# A Study Report on the Use of 4-Poster Deer Treatment Stations to Control Tick Infestations on White-tailed Deer (*Odocoileus virginianus*) in Fairfax County, Virginia

FEBRUARY 2016

FAIRFAX COUNTY POLICE DEPARTMENT,
ANIMAL SERVICES DIVISION

FAIRFAX COUNTY HEALTH DEPARTMENT,
DISEASE CARRYING INSECTS PROGRAM

A Fairfax County, Va., Publication

## REPORT AUTHORS

**Katherine E. Edwards, Ph.D.,** *Fairfax County Wildlife Management Specialist, Fairfax County Police Department, Animal Services Division – Wildlife Section, 4500 West Ox Road, Fairfax, VA 22030, USA*

**Joshua Smith**, *Environmental Health Supervisor, Fairfax County Health Department, Disease Carrying Insects Program, 10777 Main Street, Fairfax, VA 22030, USA*

**Christina A. Bankert,** *Assistant Biologist, Fairfax County Police Department, Animal Services Division – Wildlife Section, 4500 West Ox Road, Fairfax, VA 22030, USA**

**Kathryn M. Auer,** *Assistant Biologist, Fairfax County Police Department, Animal Services Division – Wildlife Section, 4500 West Ox Road, Fairfax, VA 22030, USA*

**Jeremy L. Everitts,** *Environmental Technician, Fairfax County Police Department, Animal Services Division – Wildlife Section, 4500 West Ox Road, Fairfax, VA 22030, USA**

**Amy W. O'Donnell**, *Assistant Biologist, Fairfax County Police Department, Animal Services Division – Wildlife Section, 4500 West Ox Road, Fairfax, VA 22030, USA**

**Victoria G. Monroe,** *Fairfax County Wildlife Biologist, Fairfax County Police Department, Animal Services Division – Wildlife Section, 4500 West Ox Road, Fairfax, VA 22030, USA**

**Jorge R. Arias, Ph.D.,** *Environmental Health Supervisor, Fairfax County Health Department, Disease Carrying Insects Program, 10777 Main Street, Fairfax, VA 22030, USA**

**No longer employed by Fairfax County*

This report is also available online at:
http://www.fairfaxcounty.gov/living/wildlife/pilotstudy/4-poster.htm

To request this information in an alternate format, call the Fairfax County Police Department, Animal Services Division – Wildlife Section: (703) 246-6868 TTY 711

# ABSTRACT

Vector-borne pathogens, such as the bacteria (*Borrelia burgdorferi*) causing Lyme disease, are of increasing concern in the eastern United States. High-density deer populations are inferred to be one of the principal factors in the increase of tick vectors in many suburban and urban environments. Traditional methods of prevention and management alone, including area-wide application of acaricides and deer population control, have not proven to be effective methods for tick control over large geographic areas. The 4-Poster deer treatment station is a novel technology developed for tick control by the United States Department of Agriculture and approved by the United States Environmental Protection Agency. Twenty 4-Poster devices were deployed in Fairfax County, Virginia, over a 3-year period from 2012-2015 to test whether treatment of free-roaming white-tailed deer (*Odocoileus virginianus*) with a 10% permethrin acaricide would result in a decrease in local tick abundance. Deer were harvested to collect biological data at two test sites, Hemlock Overlook Regional Park and Sully Woodlands, and two control sites, Laurel Hill Golf Course and Twin Lakes Golf Course. Although some tick control was seen, widespread reduction in tick abundance was not observed. In addition to the limited efficacy for tick control, year-round operation of 4-Poster stations resulted in negative environmental effects including sustained heavy to severe browse levels and increased damage to ground cover and soil exposure at treatment plots as the result of deer activity at feeding stations. Deer density increased at both treatment sites since the beginning of the study. Based on these results and the potential for disease spread among deer and non-target wildlife that may use feeding stations, implementation of 4-Poster stations in Fairfax County is not recommended.

# EXECUTIVE SUMMARY

## Introduction

Human exposure to high-density tick populations presents serious public health concerns. One is Lyme disease, the most prevalent vector-borne disease in the United States, which is carried by blacklegged ticks (*Ixodes scapularis*). Dense deer populations are inferred to be a principal factor in the increase of ticks in many urban and suburban environments. White-tailed deer (*Odocoileus virginianus*) are the primary food source for adult blacklegged ticks and lone star ticks (*Amblyomma americanum*), although they themselves are not competent reservoirs of the Lyme disease bacterium (*Borrelia burgdorferi*).

Controlling tick populations has been a historically difficult task. Traditional methods of prevention and management alone, including area-wide application of pesticides and deer population control, have not proven to be effective methods for tick control over large geographic areas. Non-lethal means to control the ticks that feed on deer, such as 4-Poster technology, have shown some promise.

The 4-Poster deer treatment station was approved by the United States Environmental Protection Agency for commercial use in 2004. A 4-Poster deer treatment station is a feed station that uses corn to bait deer and treat the deer with a pesticide to kill ticks. A deer rubs against rollers containing an acaricide, a pesticide specially formulated to kill ticks and mites, as it lowers its head to the trough to feed on the corn at the station. The deer further distributes the acaricide over its body while self-grooming.

## Study Goals

The objectives of the 4-Poster deer treatment study were to (1) determine the effect of the 4-Poster station on abundance of local tick populations, (2) assess the effect of baiting deer year-round through use of the 4-Poster station, (3) evaluate impacts of deer on vegetation characteristics surrounding 4-Poster stations, and (4) provide a recommendation for future use of these stations in Fairfax County.

## Study Overview

Twenty 4-Poster stations (20) were deployed from February 2012-March 2015 across two public parks: five stations at Hemlock Overlook Regional Park (NOVA Parks) and fifteen stations at Sully Woodlands (Fairfax County Park Authority [FCPA]). Two control sites were also selected: Laurel Hill Golf Course and Twin Lakes Golf Course (both FCPA). No 4-Poster stations were deployed at the control sites.

## Data Collection

1) **Host examination:** From 2012- 2014, tick collection from the ears of 105 harvested deer yielded 11,858 adult, nymphal, and larval ticks of four species (lone star tick, gulf coast tick [*Amblyomma maculatum*], winter tick [*Dermacentor albipictus*] and blacklegged tick).

2) **Tick traps:** Routine tick collections were made at treatment and control sites using carbon dioxide-baited sailcloth traps. Pre-treatment collections began in April 2010 and occurred every other week. Weekly collections began in 2012 shortly after deployment of the 4-Posters. A total of 24,179 ticks (adult, nymphal, and larval) were collected at treatment and control sites from four different species (lone star tick, gulf coast tick, American dog tick [*Dermacentor variabilis*] and blacklegged tick).

3) **Camera monitoring**: Infrared motion-sensing digital game cameras were placed within 10 m of each 4-Poster station to monitor site use by deer, other non-target wildlife species, human activity, and/or signs of tampering or damage to equipment.

4) **Deer density estimation:** Deer density (deer per square mile) was annually estimated at test sites using infrared motion-sensing digital game cameras over a 14-day period in August.

5) **Deer herd health assessment**: Deer were opportunistically harvested at each study site through sharpshooting operations to assess herd health and potential impacts of baiting. A total of 108 white-tailed deer were harvested over the project duration. Biological data were recorded from external examination of each deer including sex, age, weight, body condition, and/or signs of abnormality, injury, or disease. A gross necropsy was completed for each deer harvested and tissue samples were submitted for histological examination by the VDACS Animal Health Laboratory (Warrenton, VA) and testing for Chronic Wasting Disease (CWD) by the Wisconsin Veterinary Diagnostic Laboratory (Madison, WI).

6) **Environmental impacts:**
    a. Deer browse surveys were conducted annually to measure the severity of browse impact at each test site.
    b. Soil assessments were conducted annually at test sites to estimate the percent coverage of bare soil versus covered ground (vegetation and leaf litter) as a function of soil erosion and/or impacted soil within each sample plot.

**Study Results**

1) **Host examination:** Statistical analysis showed that abundance of lone star ticks and blacklegged ticks collected from harvested deer was similar between control and treatment sites. Winter ticks were not included in analysis due to low capture numbers. Abundance of male gulf coast ticks was significantly greater at control sites. Lone star ticks accounted for 98.22% of samples (n = 11,647). Blacklegged ticks accounted for only 0.75% (n = 89) of captures. The gulf coast tick comprised 0.73% (n = 87) of the total and the remaining 0.30% (n = 35) were the winter tick.

2) **Tick traps:**

    *Lone star tick* – No significant changes were seen in the abundance of male and female lone star ticks at treatment sites throughout the study; however, a significant decrease in abundance was seen at control sites between years two and three of the study. When compared to pre-treatment levels, significantly fewer lone star tick nymphs were collected at treatment sites following the third year of 4-Poster deployment; however; a significant reduction was also found at control sites. A significant reduction in abundance of larval lone star ticks was seen at treatment sites in the second year of 4-Poster deployment compared to previous years; whereas, larval lone star ticks at control sites fluctuated significantly from year-to-year. Analysis indicated control and possible treatment effect of the 4-Poster on the larval lone star tick; however, no control was indicated for the male, female or nymphal stages of the lone star tick.

    *Blacklegged tick* – A reduction was seen in abundance of blacklegged tick nymphs between study years one and two, prior to 4-Poster implementation; however, there was no difference or reduction in the number of blacklegged ticks collected at the treatment or control sites after the 4-Posters were deployed. Analysis indicated control and possible treatment effect of the 4-Poster on the female blacklegged tick; however, no control was indicated for male or nymphal stages of the blacklegged tick.

3) **Non-target wildlife**: Non-target wildlife species were observed inside the circular fence plots surrounding each 4-Poster including black bear (*Ursus americanus*), red fox (*Vulpes vulpes*), groundhog (*Marmota monax*), raccoon (*Procyon lotor*), gray squirrel (*Sciurus carolinensis*), Virginia opossum (*Didelphis virginiana*), Canada goose (*Branta canadensis*), and turkey vulture (*Cathartes aura*).

4) **Deer density estimation:** From 2012-2014, deer density estimates at Hemlock Overlook Regional Park and Sully Woodlands increased over 1.6 times since the initial population surveys were conducted. Surveys conducted in 2012 estimated 184 deer per square mile at Hemlock Overlook Regional Park and 113 deer per square mile at Sully Woodlands. Surveys conducted in 2014 estimated 317 deer per square mile at Hemlock Overlook Regional Park and 177 deer per square mile at Sully Woodlands.

5) **Deer herd health:** The most frequently diagnosed conditions found during herd health checks included verminous pneumonia, entercolitis, multiple organ inflammation and variable internal parasites. No CWD was detected in any sampled lymph nodes of harvested deer. Although none of the deer tested in our study were found to be positive for CWD there are serious concerns regarding the potential spread of CWD in Virginia.

6) **Environmental impacts:**

    a. At Hemlock Overlook Regional Park, there was no difference in the level of browse damage detected during the study. Browse levels at Sully Woodlands significantly differed over study years with variable results depending on survey plot. There were no trends, with browse being heavy to severe across both sites over time.
    b. Treatment locations saw a significant increase in damage to ground cover and soil exposure associated with 4-Poster station use by deer. Mean percent coverage of bare ground increased by 70% at Hemlock Overlook Regional Park and 32% at Sully Woodlands from 2012-2014.

**Conclusions**

Based on this study's results, further implementation of 4-Poster stations in Fairfax County is not recommended. The 4-Poster deer treatment station may have helped reduce tick loads on individual deer within the treatment area, but the impact on the tick population is unclear. Although the numbers of blacklegged ticks were low, no significant difference or reduction was seen within the treatment sites after the introduction of the 4-Poster. Reductions in the numbers of lone star ticks collected were seen within the treatment areas of the study during the 4-Poster deployment, but reductions in numbers of lone star ticks collected were also seen within the control areas which suggest that other factors were also contributing to the changes in tick abundance during the study.

In addition to the limited efficacy for tick control, the year-round operation of 4-Poster stations resulted in negative environmental effects including sustained high levels of deer browse, damage to ground cover and increased soil exposure as the result of deer activity at feeding stations.

The potential for disease spread at feeding stations remains a serious concern for deer and non-target wildlife. Given the close proximity of the CWD Containment area to Fairfax County and the dense herds present within the county, it is not advisable to implement a method that would require year-round supplemental feeding of deer and increase potential for spread of the disease at the feeding site. Supplemental feeding also has potential to increase disease transmission among non-target wildlife, including rabies vector species such as raccoons and foxes that were frequently seen at stations.

Lastly, feeding of deer conflicts with current management objectives for deer population reduction in Fairfax County. It would be counter-productive to current deer control efforts to introduce practices that may encourage population growth in local deer herds through provision of an ample, year-round food source. A special permit would be required from DGIF to authorize supplemental feeding of deer during most of the year.

# TABLE OF CONTENTS

## LIST OF TABLES

# LIST OF FIGURES

# INTRODUCTION

The blacklegged tick (*Ixodes scapularis*) and the lone star tick (*Amblyomma americanum*) are vectors for a diverse array of pathogens. Human exposure to high-density tick populations presents serious public health concerns in many developed and residential areas. A prominent concern is Lyme disease, the most prevalent vector-borne disease in the United States (Fish and Childs, 2009; Pound *et al.*, 2009). This disease is caused by a bacterium (*Borrelia burgdorferi*) carried naturally by the white-footed mouse (*Peromyscus leucopus*) and other small mammals. The bacterium infects the blacklegged tick as it attaches to feed on the animal's blood. White-tailed deer (*Odocoileus virginianus*) are the primary maintenance host of adult blacklegged ticks and all motile life stages of the lone star tick although they are not competent reservoirs of the Lyme disease bacterium.

