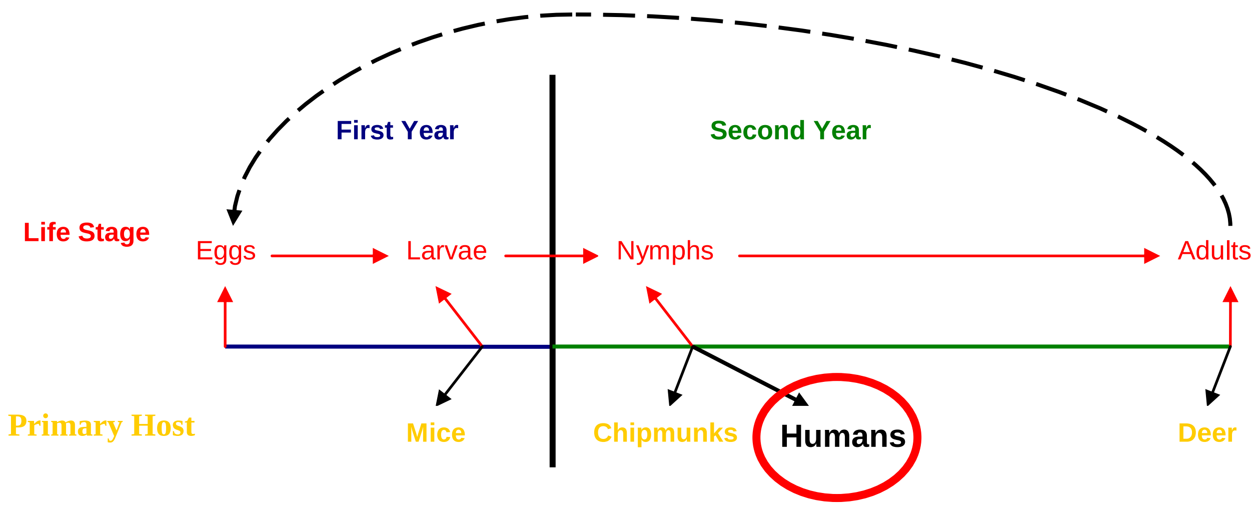


FIGURE 1. A diagram of the blacklegged tick's lifecycle in a forested habitat. The red circle indicates the stage of primary risk to humans for transmission of Lyme through tick bites.

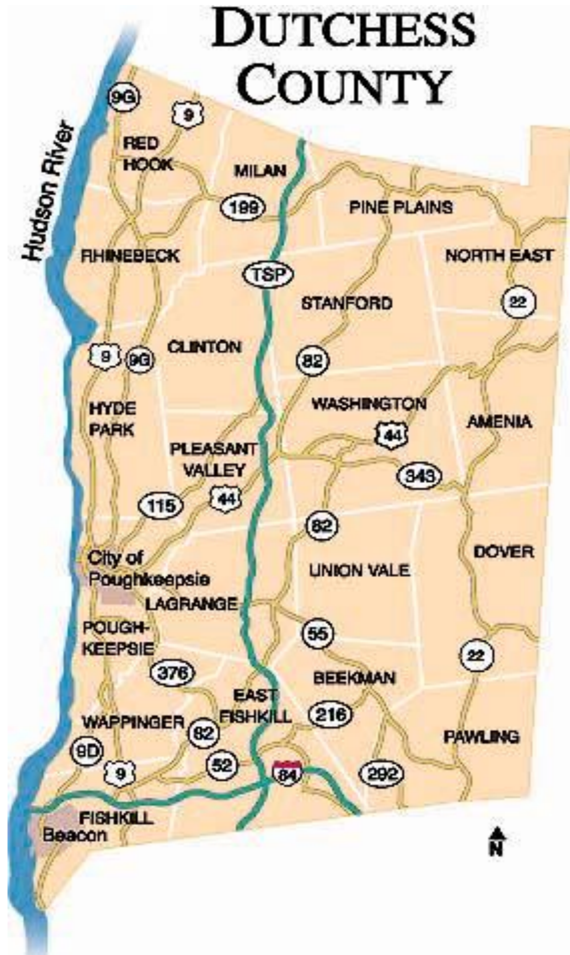


FIGURE 2. A map of Dutchess County; squares indicate the location of paired lawns with and without guinea fowl, used to compare nymphal blacklegged tick (*Ixodes scapularis*) densities.