Traditional methods of tick control include area-wide application of acaricides, habitat and landscape modification, self-application of insecticide and lethal deer population control (Childs, 2009). Some deer population control studies have shown no significant reduction of tick densities in sampled areas, wheras other studies have shown an increase in adult ticks in sampled areas (Carroll *et al.*, 2002; Fish, 2008; Fish and Childs, 2009; Piesman and Eisen, 2008; Van Deelen *et al.*, 1988). Novel non-lethal means to control the ticks that feed on deer, such as 4-Poster technology, have shown some promise (e.g. Fish and Childs, 2009; Solberg *et al.,* 2003; Stafford *et al.*, 2009).

The 4-Poster deer treatment station ('4-Poster') was developed by the United States Department of Agriculture (USDA) and approved by the United States Environmental Protection Agency (EPA) for commercial use in 2004. These stations have been used in several states by public and private stakeholders including local county governments, park authorities, private golf courses, and homeowners (Pound *et al.*, 2009). Use of 4-Poster stations in Virginia requires exemptions to state code pertaining to use of drugs on vertebrate wildlife (§29.1-508.1) and unauthorized feeding of deer (4 VAC 15-40-285).

Corn is used as bait to attract deer to the 4-Poster treatment station. Each station holds up to 250 pounds of bait inside a central storage chamber. A 4-Poster has four customized rollers (posts) and two feed ports (troughs) on opposite sides of the station. Corn enters each port at the bottom of the storage chamber. The corn used must be specially-processed (i.e., twice-cleaned) in order to facilitate easy flow into the ports from the storage area. Each port is located between two rollers. The rollers are treated with an acaricide (10% permethrin), a pesticide specially formulated to kill ticks and mites. Deer must come into direct contact with these rollers in order to reach the bait. A deer self-applies the acaricide to its head and neck as it brushes against the rollers to consume the corn. The deer further distributes acaricide over its body while self-grooming.

The 4-Poster is a method of wildlife host-based tick control. Studies of 4-Posters have demonstrated the effect of host-targeted tick control to manage tick densities in select communities (e.g. Daniels *et al.*, 2009; Hoen *et al.,* 2009; Miller *et al.*, 2009; Pound *et al.,* 2000a; Pound *et al.,* 2000b). Long-term study results compared favorably with the results of short-term, single-site studies (e.g. Brei *et al.*, 2009; Solberg *et al.*, 2003). In some field studies, blacklegged tick and lone star tick populations showed slight rebound effects following the removal of 4-Poster devices. Yet, tick densities at treatment sites remained statistically lower than tick densities at untreated sites (e.g. Carroll, 2003; Daniels *et al.*, 2009; Miller *et al.,* 2009).

Permethrin has been found to dissipate rapidly from the environment, soil, and plants (ATSDR, 2001; Pound *et al.*, 2009; U.S. EPA, 2006). It is classified by the EPA as "likely to be carcinogenic to humans" and other mammals if ingested orally but is not harmful if applied topically (Abu-Qare and Abou-Donia, 2001; ATSDR, 2001; ATSDR, 2005; US EPA, 2006). The use of 4-Poster technology limits the application of permethrin to the station, thus minimizing the potential environmental impact when compared to area-wide applications of an acaricide (Carroll, 2003). Although deer are the targeted hosts for permethrin application, non-target applications may occur due to use of the 4-poster by other animals. Venison from deer treated with a topical application of permethrin is approved as safe for human consumption by the U.S. Food and Drug Administration (FDA) and the EPA (US EPA, 2006). Deer that self-apply acaricide from a 4-Poster and are harvested at or near test sites are safe for human consumption by hunters and for donation to charities (i.e., Hunters for the Hungry); therefore 4-Posters stations can be operated during legal hunting seasons based on this factor. Although harvested deer are safe to consume, hunting over bait is prohibited by Virginia law (§ 29.1-521); therefore, efforts were taken to select sites away from active deer management areas.

Vector-borne pathogen transmission and the role deer populations can play is a serious concern in regions with high human populations, such as Fairfax County. Controlling tick populations while appropriately managing native wildlife and addressing environmental concerns has been a historically difficult task. Addressing these concerns requires an integrated and comprehensive approach (Carroll *et al.*, 2002; Childs, 2009; Fish, 2008; Piesman and Eisen, 2008).

A 4-Poster Deer Treatment Station pilot study was conducted in Fairfax County, VA to evaluate wildlife host-targeted tick control on white-tailed deer. Objectives of the study were to (1) determine the effect of the 4-Poster station on abundance of local tick populations, (2) assess the effect of baiting deer year-round through use of the 4-Poster station, (3) evaluate impacts of deer on vegetation characteristics surrounding 4-Poster stations, and (4) provide a recommendation for future use of these stations in Fairfax County.

The study was conducted by the Fairfax County Police Department – Animal Services Division, Wildlife Section (FCPD-WS) in collaboration with the Fairfax County Health Department - Disease Carrying Insects Program (DCIP), Fairfax County Park Authority (FCPA) and Northern Virginia Regional Park Authority (NOVA Parks), with the support and guidance of the Virginia Department of Game and Inland Fisheries (DGIF). Funding for the pilot study was provided by Fund 40080, Integrated Pest Management Program.

# STUDY AREA AND DURATION

### *Study duration*

The Fairfax County 4-Poster study was conducted over a 3-year period from February 2012 -March 2015. The 4-Posters stations were placed with feed only (no pesticide) for an acclimation period from February – March 2012. The 4-Poster stations with pesticide were operated from April 2012 -March 2015.

### *Study area*

Fairfax County, Virginia, is a large suburban county (396 square miles [102,564 ha]) that is home to an abundant population of free roaming white-tailed deer. Public parkland and land zoned for recreational use comprises 14.4% of the county with the majority of the remaining land zoned for commercial, industrial, and residential use.

### *Test sites*

Twenty 4-Poster stations were deployed at two test sites, 5 stations at Hemlock Overlook Regional Park (Clifton, VA; NOVA Parks) and 15 stations at a grouping of park parcels collectively referred to as "Sully Woodlands" (Centreville, VA; FCPA) (Table 1; Figure 1). Hemlock Overlook Regional Park is a native woodland parcel, approximately 400 acres (162 ha) in size, within nearly contiguous woodland park properties surrounding Bull Run. Sully Woodlands is a remnant woodland parcel that is comprised of more than 2,200 acres (890 ha) in close proximity to public and private golf courses, residential, commercial and/or industrial areas.

Test sites were located in woodland areas dominated by oaks (*Quercus alba*; *Q.velutina*), hickories (*Carya glabra*; *C. tomentosa*), black gum (*Nyssa sylvatica*), red maple (*Acer rubrum*), and Virginia pine (*Pinus virginiana*). Common midstory and understory species consisted of flowering dogwood (*Cornus florida*), greenbrier (*Smilax* spp.), American holly (*Ilex opaca*), Japanese honeysuckle (*Lonicera japonica*), and autumn olive (*Elaeagnus umbellata*).

Test sites to deploy the 4-Poster devices were non-randomly selected by the Wildlife Biologist's office based on the following factors: one station per 50-70 acres (Pound et al, 2009; Schulze et al, 2009), availability of parkland acreage available to safely place stations using the guidelines clearly established by the DGIF scientific collection permit (Appendix A); approval by the landowners (FCPA; NOVA Parks); high recorded and/or observed deer populations; and ability to conduct safe nighttime sharpshooting operations to harvest deer and collect biological data (tissue samples) by FCPD-WS. Additional consideration for test site selection included the EPA restriction limiting placement of 4-Poster devices within 100 yards (91.44 m) of buildings, playgrounds, and other areas where children might be without direct adult supervision (e.g. Stafford *et al*, 2009). The DGIF scientific collection permit also prohibited placement of stations within 100 yards of public roads. Environmental restrictions also included no application of permethrin within 100 feet (30.48 m) of any water body (streams, rivers, lakes) due to its toxicity to aquatic wildlife. Once test areas were identified, tick sampling sites were selected by DCIP staff. Although the treatment areas and tick sampling sites were identified in 2010, the individual 4-Poster sites were not identified until closer to deployment.

### *Control sites*

Two FCPA park sites, Laurel Hill Golf Course (Lorton, VA) and Twin Lakes Golf Course (Clifton, VA; Table 8), were selected as control sites. Laurel Hill Golf Course is approximately 1,195 acres (484 ha) in size; whereas, Twin Lakes Golf Course is a fenced property approximately 357 acres (144 ha) in size. No 4-Poster stations were deployed at the control sites. Tick trap data had been collected in Giles Run Park ("Lorton") and Braddock Park (which are adjacent to Laurel Hill Golf Course and Twin Lakes Golf Course, respectively) since 2010 or before.

Control sites were non-randomly selected by the Wildlife Biologist's office based on the following factors: sites that were currently in use as tick collection sites by DCIP staff; ability to conduct safe nighttime sharpshooting operations to harvest deer and collect biological data (tissue samples).

Table 1. 4-Poster station coordinates (decimal degrees) at Sully Woodlands and Hemlock Overlook Regional Park.

| Park Site | 4-Poster Station fence plots | North | West |
|---|---|---|---|
| Sully Woodlands (Richard Jones) | S01 | 38.89167 | -77.47910 |
| Sully Woodlands (Richard Jones) | S02 | 38.88820 | -77.47501 |
| Sully Woodlands (Virginia Run-Hacor) | S03 | 38.86050 | -77.49033 |
| Sully Woodlands (Elklick Preserve) | S04 | 38.85754 | -77.49524 |
| Sully Woodlands (Elklick Preserve) | S05 | 38.85516 | -77.50162 |
| Sully Woodlands (Hunter-Hacor) | S06 | 38.87672 | -77.49290 |
| Sully Woodlands (Hunter-Hacor) | S07 | 38.88163 | -77.49860 |
| Sully Woodlands (Hunter-Hacor) | S08 | 38.87659 | -77.50201 |
| Sully Woodlands (Hunter-Hacor) | S09 | 38.87239 | -77.50536 |
| Sully Woodlands (Stephens) | S10 | 38.88517 | -77.48903 |
| Sully Woodlands (Hunter-Hacor) | S11 | 38.86752 | -77.51270 |
| Sully Woodlands (Elklick Preserve) | S12 | 38.86550 | -77.50463 |
| Sully Woodlands (Elklick Preserve) | S13 | 38.86016 | -77.51016 |
| Sully Woodlands (Sappington) | S14 | 38.85579 | -77.51230 |
| Sully Woodlands (Sappington) | S15 | 38.85348 | -77.50751 |
| Hemlock Overlook Regional Park | H01 | 38.76882 | -77.40555 |
| Hemlock Overlook Regional Park | H02 | 38.77207 | -77.41124 |
| Hemlock Overlook Regional Park | H03 | 38.76606 | -77.41171 |
| Hemlock Overlook Regional Park | H04 | 38.75813 | -77.39951 |
| Hemlock Overlook Regional Park | H05 | 38.75272 | -77.40060 |

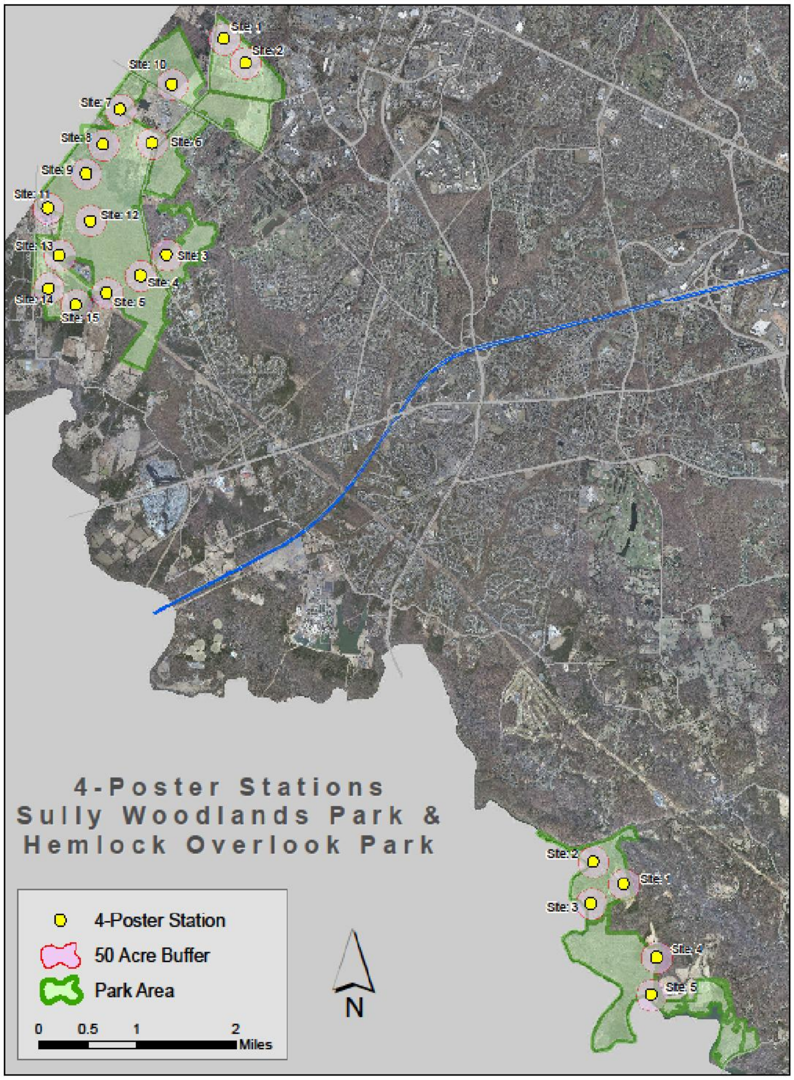



Figure 1. 4-Poster station locations at Sully Woodlands and Hemlock Overlook Regional Park.

# METHODOLOGY: 4-POSTER STATIONS

***4-Poster station fence plot establishment***

A single 4-Poster station has been shown to treat deer on approximately 28 ha (50-70 acres) of land (Pound *et al*, 2009; Schulze *et al*, 2009). Aerial maps were created using GPS coordinates to accurately record 4-Poster station fence plot locations at the test sites within 28 ha “treatment zones” for each circular fence plot. Any overlap of the “treatment zones” was successfully avoided at each test site. Circular fence plots with a 9.14 m diameter were constructed using 280 mm galvanized wire fencing and twelve 2.13 m posts to enclose each 4-Poster device. Fence plots were constructed to provide clear and appropriate warning to park patrons of each 4-Poster location on public parkland during the pilot study.

Signs were securely posted and highly visible to advise park patrons at each 4-Poster fence plot study area. Signs were placed on the outer posts of each circular fence plot within 5 m of each device. No signs were posted directly on trees to avoid damage to vegetation and/or park property. Minimal wording and universal symbols were used to convey appropriate information to individuals of all reading comprehension levels, including those unable to read. All signs were posted in English with Spanish subtitles (Figure 2).

Infrared motion-sensing digital game cameras were placed within 10 m of each 4-Poster station to monitor site use by deer, other non-target wildlife species, human activity, and/or signs of tampering or damage to equipment.


Figure 2. 4-Poster station fence plot and sign.

### *Corn addition and operation*

Corn was placed in 4-Posters at both test sites during February and March 2012 as an acclimation period for deer to locate the stations. Operation of the 4-Poster stations with pesticide began in April 2012. Each 4-Poster device was checked by Wildlife Biologist office personnel one to two times a week, to ensure the devices remained full of corn and that corn could flow unobstructed into the troughs for the deer to eat. Appropriate maintenance of each device included the weekly provision of corn (bait), recording amount of corn consumed and corn supplied, and systematic cleaning of debris and/or corn trapped in each trough. Twice-washed whole kernel corn was used in the study as it is recognized as the only bait type compatible with 4-Poster use to minimize the occurrence of bait contamination, molding and/or insect infestations (e.g. Pound *et al.*, 2000a; Solberg *et al.*, 2003).

### *Station maintenance*

Thorough cleaning and ongoing maintenance of the 4-Posters was periodically necessary to prevent the buildup of dirt, debris, and mold which hindered corn from flowing into the trough. Cleaning of each 4-Poster corn bin and trough was completed using a high-pressure power washer. Temporary removal of all 4-Poster stations for one to three days per station over a period of two weeks was necessary for cleaning in 2012. The vendor for the corn supply was changed in 2013 which led to a reduction in dust from bagged corn and less clogging and mold in the 4-Poster trough. Removal of corn from clogged troughs was mostly handled in the field after this change, and only two stations were removed for cleaning for a period of two days in 2014.

### *Pesticide application*

Virginia Pesticide Applicator permit (Category 8) training and certification was obtained by both the Environmental Technician and Biologist Assistant (FCPD-WS) in order to apply acaricide to each 4-Poster. Forty hours of applicable field training, online training, and manual review were required to obtain the permit. The Virginia Pesticide Applicator permits were issued by the Virginia Department of Agriculture and Consumer Services (VDACS).

Permethrin acaricide (10%) was applied to the rollers of each 4-Poster on a weekly basis. The amount of acaricide applied to each roller was based on corn consumption from the 4-Poster device. For example, if 13.5 kg (~30 lbs.) of corn is consumed by deer, then 5 ml of acaricide must be applied to each roller. Deer self-apply the acaricide to their head and neck when making contact with any treated rollers while eating corn from the 4-Poster device and further spread the substance on the body during regular grooming activity.

Permethrin was applied to rollers using a spray gun applicator while wearing the appropriate Personal Protective Equipment (PPE), including protective gloves and eyewear, and according to the label. The PPE guidelines and minimum requirements for safe application of the acaricide were clearly defined by the Occupational Safety and Health Administration and other federal guidelines.

### *Dye application*

A non-toxic, long-lasting dye (color: fluorescent pink) was periodically added to new rollers without acaricide to visually mark and identify deer using the 4-Posters at each test site. Dye was added approximately one week prior to deer harvesting activities to help staff identify deer that were using the stations.

### *Pesticide storage*

All permethrin purchased during the pilot study was stored in one-gallon containers in an approved FCPA facility, Pleasant Valley Golf Course (Chantilly, VA), located at Sully Woodlands. Pleasant Valley Golf Course has a storage facility constructed for the safe storage of commercial pesticides and other chemicals used to maintain the property. Each gallon container of permethrin was stored upright at room temperature in a stand-alone, temperature-regulated building.

### *Electric bear exclusion fencing*

Juvenile black bears (*Ursus americanus*) were observed on game cameras visiting eight 4-Poster stations at Sully Woodlands on several occasions from July - November 2012 and in June 2013. It was presumed that the animals were attracted to the 4-Posters by the scent and availability of corn in each bait station. Following the initial bear activity, corn was removed from feeders at these locations for a period of 2 weeks while guidance was sought from DGIF. It is illegal to feed or bait bears - intentionally or otherwise - in Virginia. As a means of deterring nuisance bears, electric bear exclusion fences were constructed in April 2013 around eleven “high interest” 4-Poster sites at Sully Woodlands (S4-S9 and S11-S15) after receiving guidance from DGIF and Fairfax County Government (Risk Management) and permission from FCPA and Fairfax County Government (Risk Management) to construct the fences on public parkland. Most of the electric fencing was built onto the existing circular fences surrounding each of the eleven 4-Posters (Figure 3). A few of the electric fences were constructed around the existing fence by placing additional T-posts around the original posts. Each electric fence was a minimum of 560 mm in height and powered by an AN90 battery energizer with solar panel (Speedrite by Tru-Test Electric Fence Systems, Mineral Wells, Texas, USA). A juvenile black bear was observed on a game camera to have visited another 4-Poster site (S10) in proximity to the other high interest 4-Poster sites in June 2013. An electric fence was then constructed around that 4-Poster site. An additional fence was constructed at a nearby site (S13) in June 2013 as a precaution but was not electrified. Black bear activity was not documented at study sites after June 2013. Deer were not seen inside the fence at many of the Sully Woodlands treatment stations following installation of the electric fences in April 2013. Due to a decrease in deer activity within these fenced sites, the electric fencing was removed from all 4-Poster sites beginning in November 2013 with permission of DGIF. The solar energizers and the top two strands of the barbed wire were removed to allow easier access to the 4-Poster for the deer. The original fencing remained intact. Monitoring of bear activity continued for the duration of the study with no additional visitations documented.


Figure 3. 4-Poster station with electric fence and signs.

***Study cost and workload***

General costs and workload were estimated and included the following: the initial purchase of 4-Poster stations, corn, pesticide, staff time (administration, station installation, station maintenance, data collection, and data reporting), field equipment, PPE, and laboratory testing and pathology for deer herd health checks.

***Public education and outreach***

FCPD staff conducted an education and outreach campaign to provide information on the 4-Poster study through media releases, phone and on-air interviews. A media release was issued through the Fairfax County Police Department's Public Information Office (FCPD PIO) in March 2012 to provide background on the research study including its purpose and budget. An additional media release was issued through FCPD PIO in August 2012 that targeted hunter awareness and precautions to take for handling and consumption of harvested "pink" deer to avoid direct exposure to permethrin. Public information meetings were also hosted at the county's Wildlife Biologist office for public inquiries. Information on the study was highlighted in a variety of media outlets including the county's website, WashingtonPost.com, Washington Examiner, WTOP, NBC4, The Patch, The Connection and Field & Stream, among others.

# METHODOLOGY: BIOLOGICAL DATA COLLECTION

***Tick sampling***

Ticks were collected using two different methods: host examination and tick sail traps.

Method 1: Host examination

Ticks were collected from deer that were harvested throughout the project. Samples were obtained by removing both ears from harvested deer. Ears were removed from deer by the wildlife technicians and placed in a plastic, zip-lock bag with the sample number, site, and date harvested. The ears were frozen and taken to the Health Department where the ticks were removed from the ears. Ticks were identified to species, life stage, and sex, and counted.

Method 2: Tick sail traps

Routine tick collections were made at treatment and control sites using carbon dioxide-baited traps. Each site contained four trapping stations. Sampling sites were established in the treatment areas based on selection of the parks by the Wildlife Biologist's office. Sampling sites in the control areas were pre-existing trap sites that were later selected as control sites by the Wildlife Biologist's office. Each trap consisted of a one square meter piece of sail cloth with a cooler containing dry ice set in the middle of each cloth. On the day of the collections, the traps were set in the morning and picked up in the afternoon. Pre-treatment collections began in April 2010 and occurred every other week. Weekly collections began in 2012 shortly after deployment of the 4-Posters. Tick trapping was done by Health Department staff. All samples were placed in plastic, zip-lock bags with the collection date, site, and trap station. Samples were returned to the Health Department and placed in a freezer for at least two days. Ticks were identified to species, life stage, and sex, and counted.

***Deer sampling***

Deer were opportunistically harvested through night-time sharpshooting operations conducted by FCPD at each study site to collect biological data. A minimum of three deer was the target harvest level for each site. Deer with pink ears or deer observed at the 4-Posters were the primary targets at the treatment sites. Harvesting of more than three deer was used to provide a larger sample size (when feasible). Starting in January 2012, sampling was conducted at test sites every third month of each calendar year. If fewer than three deer were harvested during the nighttime data collection operation, FCPD-WS staff continued to harvest deer during subsequent operations until the three deer minimum was reached. Sampling at each control site was initially conducted on a different schedule with sampling occurring twice a year, once every six months (in March and September 2012). In March 2013, protocol was amended to pair each test site with a control site and to change the sampling schedule to allow for a more consistent sampling effort within the same general time frame. Following this change in protocol, harvesting of deer was conducted in March/April, July/August, and October/November at both test sites and control sites. Sully Woodlands was collected in the same week, when possible, as Laurel Hill Golf Course. Hemlock Overlook Regional Park was collected the same week, when possible, as Twin Lakes Golf Course.

Biological data were recorded from external examination of each deer including sex, age, weight, body condition, and/or signs of abnormality, injury, or disease. A gross necropsy was completed for each deer harvested and tissue samples were collected for further histological examination. Tissue samples, with the exception of half of each lymph node sample, were delivered by FCPD-WS staff to the VDACS Animal Health Laboratory in Warrenton, VA. The histological examination included fecal testing, parasite identification, acid fast staining for bovine tuberculosis, and a pathology examination/review. Toxicology screening was not included as part of the testing protocol. Lymph node samples were sent by mail to the Wisconsin Veterinary Diagnostic Laboratory (Madison, WI) for Chronic Wasting Disease (CWD) testing. Biological sampling protocols were established with the collaborative assistance and expertise of the DGIF Wildlife Veterinarian, Dr. Megan Kirchgessner.

***Deer density surveys***

Infrared motion-sensing digital game cameras were checked on a weekly basis to obtain photo data. Deer density (deer per square mile) was estimated at treatment sites over a 14-day period in August according to methods described in Jacobson *et al.* (1997).

***Environmental impact surveys***

Vegetation and soil surveys were conducted within each 4-Poster circular fence plot to assess the environmental impact of white-tailed deer on the surrounding area. Deer browse damage has been found to be directly related to the density of a local deer population (Grenier *et al.*, 1999; Lewis and Rongstad, 1998; McBryde, 1995). Deer browse surveys were conducted annually to measure the severity of browse impact at each test site. Surveys were conducted within each circular fence plot and at four 1 $m^2$ sample plots located around each circular fence plot. The first sample plot was located 1 m from the outside of the circular fence plot and each corresponding sample plot was located 45.5 m from the previous one. Woody plants and trees from 15 cm in height up to 1.8 m were used to estimate the severity of browse impact at all plots. All native woody plant species were evaluated on a scale of 0-5, with “5” being a rating of severely browsed and “0” being a rating of no browse damage observed. All plots were given a browse rating to represent the overall level of browse for that area.

Soil assessments were conducted annually to estimate the percent coverage of bare soil versus covered ground (vegetation and leaf litter) as a function of soil erosion and/or impacted soil within each sample plot. Circular fence plots were split into quadrants (e.g. northeast, northwest, southeast, southwest) and ocular estimation was used to determine the percent coverage of bare soil versus covered ground.

## STATISTICAL ANALYSES

---

***Tick control using 4-Poster stations***

Method 1: Host examination

A one-way Analysis of Variance (SPSS 23) was used to determine if mean tick abundance collected from harvested deer varied between control and treatment sites. A Welch test was also run for data that violated the homogeneity of variances assumption. All statistics were considered significant at $P \leq 0.05$.

Method 2: Tick sail traps

Non-parametric (Kruskal-Wallis) tests were used to analyze tick trap data (SPSS 23). Statistics were considered significant at $P \leq 0.05$. The Henderson-Tilton (1955) formula was used to look at efficacy of pesticides in non-uniform populations. This formula calculates the percent control due to treatment using the following equation:

$\text{Percent control} = 100 * (1 - (\text{Tpost} * \text{Cpre}/\text{Tpre} * \text{Cpost}))$ where $\text{Tpost}$ = post-treatment at treatment sites, Cpre = pre-treatment at control sites, Tpre = pre-treatment at treatment sites, and Cpost = post-treatment at control sites.

***Environmental impact surveys***

A one-way Analysis of Variance with repeated measures (GLM; GNU PSPP) was conducted to determine whether there was a difference in mean percent coverage of bare ground over time following deployment of the 4-Posters treatment stations at Hemlock Overlook Regional Park and Sully Woodlands. Post-hoc analyses for pairwise comparisons were completed using the Bonferroni correction if significant differences were found. Results were considered significant at $P \leq 0.05$.

A Wilcoxon signed-rank test (Microsoft Excel) was conducted to determine if the median difference in browse levels differed significantly between 2012 and 2014. Results were considered significant at $P \leq 0.05$.