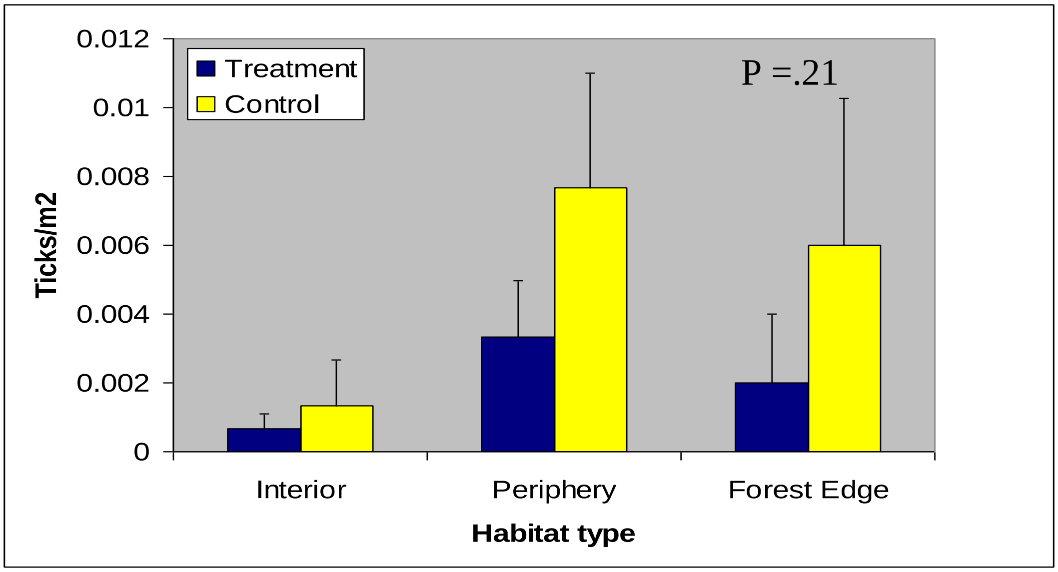


FIGURE 3. A graph of the density (ticks/meter squared) of nymphal blacklegged ticks (*Ixodes scapularis*) found in three habitats in yards with guinea fowl (treatment) compared to yards without guinea fowl (control) in Dutchess Co. Results revealed densities between treatment and control yards were not significantly different (Wilcoxon z-value = 1.26, p=0.21).

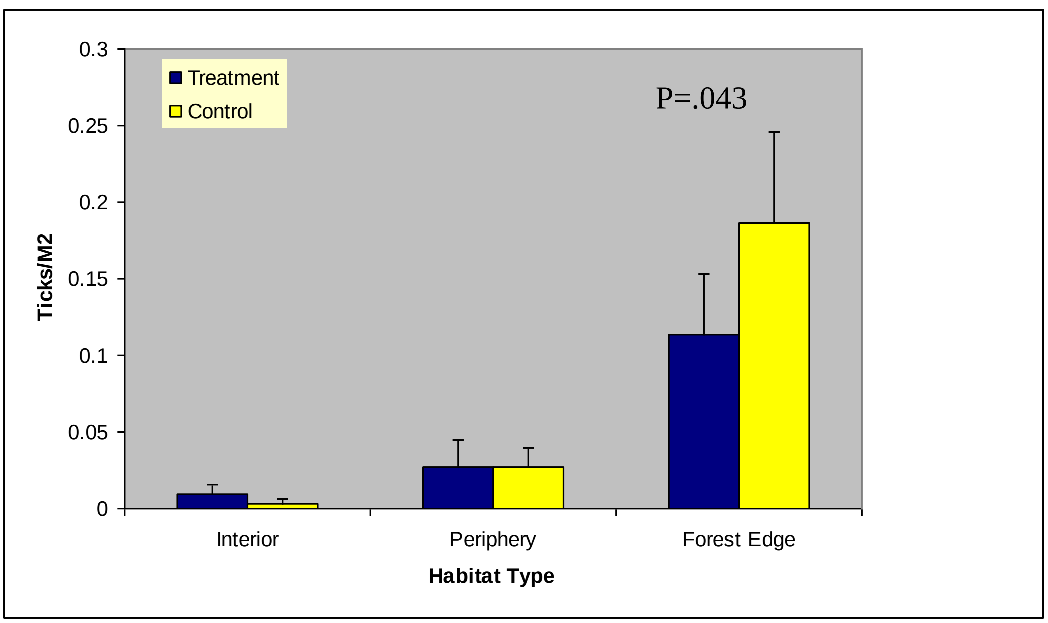


FIGURE 4. A graph of the density (ticks/meter squared) of adult blacklegged ticks (*Ixodes scapularis*) found in three habitats in yards with guinea fowl (treatment) compared to yards without guinea fowl (control) in Dutchess Co. Results revealed densities between treatment and control yards were significantly different (Wilcoxon z-value = 2.03, p=.043).