## RESULTS

---

### ***Tick control using 4-Poster stations***

Method 1: Host examination

Ticks removed from the ears of deer harvested at each test and control site (n = 105) were identified to species, life stage, and sex, and counted. (Tables 2-5). From 2012- 2014, 11,858 adult, nymphal, and larval ticks of four species (lone star tick [*Amblyomma americanum*], gulf coast tick [*Amblyomma maculatum*], winter tick [*Dermacentor albipictus*], and blacklegged tick [*Ixodes scapularis*]) were collected from harvested deer. Lone star ticks accounted for 98.22% of samples (n = 11,647). Blacklegged ticks accounted for 0.75% (n = 89) of captures. The gulf coast tick comprised 0.73% (n = 87) of the total and the remaining 0.30% (n = 35) were the winter tick. Male and nymphal winter ticks were infrequently collected and were not included in analyses. Nymphs of the gulf coast tick and females of the winter tick were not collected at all. One-way ANOVA results comparing tick abundance from harvested deer between control and treatment sites are found in Table 6. Male gulf coast ticks were significantly different between control and treatment sites which can be attributed to the majority of them (n = 64) being removed from deer collected at the Laurel Hill Golf Course/Lorton site. The remaining male gulf coast ticks (n = 5) were collected from deer harvested at Sully Woodlands.

Table 2. Total and mean tick abundance of lone star ticks (*Amblyomma americanum)* and blacklegged ticks (*Ixodes scapularis*) collected from harvested deer at Hemlock Overlook Regional Park, 2012-2014.

**Hemlock Overlook Non-Pink Deer Ears**

| Year | # Deer | *Amblyomma americanum* | | | | | | | | *Ixodes scapularis* | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Male | | Female | | Nymph | | Larva | | Male | | Female | | Nymph | |
| | | Total | Mean (SE) | Total | Mean (SE) | Total | Mean (SE) | Total | Mean (SE) | Total | Mean (SE) | Total | Mean (SE) | Total | Mean (SE) |
| 2012 | 8 | 111 | 13.8 (7.7) | 27 | 3.4 (1.5) | 363 | 45.4 (24.4) | 2 | 0.3 (0.3) | 0 | 0 (0) | 0 | 0 (0) | 0 | 0 (0) |
| 2013 | 4 | 6 | 1.5 (1.2) | 1 | 0.3 (0.3) | 199 | 49.8 (23.1) | 0 | 0 (0) | 0 | 0 (0) | 0 | 0 (0) | 0 | 0 (0) |
| 2014 | 2 | 1 | 0.5 (0.5) | 0 | 0 (0) | 82 | 41.0 (25.0) | 2 | 1.0 (1.0) | 0 | 0 (0) | 0 | 0 (0) | 0 | 0 (0) |

**Hemlock Overlook Pink Deer Ears**

| Year | # Deer | *Amblyomma americanum* | | | | | | | | *Ixodes scapularis* | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Male | | Female | | Nymph | | Larva | | Male | | Female | | Nymph | |
| | | Total | Mean (SE) | Total | Mean (SE) | Total | Mean (SE) | Total | Mean (SE) | Total | Mean (SE) | Total | Mean (SE) | Total | Mean (SE) |
| 2012 | 2 | 0 | 0 (0) | 0 | 0 (0) | 94 | 47.0 (47.0) | 914 | 457.0 (457.0) | 0 | 0 (0) | 0 | 0 (0) | 0 | 0 (0) |
| 2013 | 10 | 25 | 2.5 (1.2) | 16 | 1.6 (1.1) | 217 | 21.7 (10.4) | 0 | 0 (0) | 0 | 0 (0) | 0 | 0 (0) | 0 | 0 (0) |
| 2014 | 5 | 6 | 0.9 (0.3) | 1 | 0.2 (0.2) | 43 | 8.6 (6.4) | 0 | 0 (0) | 1 | 0.2 (0.2) | 1 | 0.2 (0.2) | 0 | 0 (0) |

**Hemlock Overlook Total**

| Year | # Deer | *Amblyomma americanum* | | | | | | | | *Ixodes scapularis* | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Male | | Female | | Nymph | | Larva | | Male | | Female | | Nymph | |
| | | Total | Mean (SE) | Total | Mean (SE) | Total | Mean (SE) | Total | Mean (SE) | Total | Mean (SE) | Total | Mean (SE) | Total | Mean (SE) |
| 2012 | 10 | 111 | 11.1 (6.4) | 27 | 2.7 (1.3) | 457 | 45.7 (20.5) | 916 | 91.6 (91.4) | 0 | 0 (0) | 0 | 0 (0) | 0 | 0 (0) |
| 2013 | 14 | 31 | 2.1 (0.9) | 17 | 1.21 (0.8) | 416 | 29.7 (10.1) | 0 | 0 (0) | 0 | 0 (0) | 0 | 0 (0) | 0 | 0 (0) |
| 2014 | 7 | 6 | 0.9 (0.3) | 1 | 0.1 (0.1) | 125 | 17.9 (9.2) | 2 | 0.3 (0.3) | 1 | 0.1 (0.1) | 1 | 0.1 (0.1) | 0 | 0 (0) |

Table 3. Total and mean tick abundance of lone star ticks (*Amblyomma americanum)* and blacklegged ticks (*Ixodes scapularis*) collected from harvested deer at Sully Woodlands, 2012-2014.

**Sully Woodlands Non-Pink Deer Ears**

| Year | # Deer | *Amblyomma americanum* | | | | | | | | *Ixodes scapularis* | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Male | | Female | | Nymph | | Larva | | Male | | Female | | Nymph | |
| | | Total | Mean (SE) | Total | Mean (SE) | Total | Mean (SE) | Total | Mean (SE) | Total | Mean (SE) | Total | Mean (SE) | Total | Mean (SE) |
| 2012 | 11 | 616 | 56.0 (34.0) | 200 | 18.2 (10.8) | 477 | 43.4 (30.1) | 3 | 0.3 (0.1) | 2 | 0.2 (0.1) | 5 | 0.5 (0.2) | 3 | 0.3 (0.2) |
| 2013 | 5 | 62 | 12.4 (8.4) | 20 | 4.0 (3.3) | 240 | 48.0 (24.3) | 45 | 9.0 (9.0) | 0 | 0 (0) | 6 | 1.2 (1.0) | 1 | 0.2 (0.2) |
| 2014 | 3 | 73 | 24.3 (20.1) | 11 | 3.7 (1.9) | 73 | 24.3 (15.2) | 1500 | 500.0 (500.0 ) | 8 | 2.7 (2.7) | 12 | 4.0 (3.5) | 0 | 0 (0) |

**Sully Woodlands Pink Deer Ears**

| Year | # Deer | *Amblyomma americanum* | | | | | | | | *Ixodes scapularis* | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Male | | Female | | Nymph | | Larva | | Male | | Female | | Nymph | |
| | | Total | Mean (SE) | Total | Mean (SE) | Total | Mean (SE) | Total | Mean (SE) | Total | Mean (SE) | Total | Mean (SE) | Total | Mean (SE) |
| 2012 | 0 | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 2013 | 7 | 1 | 0.1 (0.1) | 0 | 0 (0) | 0 | 0 (0) | 0 | 0 (0) | 5 | 0.7 (0.4) | 8 | 1.1 (0.6) | 1 | 0.2 (0.2) |
| 2014 | 9 | 92 | 10.2 (8.8) | 18 | 2.0 (1.3) | 587 | 65.2 (30.8) | 101 | 11.2 (7.5) | 0 | 0 (0) | 2 | 0.2 (0.1) | 0 | 0 (0) |

**Sully Woodlands Total**

| Year | # Deer | *Amblyomma americanum* | | | | | | | | *Ixodes scapularis* | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Male | | Female | | Nymph | | Larva | | Male | | Female | | Nymph | |
| | | Total | Mean (SE) | Total | Mean (SE) | Total | Mean (SE) | Total | Mean (SE) | Total | Mean (SE) | Total | Mean (SE) | Total | Mean (SE) |
| 2012 | 11 | 616 | 56.0 (34.0) | 200 | 18.2 (10.8) | 477 | 43.4 (30.1) | 3 | 0.3 (0.1) | 2 | 0.2 (0.1) | 5 | 0.5 (0.2) | 3 | 0.3 (0.2) |
| 2013 | 12 | 63 | 5.3 (3.7) | 20 | 1.7 (1.4) | 240 | 20.0 (11.8) | 45 | 3.8 (3.8) | 5 | 0.4 (0.3) | 14 | 1.2 (0.5) | 1 | 0.1 (0.1) |
| 2014 | 12 | 165 | 13.8 (8.1) | 29 | 2.4 (1.1) | 660 | 55.0 (23.6) | 1601 | 133.4 (124.4) | 8 | 0.7 (0.7) | 14 | 1.2 (0.9) | 0 | 0 (0) |

Table 4. Total and mean tick abundance of lone star ticks (*Amblyomma americanum)* and blacklegged ticks (*Ixodes scapularis*) collected from harvested deer at Laurel Hill Golf Course, 2012-2014.

**Laurel Hill Golf Course Total**

| Year | # Deer | *Amblyomma americanum* | | | | | | | | *Ixodes scapularis* | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Male | | Female | | Nymph | | Larva | | Male | | Female | | Nymph | |
| | | Total | Mean (SE) | Total | Mean (SE) | Total | Mean (SE) | Total | Mean (SE) | Total | Mean (SE) | Total | Mean (SE) | Total | Mean (SE) |
| 2012 | 6 | 73 | 12.2 (6.0) | 40 | 6.7 (3.7) | 604 | 100.7 (37.1) | 931 | 155.2 (71.4) | 0 | 0 (0) | 0 | 0 (0) | 1 | 0.2 (0.2) |
| 2013 | 11 | 264 | 24.0 (7.6) | 100 | 9.1 (4.5) | 858 | 78.0 (26.8) | 0 | 0 (0) | 5 | 0.5 (0.3) | 17 | 1.6 (0.9) | 1 | 0.1 (0.1) |
| 2014 | 5 | 74 | 14.8 (8.3) | 22 | 4.4 (2.6) | 167 | 33.4 (10.5) | 839 | 167.8 (135.7) | 1 | 0.2 (0.2) | 2 | 0.4 (0.2) | 0 | 0 (0) |

Table 5. Total and mean tick abundance of lone star ticks (*Amblyomma americanum)* and blacklegged ticks (*Ixodes scapularis*) collected from harvested deer at Twin Lakes Golf Course, 2012-2014.

| Twin Lakes Golf Course Deer | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Year | # Deer | *Amblyomma americanum* | | | | | | | | *Ixodes scapularis* | | | | | | |
| | | Male | | Female | | Nymph | | Larva | | Male | | Female | | Nymph | | |
| | | Total | Mean (SE) | Total | Mean (SE) | Total | Mean (SE) | Total | Mean (SE) | Total | Mean (SE) | Total | Mean (SE) | Total | Mean (SE) |
| 2012 | 7 | 103 | 14.7 (9.0) | 73 | 10.4 (8.5) | 320 | 45.7 (14.0) | 407 | 58.1 (27.7) | 1 | 0.1 (0.1) | 3 | 0.4 (0.4) | 0 | 0 (0) |
| 2013 | 10 | 105 | 10.5 (4.2) | 57 | 5.7 (2.4) | 382 | 38.2 (16.3) | 0 | 0 (0) | 1 | 0.1 (0.1) | 2 | 0.2 (0.1) | 1 | 0.1 (0.1) |
| 2014 | 0 | - | - | - | - | - | - | - | - | - | - | - | - | - | - |

Table 6. One-way ANOVA and Welch test results comparing abundance of lone star ticks (*Amblyomma americanum),* blacklegged ticks (*Ixodes scapularis*), and gulf coast tick (*Amblyomma maculatum*) from harvested deer between control and treatment sites.

| Tick species, stage | Test | *F* Statistic | *df*1 | *df*2 | *P*-value |
|---|---|---|---|---|---|
| *Amblyomma americanum* Male | Welch | 0.015 | 1 | 92.726 | 0.904 |
| *Amblyomma americanum* Female | Welch | 1.132 | 1 | 91.556 | 0.290 |
| *Amblyomma americanum* Nymph | Welch | 3.120 | 1 | 75.306 | 0.081 |
| *Amblyomma americanum* Larva | Welch | 0.239 | 1 | 101.970 | 0.626 |
| *Ixodes scapularis* Male | Welch | 0.054 | 1 | 102.174 | 0.816 |
| *Ixodes scapularis* Female | Welch | 0.085 | 1 | 73.139 | 0.772 |
| *Ixodes scapularis* Nymph | Welch | 0.083 | 1 | 86.194 | 0.774 |
| *Amblyomma maculatum* Male | ANOVA | 5.741 | 1 | 103.000 | 0.018* |
| *Amblyomma maculatum* Female | ANOVA | 2.502 | 1 | 103.000 | 0.117 |
| Total | Welch | 1.440 | 1 | 102.989 | 0.233 |

*significant at $P \leq 0.05$

Method 2: Tick sail traps

Tick traps were used to monitor tick abundance throughout the study period. In order to help standardize tick trap results, the week, month, and year of collection were adjusted to treatment week, treatment month, and treatment year, all of which began in the first week of April 2010. Ticks collected via carbon dioxide-baited traps at treatment and control sites were identified to species, life stage, and sex and counted and are summarized in Tables 7 and 8. Throughout the study period, April through July (treatment months 1-4) had the highest average number of ticks collected at each study site and December through January (treatment months 9-10) consistently had the lowest number of ticks collected at each study site. Throughout the study, 24,179 total ticks (adult, nymphal, and larval) were collected from four different species (lone star tick [*Amblyomma americanum*], gulf coast tick [*Amblyomma maculatum*], American dog tick [*Dermacentor variabilis*], and blacklegged tick [*Ixodes scapularis*]). Lone star ticks accounted for 94.99% of ticks collected (n = 22,968). Blacklegged ticks accounted for 3.21% (n = 777) of captures. The American dog tick comprised 1.76% (n = 425) of the total and the remaining 0.04% were the gulf coast tick (n = 9). The gulf coast tick and the American dog tick were not included in the analyses. The average number of lone star tick males, females, nymphs, and larvae and blacklegged tick males, females, and nymphs collected by treatment and control site over the duration of the study period are shown in Figures 4-10.

Table 7. Total, mean, and standard error of select stages of lone star tick (*Amblyomma americanum*) collected at treatment and control sites.

| Site | Treatment Year | ***Amblyomma americanum* Male** | | ***Amblyomma americanum* Female** | | ***Amblyomma americanum* Nymph** | | ***Amblyomma americanum* Larva** | |
|---|---|---|---|---|---|---|---|---|---|
| | | Total | Mean (SE) | Total | Mean (SE) | Total | Mean (SE) | Total | Mean (SE) |
| Braddock Park [a] | 1 | 25 | 0.25 (0.07) | 22 | 0.22 (0.06 | 685 | 6.85 (2.24) | -- | -- |
| Braddock Park | 2 | 90 | 0.87 (0.27) | 97 | 0.93 (0.26) | 414 | 3.98 (1.11) | 130 | 1.25 (0.92) |
| Braddock Park | 3 | 43 | 0.22 (0.05) | 44 | 0.23 (0.06) | 69 | 0.36 (0.07) | 1 | 0.01 (0.01) |
| Braddock Park | 4 | 27 | 0.13 (0.03) | 43 | 0.21 (0.05) | 137 | 0.67 (0.14) | 389 | 1.92 (1.22) |
| Braddock Park | 5 | 36 | 0.18 (0.04) | 39 | 0.20 (0.06) | 416 | 2.08 (0.33) | 453 | 2.26 (1.47) |
| Hemlock Overlook [b] | 1 | 46 | 0.34 (0.08) | 61 | 0.45 (0.12) | 372 | 2.74 (0.46) | -- | -- |
| Hemlock Overlook | 2 | 45 | 0.43 (0.11) | 30 | 0.29 (0.08) | 428 | 4.12 (0.77) | 780 | 7.50 (5.12) |
| Hemlock Overlook | 3 | 21 | 0.11 (0.03) | 30 | 0.16 (0.04) | 263 | 1.37 (0.23) | 551 | 2.87 (2.55) |
| Hemlock Overlook | 4 | 59 | 0.29 (0.06) | 59 | 0.29 (0.06) | 493 | 2.42 (0.37) | 1 | 0.00 (0.01) |
| Hemlock Overlook | 5 | 46 | 0.23 (0.05) | 49 | 0.24 (0.05) | 115 | 0.56 (0.11) | 1 | 0 (0.01) |
| Lorton [c] | 1 | 50 | 0.50 (0.19) | 53 | 0.53 (0.18) | 361 | 3.61 (1.00) | -- | -- |
| Lorton | 2 | 102 | 1.02 (0.22) | 90 | 0.90 (0.20) | 1283 | 12.83 (4.19) | 32 | 0.32 (0.26) |
| Lorton | 3 | 75 | 0.38 (0.08) | 137 | 0.70 (0.14) | 1337 | 6.82 (1.48) | 2136 | 10.90 (5.34) |
| Lorton | 4 | 142 | 0.70 (0.12) | 189 | 0.93 (0.19) | 1050 | 5.15 (0.69) | 239 | 1.17 (1.08) |
| Lorton | 5 | 73 | 0.36 (0.06) | 72 | 0.35 (0.07) | 175 | 0.86 (0.15) | 1027 | 5.03 (1.63) |
| Pleasant Valley [d] | 1 | 104 | 1.13 (0.35) | 170 | 1.85 (0.53) | 423 | 4.60 (1.00) | -- | -- |
| Pleasant Valley | 2 | 74 | 0.71 (0.16) | 75 | 0.72 (0.16) | 405 | 3.89 (0.76) | 459 | 4.41 (2.05) |
| Pleasant Valley | 3 | 130 | 0.69 (0.15) | 152 | 0.81 (0.15) | 926 | 4.93 (0.89) | 1029 | 5.47 (2.14) |
| Pleasant Valley | 4 | 163 | 0.82 (0.14) | 171 | 0.88 (.015) | 1204 | 6.02 (1.30) | 579 | 2.90 (1.57) |
| Pleasant Valley | 5 | 117 | 0.57 (0.11) | 161 | 0.79 (0.16) | 1213 | 5.95 (1.02) | 176 | 0.86 (0.39) |

Years* 1-2 were prior to 4-Poster deployment; years 3-5 were during 4-Poster deployment.

*Both treatment months and treatment years begin in April. Treatment year 1 began in 2010.

[a] Braddock Park (Twin Lakes Golf Course) (Control Site).

[b] Hemlock Overlook Regional Park (Test Site).

[c] Lorton (Laurel Hill Golf Course) (Control Site).

[d] Pleasant Valley Golf Course (Sully Woodlands) (Test Site).

Table 8. Total, mean, and standard error of select stages of blacklegged tick (*Ixodes scapularis*) collected at treatment and control sites.

| Site | Treatment Year | *Ixodes scapularis* Male | | *Ixodes scapularis* Female | | *Ixodes scapularis* Nymph | |
|---|---|---|---|---|---|---|---|
| | | Total | Mean (SE) | Total | Mean (SE) | Total | Mean (SE) |
| Braddock Park [a] | 1 | 2 | 0.02 (0.02) | 0 | 0 (0) | 3 | 0.03 (0.02) |
| Braddock Park | 2 | 2 | 0.02 (0.01) | 1 | 0.01 (0.01) | 0 | 0 (0) |
| Braddock Park | 3 | 1 | 0.01 (0.01) | 3 | 0.02 (0.01) | 4 | 0.02 (0.01) |
| Braddock Park | 4 | 2 | 0.01 (0.01) | 0 | 0 (0) | 1 | 0 (0) |
| Braddock Park | 5 | 2 | 0.01 (0.01) | 2 | 0.01 (0.01) | 9 | 0.05 (0.02) |
| Hemlock Overlook [b] | 1 | 1 | 0.01 (0.01) | 2 | 0.01 (0.01) | 273 | 2.01 (0.31) |
| Hemlock Overlook | 2 | 0 | 0 (0) | 1 | 0.01 (0.01) | 15 | 0.14 (0.03) |
| Hemlock Overlook | 3 | 2 | 0.01 (0.01) | 6 | 0.03 (0.01) | 26 | 0.14 (0.04) |
| Hemlock Overlook | 4 | 1 | 0 (0) | 1 | 0 (0) | 21 | 0.10 (0.04) |
| Hemlock Overlook | 5 | 1 | 0 (0) | 3 | 0.01 (0.01) | 33 | 0.16 (0.04) |
| Lorton [c] | 1 | 1 | 0.01 (0.01) | 1 | 0.01 (0.01) | 38 | 0.38 (0.14) |
| Lorton | 2 | 3 | 0.03 (0.02) | 0 | 0 (0) | 29 | 0.29 (0.10) |
| Lorton | 3 | 3 | 0.02 (0.01) | 6 | 0.03 (0.01) | 23 | 0.12 (0.03) |
| Lorton | 4 | 8 | 0.04 (0.02) | 8 | 0.04 (0.02) | 44 | 0.22 (0.05) |
| Lorton | 5 | 1 | 0 (0) | 2 | 0.01 (0.01) | 51 | 0.25 (0.05) |
| Pleasant Valley [d] | 1 | 2 | 0.02 (0.02) | 4 | 0.04 (0.02) | 17 | 0.18 (0.07) |
| Pleasant Valley | 2 | 1 | 0.01 (0.01) | 4 | 0.04 (0.02) | 5 | 0.05 (0.02) |
| Pleasant Valley | 3 | 2 | 0.01 (0.01) | 5 | 0.03 (0.01) | 16 | 0.09 (0.03) |
| Pleasant Valley | 4 | 1 | 0.01 (0.01) | 2 | 0.01 (0.01) | 12 | 0.06 (0.02) |
| Pleasant Valley | 5 | 3 | 0.01 (0.01) | 2 | 0.01 (0.01) | 15 | 0.07 (0.02) |

Years* 1-2 were prior to 4-Poster deployment; years 3-5 were during 4-Poster deployment.
*Both treatment months and treatment years begin in April. Treatment year 1 began in 2010.
[a] Braddock Park (Twin Lakes Golf Course) (Control Site).
[b] Hemlock Overlook Regional Park (Test Site).
[c] Lorton (Laurel Hill Golf Course) (Control Site).
[d] Pleasant Valley Golf Course (Sully Woodlands) (Test Site).

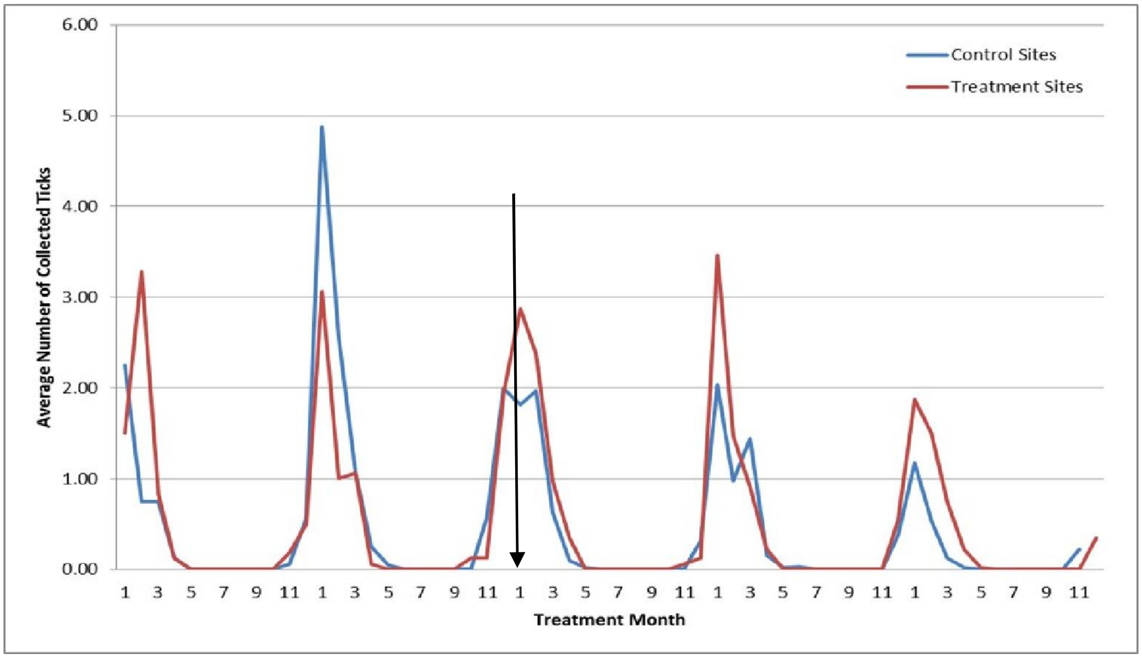



Figure 4. Average number of male lone star (*Amblyomma americanum*) ticks collected on carbon dioxide-baited traps by treatment site and treatment month, years 1-5. Both treatment months and treatment years begin in April. Treatment year 1 began in 2010. Black arrow indicates 4-Poster deployment.

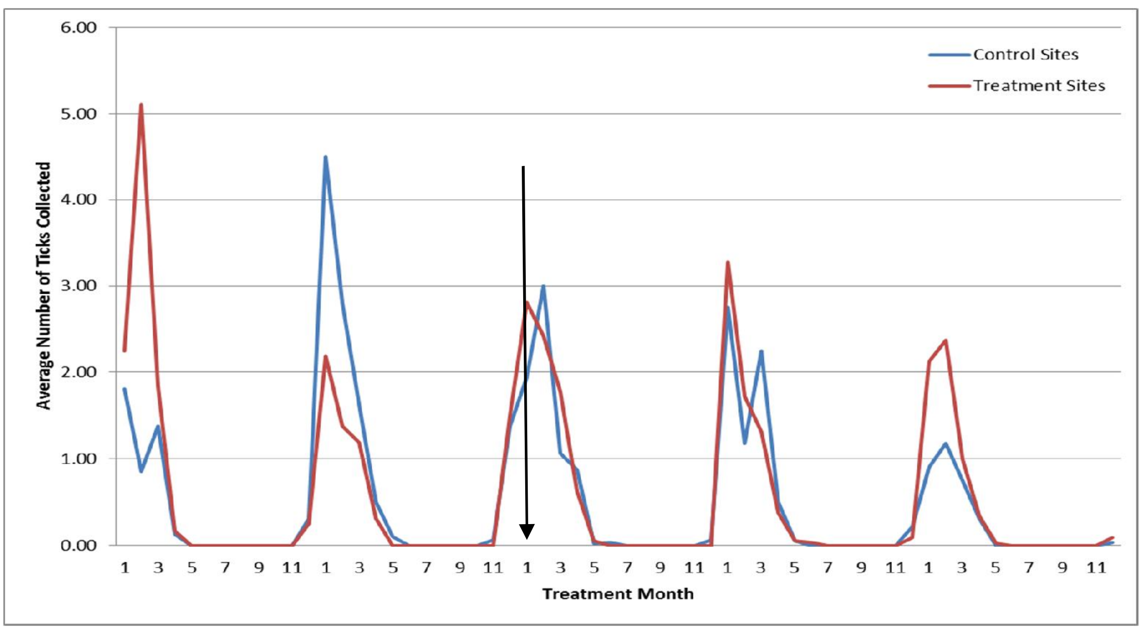



Figure 5. Average number of female lone star (*Amblyomma americanum*) ticks collected on carbon dioxide-baited traps by treatment site and treatment month, years 1-5. Both treatment months and treatment years begin in April. Treatment year 1 began in 2010. Black arrow indicates 4-Poster deployment.