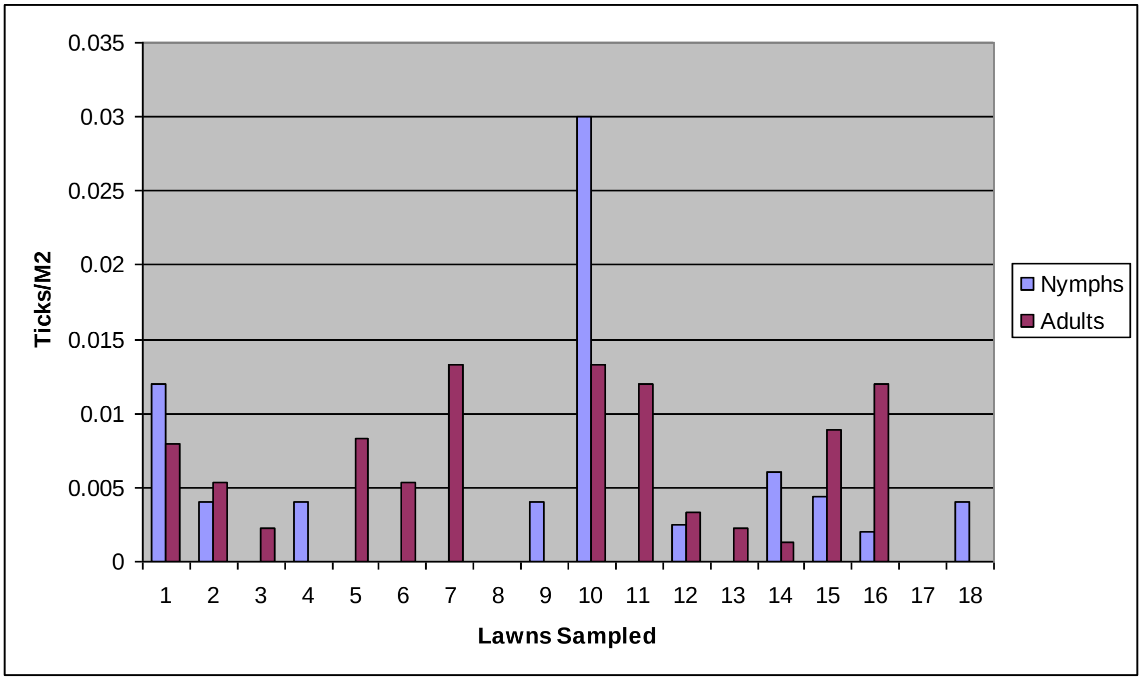
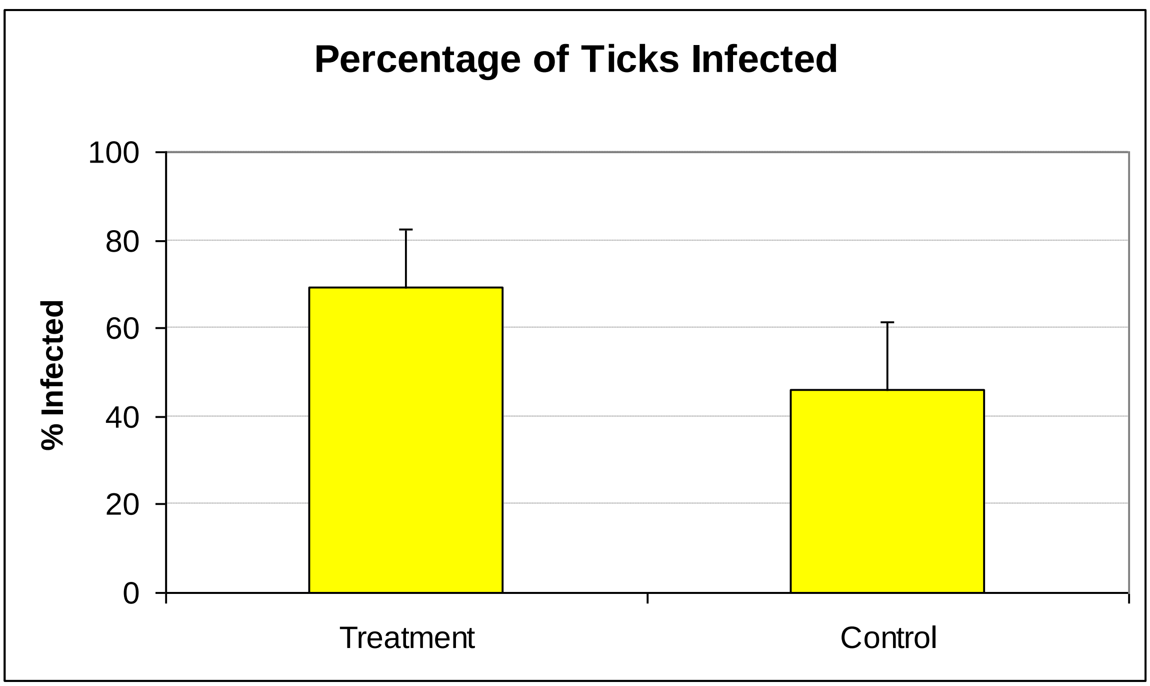