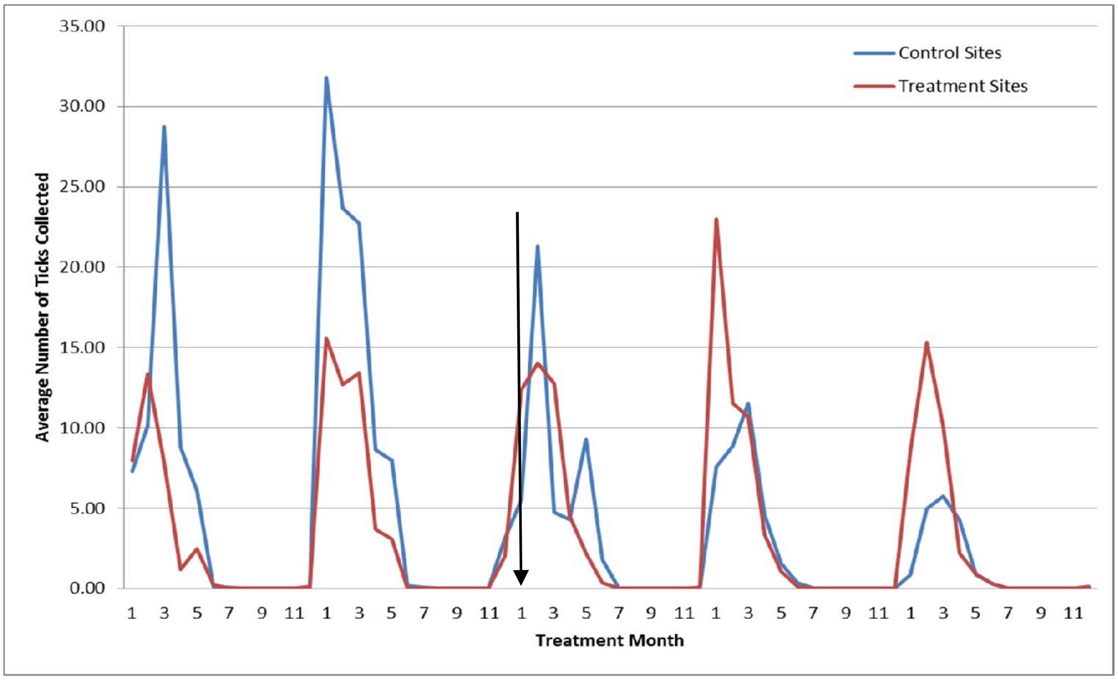



Figure 6. Average number of nymphal lone star (*Amblyomma americanum*) ticks collected on carbon dioxide-baited traps by treatment site and treatment month, years 1-5. Both treatment months and treatment years begin in April. Treatment year 1 began in 2010. Black arrow indicates 4-Poster deployment.

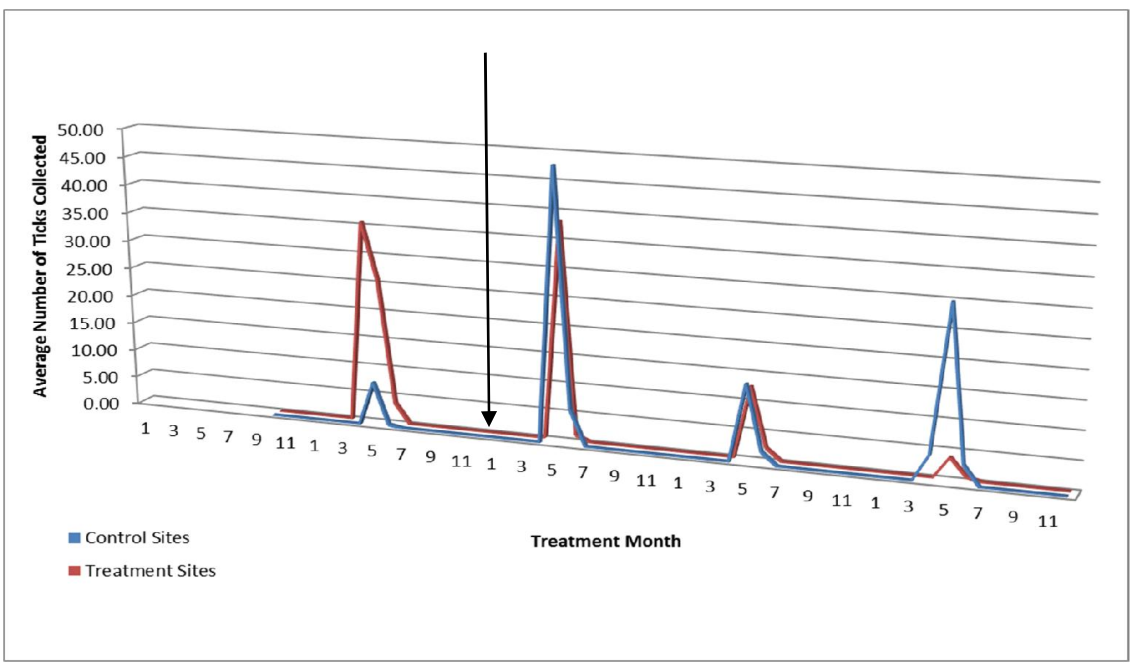



Figure 7. Average number of larval lone star (*Amblyomma americanum*) ticks collected on carbon dioxide-baited traps by treatment site and treatment month, years 1-5. Both treatment months and treatment years begin in April. Treatment year 1 began in 2010. Black arrow indicates 4-Poster deployment.

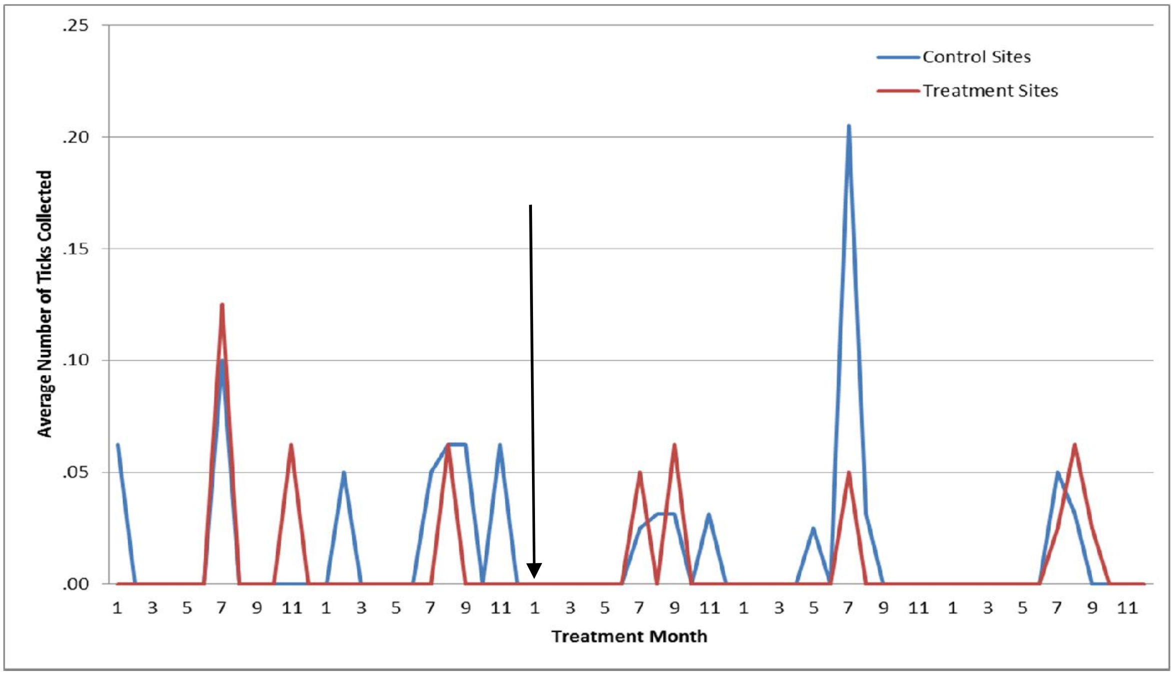



Figure 8. Average number of male blacklegged (*Ixodes scapularis*) ticks collected on carbon dioxide-baited traps by treatment site and treatment month, years 1-5. Both treatment months and treatment years begin in April. Treatment year 1 began in 2010. Black arrow indicates 4-Poster deployment.

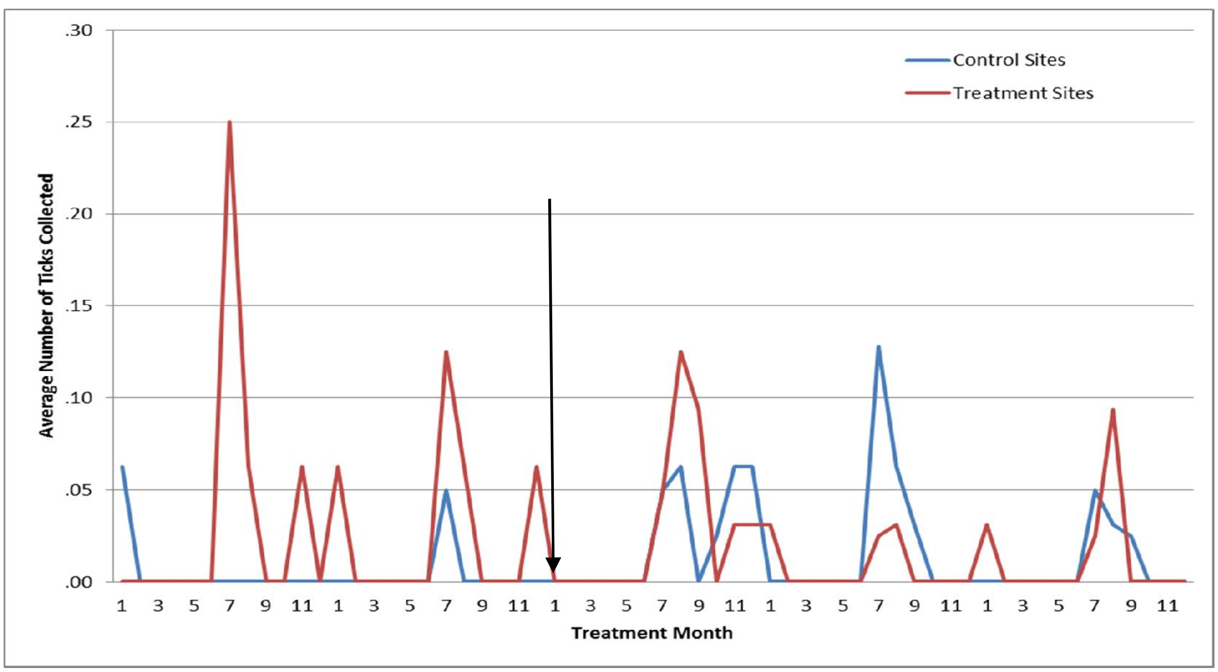



Figure 9. Average number of female blacklegged (*Ixodes scapularis*) ticks collected on carbon dioxide-baited traps by treatment site and treatment month, years 1-5. Both treatment months and treatment years begin in April. Treatment year 1 began in 2010. Black arrow indicates 4-Poster deployment.

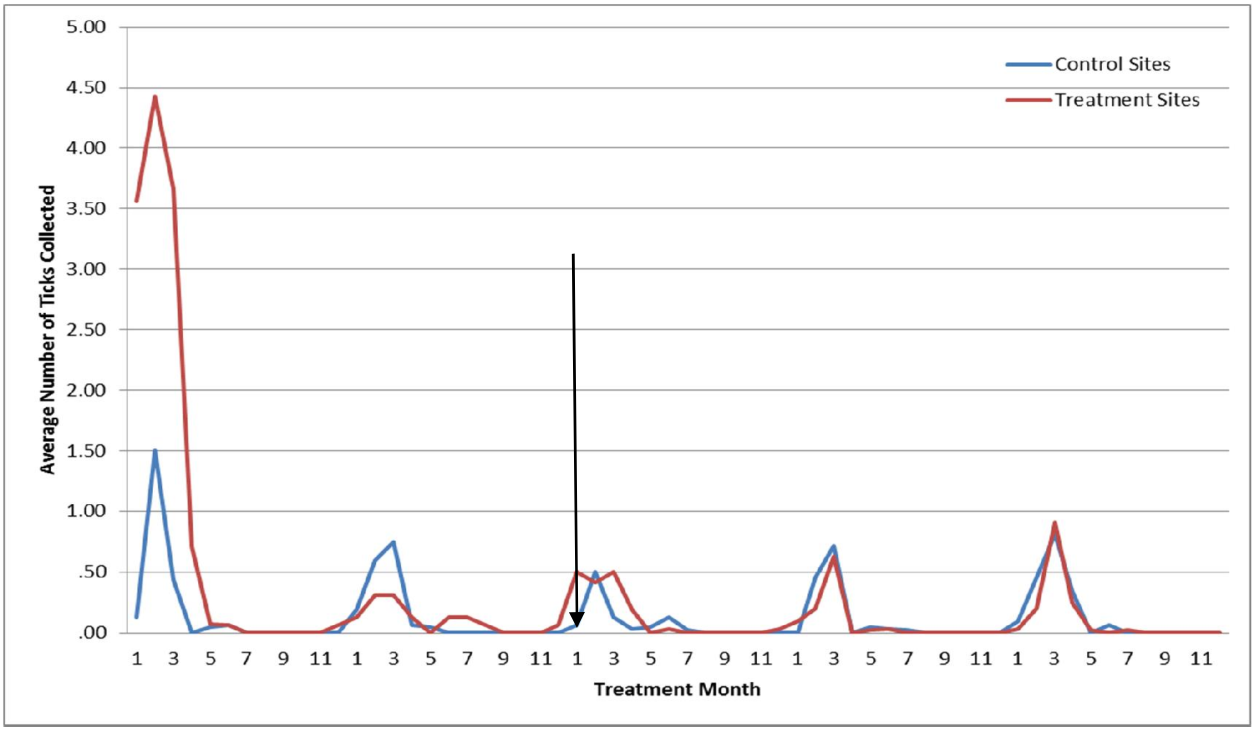



Figure 10. Average number of nymphal blacklegged (*Ixodes scapularis*) ticks collected on carbon dioxide-baited traps by treatment site and treatment month, years 1-5. Both treatment months and treatment years begin in April. Treatment year 1 began in 2010. Black arrow indicates 4-Poster deployment.

### *Pre-treatment tick abundance on tick traps between control and treatment sites*

Kruskal-Wallis tests found that mean ranks of larval lone star ticks were significantly greater at treatment sites compared to control sites prior to 4-Poster deployment ($H$ = 10.129, $df$ =1, $P$ = 0.001). Mean ranks of other stages of lone star ticks (male, female and nymphal ticks) were similar between control and treatment sites in pre-treatment years prior to the 4-Poster stations being deployed (Table 9).

Kruskal-Wallis tests found that mean ranks of male blacklegged ticks were similar between control and treatment sites in pre-treatment years prior to the 4-Poster stations being deployed. Mean ranks of female blacklegged ticks ($H$ = 5.653, $df$ =1, $P$ = 0.017) and nymphal blacklegged ticks ($H$ = 24.902, $df$ =1, $P$ <0.001) were significantly greater at treatment sites compared to control sites prior to 4-Poster implementation (Table 9).

Table 9. Kruskal-Wallis test results comparing tick trap abundance of lone star (*Amblyomma americanum)* and blacklegged ticks (*Ixodes scapularis*) between control and treatment sites before 4-Poster stations were deployed.

| Tick Species (life stage) | *H* | *df* | *P* | Mean rank (Control) | Mean rank (Treatment) |
|---|---|---|---|---|---|
| *A. americanum* (adult male) | 0.003 | 1 | 0.956 | 420.84 | 420.18 |
| *A. americanum* (adult female) | 0.021 | 1 | 0.885 | 419.60 | 421.33 |
| *A. americanum* (nymph) | 0.072 | 1 | 0.789 | 418.44 | 422.41 |
| *A. americanum* (total, no larva) | 0.001 | 1 | 0.979 | 420.71 | 420.31 |
| *A. americanum* (larva) | 10.129 | 1 | 0.001 | 241.45 | 259.40 |
| *A. americanum* (total, with larva) | 0.395 | 1 | 0.530 | 415.48 | 425.15 |
| *I. scapularis* (adult male) | 1.083 | 1 | 0.298 | 422.28 | 418.85 |
| *I. scapularis* (adult female) | 5.653 | 1 | 0.017 | 416.08 | 424.60 |
| *I. scapularis* (nymph) | 24.902 | 1 | <0.001 | 395.07 | 444.07 |
| *I. scapularis* (total) | 25.424 | 1 | <0.001 | 392.66 | 446.30 |

Shaded cells indicate a significant difference.

***Treatment tick abundance on tick traps between control and treatment sites***

Kruskal-Wallis tests found that mean ranks of lone star ticks (male, female, and larval) were similar between control and treatment sites after deployment of the 4-Poster stations in 2012. Mean rank of nymphal lone star ticks was significantly greater ($H = 5.465$, $df = 1$, $P = 0.019$) at treatment sites compared to control sites following deployment of the 4-Poster stations in 2012 (Table 10).

Kruskal-Wallis tests found that mean ranks of blacklegged ticks (adult male, adult female and nymphal ticks) were similar between control and treatment sites after deployment of the 4-Poster stations in 2012 (Table 10).

Table 10. Kruskal-Wallis test results comparing tick trap abundance of lone star (*Amblyomma americanum)* and blacklegged ticks (*Ixodes scapularis*) between control and treatment sites after 4-Poster stations were deployed.

| Tick Species (life stage) | *H* | *df* | *P* | Mean rank (Control) | Mean rank (Treatment) |
|---|---|---|---|---|---|
| *A. americanum* (adult male) | 0.447 | 1 | 0.504 | 1189.94 | 1202.09 |
| *A. americanum* (adult female) | 2.900 | 1 | 0.089 | 1180.17 | 1211.92 |
| *A. americanum* (nymph) | 5.465 | 1 | 0.019 | 1168.72 | 1223.44 |
| *A. americanum* (total, no larva) | 1.714 | 1 | 0.191 | 1180.12 | 1211.97 |
| *A. americanum* (larva) | 1.795 | 1 | 0.180 | 1203.54 | 1188.41 |
| *A. americanum* (total, with larva) | 0.502 | 1 | 0.478 | 1187.20 | 1204.85 |
| *I. scapularis* (adult male) | 0.987 | 1 | 0.320 | 1198.46 | 1193.52 |
| *I. scapularis* (adult female) | 0.021 | 1 | 0.884 | 1196.45 | 1195.55 |
| *I. scapularis* (nymph) | 0.011 | 1 | 0.915 | 1195.34 | 1196.66 |
| *I. scapularis* (total) | 0.017 | 1 | 0.895 | 1196.94 | 1195.06 |

Shaded cells indicate a significant difference.

***Pre-treatment vs. treatment tick abundance on tick traps at treatment sites***

Kruskal-Wallis tests found that mean ranks of male lone star ticks ($H = 4.328$, $df = 1$, $P = 0.037$), nymphal lone star ticks ($H = 8.470$, $df = 1$, $P = 0.0036$) and larval lone star ticks ($H = 11.004$, $df = 1$, $P = 0.001$) at treatment sites were significantly lower than pre-treatment levels through the course of the study. There was no difference in mean ranks of female lone star ticks between pre- and post-treatment levels at treatment sites (Table 11).

Mean ranks of nymphal blacklegged ticks ($H = 52.334$, $df = 1$, $P < 0.001$) at treatment sites were significantly lower than pre-treatment levels through the course of the study. There was no difference in mean ranks of male or female blacklegged ticks between pre- and post-treatment levels at treatment sites (Table 11).

Table 11. Kruskal-Wallis test results comparing tick trap abundance of lone star (*Amblyomma americanum)* and blacklegged ticks (*Ixodes scapularis*) at treatment sites before and after 4-Poster stations were deployed.

| **Tick Species (life stage)** | ***H*** | ***df*** | ***P*** | **Mean rank (Pretreatment)** | **Mean rank (Treatment)** |
|---|---|---|---|---|---|
| *A. americanum* (adult male) | 4.328 | 1 | 0.037 | 841.25 | 804.72 |
| *A. americanum* (adult female) | 1.680 | 1 | 0.195 | 831.71 | 808.21 |
| *A. americanum* (nymph) | 8.292 | 1 | 0.004 | 862.14 | 797.08 |
| *A. americanum* (total, no larva) | 9.879 | 1 | 0.002 | 867.86 | 794.98 |
| *A. americanum* (larva) | 11.004 | 1 | 0.001 | 754.97 | 715.64 |
| *A. americanum* (total, with larva) | 9.857 | 1 | 0.002 | 868.67 | 794.69 |
| *I. scapularis* (adult male) | 0.023 | 1 | 0.879 | 814.97 | 814.33 |
| *I. scapularis* (adult female) | 1.522 | 1 | 0.217 | 820.04 | 812.47 |
| *I. scapularis* (nymph) | 52.334 | 1 | <0.001 | 887.07 | 787.96 |
| *I. scapularis* (total) | 49.769 | 1 | <0.001 | 892.94 | 785.81 |

Shaded cells indicate a significant difference.

***Pre- treatment vs. treatment tick abundance on tick traps at control sites***

Kruskal-Wallis tests found that mean ranks of male lone star ticks ($H = 6.895$, $df = 1$, $P = 0.009$), female lone star ticks ($H = 5.509$, $df = 1$, $P = 0.019$) and nymphal lone star ticks ($H = 16.320$, $df = 1$, $P < 0.001$) at control sites were significantly lower than pre-treatment levels through the course of the study. There was no difference in mean tick abundance of larval lone star ticks between pre-and post-treatment levels at control sites (Table 12).

There was no difference in mean tick abundance of male, female, or nymphal blacklegged ticks between pre- and post-treatment levels at control sites (Table 12).

Table 12. Kruskal-Wallis test results comparing tick trap abundance of lone star (*Amblyomma americanum)* and blacklegged ticks (*Ixodes scapularis*) at control sites before and after 4-Poster stations were deployed.

| **Tick Species (life stage)** | ***H*** | ***df*** | ***P*** | **Mean rank (Pretreatment)** | **Mean rank (Treatment)** |
|---|---|---|---|---|---|
| *A. americanum* (adult male) | 6.895 | 1 | 0.009 | 836.48 | 790.38 |
| *A. americanum* (adult female) | 5.509 | 1 | 0.019 | 832.87 | 791.60 |
| *A. americanum* (nymph) | 16.320 | 1 | <0.001 | 868.93 | 779.45 |
| *A. americanum* (total, no larva) | 16.028 | 1 | <0.001 | 871.52 | 778.57 |
| *A. americanum* (larva) | 3.500 | 1 | 0.061 | 705.79 | 727.77 |
| *A. americanum* (total, with larva) | 7.862 | 1 | 0.005 | 851.68 | 785.26 |
| *I. scapularis* (adult male) | 0.518 | 1 | 0.472 | 804.89 | 801.03 |
| *I. scapularis* (adult female) | 3.072 | 1 | 0.080 | 794.97 | 804.37 |
| *I. scapularis* (nymph) | 0.115 | 1 | 0.735 | 804.96 | 801.00 |
| *I. scapularis* (total) | 0.002 | 1 | 0.965 | 802.44 | 801.85 |

Shaded cells indicate a significant difference.

***Tick abundance at control and treatment sites on tick traps by year***

At control sites, Kruskal-Wallis tests found that there was a significant difference between years for male lone star tick mean rank ($H$ = 14.935, $df$ =4, $P$ = 0.005). A significant difference was also found between years for female lone star tick mean rank ($H$ = 24.040, $df$ =4, $P$ <0.001). For both male and female lone star ticks, year two was the only year that had a different mean rank than all other years. A significant difference between years for nymphal mean rank was also seen at control sites ($H$ = 20.500, $df$ =4, $P$ <0.001). Among nymphal lone star ticks at control sites, years one and two had similar mean ranks, but the rank of year two was higher than years three, four, and five. A significant difference was also seen between years for larval lone star tick mean ranks ($H$ = 12.799, $df$ = 3, $P$ = 0.005). Years two and four had similar mean ranks as did years three and five, but the two groups were different from each other. Data on larval lone star ticks were not recorded during the first year of the project (Table 13).

Mean ranks of male, female, and nymphal blacklegged ticks at control sites did not significantly differ by year (Table 13).

At treatment sites, Kruskal-Wallis tests found that there was a significant difference between years for nymphal lone star tick mean rank ($H$ = 12.308, $df$ =4, $P$ = 0.005). Years one through four had similar mean ranks and years one and three through five had similar mean ranks. A significant difference was also seen between years for larval lone star tick mean ranks ($H$ = 26.009, $df$ = 3, $P$ <0.001). Years two and three had similar mean ranks as did years four and five, but the two groups were different from each other. Data on larval lone star ticks was not recorded during the first year of the project. Mean ranks of male and female lone star ticks did not significantly differ by year (Table 13).

The mean ranks of nymphal blacklegged ticks at treatment sites showed a significant difference at the year level ($H$ = 94.835, $df$ =4, $P$ <0.001). Year one was the only year that had a different mean rank than all other years. Mean ranks of male and female blacklegged ticks did not significantly differ by year (Table 13).

**Henderson-Tilton results**

A modified version of Abbott's formula (1925), the Henderson-Tilton formula (1955), was used to look at the impact of the pesticide application (Table 14). This calculation compares untreated (control) and treated areas before and after treatment was applied. Year two of the study was used as the pre-treatment reference year. Percent control is shown in Table 14. A negative number or zero would indicate no control or no reduction in the pest population at the treatment site. According to the results, the only consistent control was seen in larval lone star ticks and adult female blacklegged ticks. No control was seen among other stages of either species or for the combined numbers for lone star ticks (not including the larvae) and inconsistent results (reduction and no reduction) were seen when looking at the combined numbers for each species. For the non-larval stages of lone star ticks, the numbers appear to be trending the opposite direction. Although reductions in numbers of ticks were seen for certain stages, the results were not consistent.