FIGURE 5. A graph of the comparative densities of nymphal and adult blacklegged ticks found across nine treatment yards (yards 1-9, with guinea fowl) and nine control yards (10-10, without guinea fowl). No apparent correlation exists between the abundances of these two life-stages in a lawn habitat.



P = .20

FIGURE 6. A graph comparing the percentage of nymphal blacklegged ticks (*Ixodes scapularis*) infected with *B. burgdorferi*, the bacteria that causes Lyme disease, in lawns with guinea fowl (treatment) and lawns without guinea fowl (control). Results from a Chi-squared Test revealed infection prevalence between treatment and control yards were not significantly different, $\chi^2(1, N = 39) = 3.84$, $p = 0.20$.

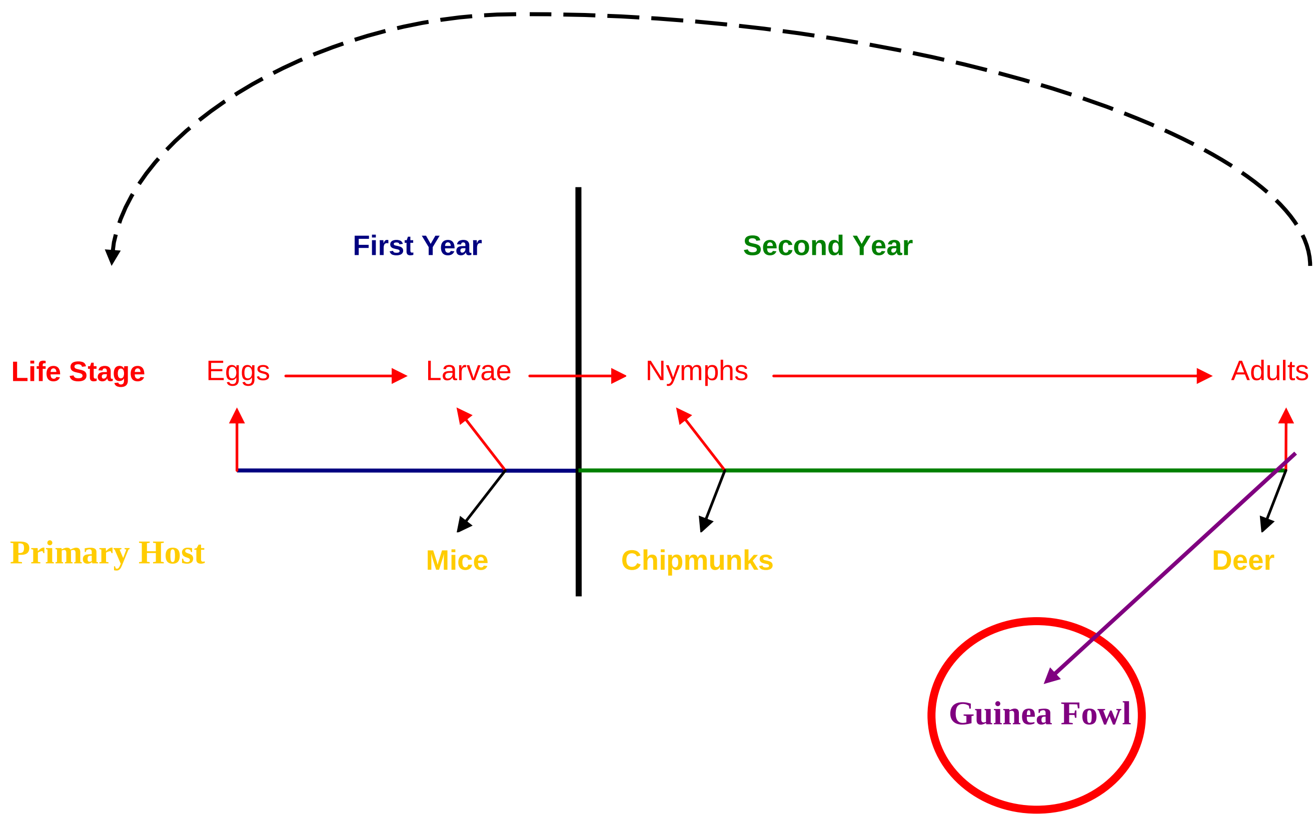


FIGURE 7. A diagram of a blacklegged tick's lifecycle depicting the Predation Hypothesis which postulates that guinea fowl are effectively able to reduce adult tick abundances by actively finding and consuming host seeking adults.

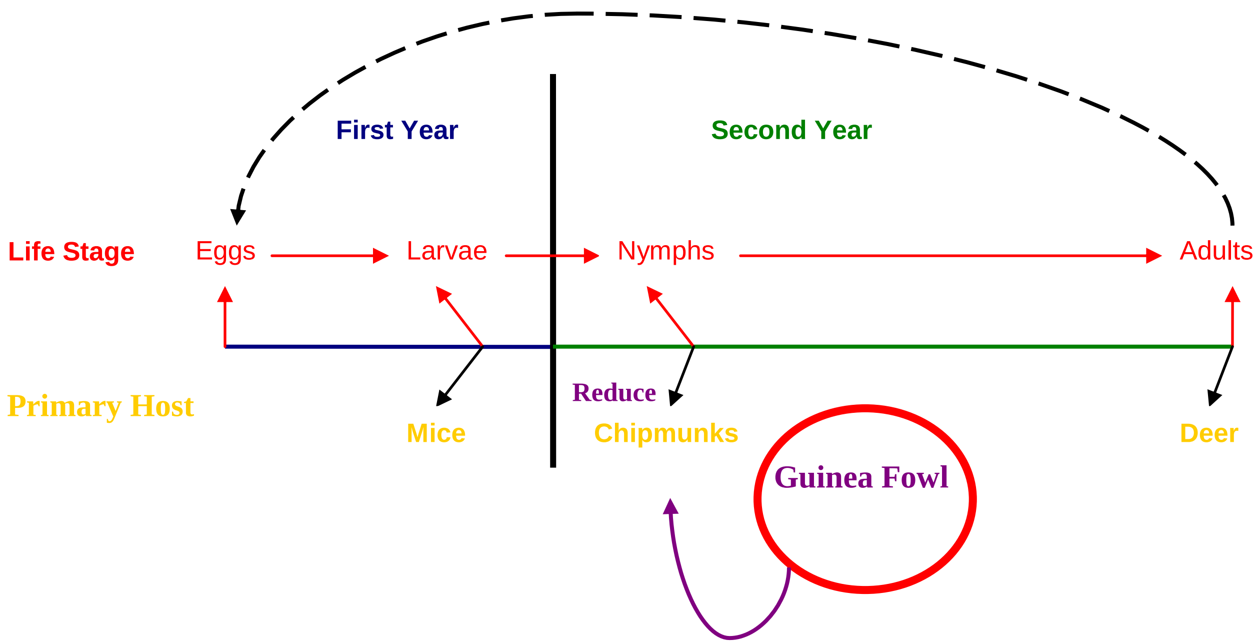


FIGURE 8. A diagram of the blacklegged tick's lifecycle depicting the Aggressive Exclusion Hypothesis, which postulates that guinea fowl are effectively able to reduce adult tick abundances by deterring their nymphal stage hosts from entering lawns and thereby reducing the number of host-seeking adults in the following season.