Table 13. Summary of host seeking lone star ticks (*Amblyomma americanum*) and blacklegged ticks (*Ixodes scapularis*) (mean ± SE) at the treatment and control sites, years 1-5.

| Species, Stage, Location | | Treatment Year | | | | | Kruskal-Wallis test |
|---|---|---|---|---|---|---|---|
| | | Pre-treatment | | Treatment | | | |
| | | 1 | 2 | 3 | 4 | 5 | |
| | | Mean ± SE | Mean ± SE | Mean ± SE | Mean ± SE | Mean ± SE | |
| *A. americanum* | | | | | | | |
| Larvae* | Control | -- | 0.79 ± 0.48 | 5.51 ± 2.71 a** | 1.54 ± 0.8 1 | 3.66 ± 1.10 a | $H$ =12.799; $df$ = 3; $P$ = 0.005 |
| | Treatment | -- | 5.96 ± 2.78 a | 4.16 ± 1.67 a | 1.44 ± 0.78 | 0.43 ± 0.20 | $H$ = 26.009; $df$ = 3; $P$ < 0.001 |
| Nymphs | Control | 5.23 ± 1.23 a,b | 8.32 ± 2.15 b | 3.62 ± 0.77 a | 2.92 ± 0.37 a | 1.46 ± 0.18 a | $H$ = 20.500; $df$ = 4; $P$ < 0.001 |
| | Treatment | 3.49 ± 0.49 a.b | 4.01 ± 0.54 b | 3.13 ± 0.47 a.b | 4.20 ± 0.68 a.b | 3.26 ± 0.53 a | $H$ = 12.308; $df$ = 4; $P$ = 0.015 |
| Males | Control | 0.38 ± 0.10 | 0.94 ± 0.17 a | 0.30 ± 0.05 | 0.42 ± 0.07 | 0.27 ± 0.04 | $H$ = 14.935; $df$ = 4; $P$ = 0.005 |
| | Treatment | 0.66 ± 0.15 | 0.57 ± 0.10 | 0.40 ± 0.08 | 0.55 ± 0.08 | 0.40 ± 0.06 | $H$ = 7.778; $df$ = 4; $P$ = 0.100 |
| Females | Control | 0.38 ± 0.10 | 0.92 ± 0.17 a | 0.47 ± 0.08 | 0.57 ± 0.10 | 0.28 ± 0.04 | $H$ = 24.040; $df$ = 4; $P$ < 0.001 |
| | Treatment | 1.01 ± 0.23 | 0.51 ± 0.09 | 0.48 ± 0.08 | 0.58 ± 0.08 | 0.52 ± 0.08 | $H$ = 3.251; $df$ = 4; $P$ = 0.517 |
| *I. scapularis* | | | | | | | |
| Nymphs | Control | 0.21 ± 0.07 | 0.14 ± 0.05 | 0.07 ± 0.02 | 0.11 ± 0.03 | 0.15 ± 0.03 | $H$ = 5.098; $df$ = 4; $P$ = 0.277 |
| | Treatment | 1.27 ± 0.20 a | 0.10 ± 0.02 | 0.11 ± 0.02 | 0.08 ± 0.02 | 0.12 ± 0.02 | $H$ = 94.835; $df$ = 4; $P$ < 0.001 |
| Males | Control | 0.02 ± 0.01 | 0.03 ± 0.01 | 0.01 ± 0.01 | 0.03 ± 0.01 | 0.01 ± 0.00 | $H$ = 4.531; $df$ = 4; $P$ = 0.339 |
| | Treatment | 0.01 ± 0.01 | 0.01 ± 0.00 | 0.01 ± 0.01 | 0.01 ± 0.00 | 0.01 ± 0.00 | $H$ = 1.771; $df$ = 4; $P$ = 0..778 |
| Females | Control | 0.01 ± 0.01 | 0.01 ± 0.00 | 0.02 ± 0.01 | 0.02 ± 0.01 | 0.01 ± 0.00 | $H$ = 5.665; $df$ = 4; $P$ = 0.226 |
| | Treatment | 0.03 ± 0.01 | 0.02 ± 0.01 | 0.03 ± 0.01 | 0.01 ± 0.00 | 0.01 ± 0.01 | $H$ = 7.030; $df$ = 4; $P$ = 0.134 |

*No larvae recorded for most of treatment year 1.
**Means in the same row followed by the same letter are not significantly different.

Table 14. Percent control of each life stage and summary of life stages for lone star ticks (*Amblyomma americanum*) and blacklegged ticks (*Ixodes scapularis*) as calculated by the Henderson-Tilton (1955) formula.

| | *Amblyomma americanum* | | | | | | *Ixodes scapularis* | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Male (M) | Female (F) | Nymph (N) | Total (M,F,N) | Larva (L) | Total (M,F,N,L) | Male (M) | Female (F) | Nymph (N) | Total (M,F,N) |
| % ctrl (2 v 3) | -106.47 | -79.08 | -72.28 | -75.32 | 90.33 | 21.30 | -400.00 | 75.56 | -125.56 | -91.83 |
| % ctrl (2 v 4) | -111.94 | -79.63 | -191.25 | -166.28 | 87.92 | -20.21 | 0.00 | 92.50 | -6.33 | 18.80 |
| % ctrl (2 v 5) | -141.28 | -236.94 | -357.77 | -311.94 | 98.44 | 20.10 | -566.67 | 75.00 | -16.00 | -14.52 |

Shaded cells indicate no calculated control

***Deer sampling***

A total of 108 white-tailed deer were harvested for data collection over the project duration (Table 15). Histological examinations were conducted for harvested deer by VDACS Animal Health Laboratory (Warrenton, VA). The most common histopathological diagnoses included verminous pneumonia, enterocolitis, enteritis and multiple organ inflammation. Other less frequent diagnoses included endoparasitism (pulmonary, abomasal and enteric), other types of pneumonia (fungal and possibly viral), omasitis, lymphadenitis indicating a possible mycobacterial infection, myocardial degeneration and fibropapilloma. A majority of fecal samples tested showed scant to light loads of various parasites, common to white-tailed deer. A few deer presented with a heavy tapeworm load (Table 16).

Lymph node samples were sent from 93 deer (86%) to the Wisconsin Veterinary Diagnostic Lab to test for the presence of CWD. Pathology results were not provided for several samples containing insufficient follicles or tissues exhibiting freeze damage. Of the samples that were testable (n = 76), CWD was not detected in any sampled lymph nodes of harvested deer.

Table 15. Deer harvest totals from each test site and control site from 2012-2014.

| Deer | Hemlock Overlook Regional Park | | | Sully Woodlands | | | Twin Lakes Golf Course | | | Laurel Hill Golf Course | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2012 | 2013 | 2014 | 2012 | 2013 | 2014 | 2012 | 2013 | 2014 | 2012 | 2013 | 2014 |
| Doe (adult) | 9 | 8 | 3 | 5 | 3 | 4 | 6 | 6 | 0 | 5 | 10 | 2 |
| Doe (fawn) | 0 | 2 | 0 | 0 | 0 | 1 | 1 | 1 | 0 | 0 | 0 | 0 |
| Buck (adult) | 1 | 1 | 4 | 2 | 4 | 6 | 0 | 1 | 0 | 0 | 1 | 3 |
| Buck (fawn) | 1 | 3 | 1 | 4 | 5 | 2 | 0 | 2 | 0 | 1 | 1 | 0 |
| Total | 11 | 14 | 7 | 11 | 12 | 13 | 7 | 10 | 0 | 6 | 12 | 5 |

Table 16. Parasitology and pathology summary results from harvested deer at 4-Poster treatment and control sites.

| Summary Diagnosis | 4-Poster Treatment Sites | | Control Sites | |
|---|---|---|---|---|
| | Hemlock Regional Overlook Park Deer (n = 23) # positive (% positive) | Sully Woodlands Deer (n = 18) # positive (% positive) | Laurel Hill Golf Course Deer (n = 15) # positive (% positive) | Twin Lakes Golf Course Deer (n = 13) # positive (% positive) |
| Abomasal endoparasitism | 1 (4.3) | 0 (0.0) | 1 (6.7) | 1 (7.7) |
| Colitis | 0 (0.0) | 2 (11.1) | 0 (0.0) | 0 (0.0) |
| Enteric endoparasitism | 2 (8.7) | 0 (0.0) | 0 (0.0) | 0 (0.0) |
| Enteritis | 1 (4.3) | 1 (5.6) | 0 (0.0) | 1 (7.7) |
| Enterocolitis | 10 (43.5) | 10 (55.6) | 6 (40.0) | 9 (69.2) |
| Fibropapilloma | 0 (0.0) | 2 (11.1) | 0 (0.0) | 0 (0.0) |
| Forestomachs mural gastritis | 1 (4.3) | 0 (0.0) | 0 (0.0) | 0 (0.0) |
| Fungal pneumonia | 1 (4.3) | 0 (0.0) | 0 (0.0) | 0 (0.0) |
| Lymphadenitis | 1 (4.3) | 1 (5.6) | 0 (0.0) | 0 (0.0) |
| Multiple organ inflammation | 12 (52.2) | 8 (44.4) | 10 (66.7) | 4 (30.8) |
| Myocardial degeneration | 1 (4.3) | 0 (0.0) | 0 (0.0) | 0 (0.0) |
| Omasitis | 1 (4.3) | 0 (0.0) | 0 (0.0) | 0 (0.0) |
| Parasite - *Capillaria* spp. | 7 (30.4) | 2 (11.1) | 0 (0.0) | 2 (15.4) |
| Parasite - Coccidia | 4 (17.4) | 4 (22.2) | 2 (13.3) | 5 (38.5) |
| Parasite - *Muellerius* spp. | 1 (4.3) | 0 (0.0) | 0 (0.0) | 1 (7.7) |
| Parasite - *Nematodirus* spp. | 2 (8.7) | 0 (0.0) | 0 (0.0) | 0 (0.0) |
| Parasite - Strongyle spp. | 11 (47.8) | 11 (61.1) | 12 (80.0) | 7 (53.8) |
| Parasite - Strongyloides spp. | 0 (0.0) | 2 (11.1) | 0 (0.0) | 0 (0.0) |
| Parasite - Tapeworm spp. | 1 (4.3) | 2 (11.1) | 0 (0.0) | 0 (0.0) |
| Parasite - *Trichuris* spp. | 1 (4.3) | 0 (0.0) | 0 (0.0) | 0 (0.0) |
| Pneumonia | 0 (0.0) | 2 (11.1) | 0 (0.0) | 0 (0.0) |
| Possible viral pneumonia | 1 (4.3) | 0 (0.0) | 0 (0.0) | 0 (0.0) |
| Pulmonary endoparasitism | 1 (4.3) | 0 (0.0) | 0 (0.0) | 0 (0.0) |
| Verminous pneumonia | 15 (65.2) | 7 (38.9) | 6 (40.0) | 7 (53.8) |

### *Deer density surveys*

Deer density surveys conducted from 13 August through 27 August 2012 estimated 184 deer per square mile at Hemlock Overlook Regional Park and 113 deer per square mile at Sully Woodlands. In 2013, deer density surveys conducted from 5 August through 19 August 2013 yielded an estimate of 156 deer per square mile at Hemlock Overlook Regional Park. Deer density surveys were not conducted at Sully Woodlands in 2013 because deer visitation at the 4-Poster sites dropped following installation of the electric fences. For many of the Sully Woodlands treatment stations, a deer was not seen inside the fence from April 2013, when the electric fences were constructed, until electric fences were disabled in November 2013. Fences were not fully removed from all sites until February 2014. Deer density surveys conducted from 21 August through 4 September 2014 estimated 317 per square mile at Hemlock Overlook Regional Park and 177 per square mile at Sully Woodlands during the final survey of the study (Table 17; Figure 11).

Table 17. Deer density survey results for Hemlock Overlook Regional Park and Sully Woodlands, 2012-2014.

| Survey Metric | Hemlock Overlook | | | Sully Woodlands | | |
|---|---|---|---|---|---|---|
| | **2012** | **2013** | **2014** | **2012** | **2013** | **2014** |
| Spike:Branch Antlered Buck Ratio | 0.23 | 0.09 | 0.06 | 0.44 | -- | 0.10 |
| Estimated Buck Population | 41.96 | 27.12 | 53.80 | 51.98 | -- | 114.74 |
| Doe:Buck Ratio | 1.16 | 1.78 | 1.54 | 2.22 | -- | 1.19 |
| Estimated Total Doe Population | 48.60 | 48.36 | 82.81 | 115.42 | -- | 136.41 |
| Estimated Fawn Population | 3.00 | 3.61 | 24.25 | -- | -- | 11.30 |
| Estimated Deer Population Size | 93.56 | 79.08 | 160.86 | 167.40 | -- | 262.47 |
| Deer Density (Deer per Square Mile) | 184.24 | 155.74 | 316.77 | 112.77 | -- | 177.35 |

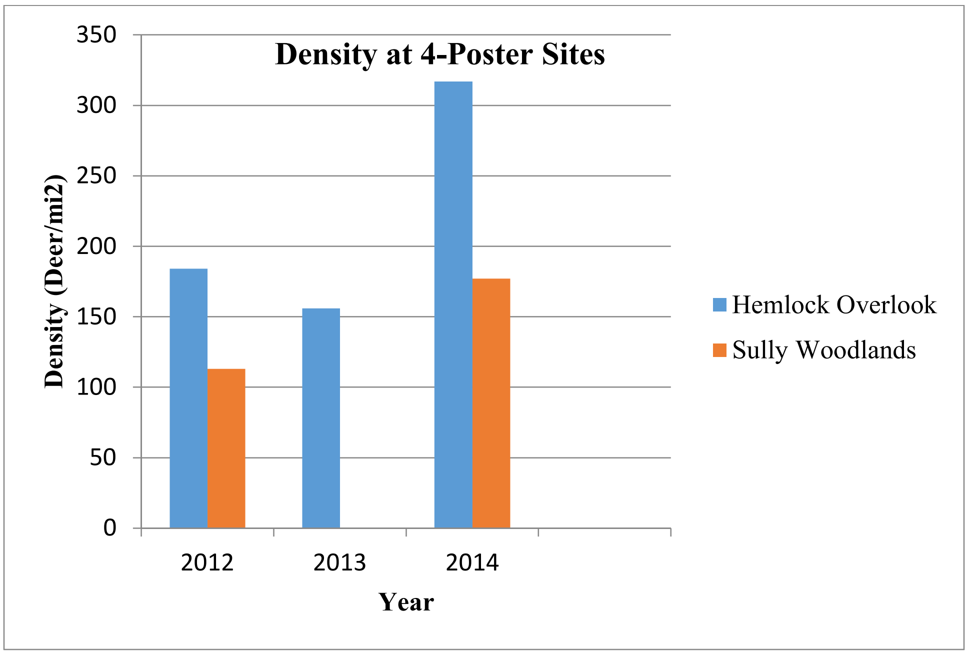



Figure 11. Estimated deer density at 4-Poster treatment sites, Hemlock Overlook Regional Park and Sully Woodlands, 2012-2014. Deer density surveys were not conducted in Sully Woodlands in 2013.

***Environmental impact surveys***

ANOVA with repeated measures found that mean percent coverage of bare ground at Hemlock Overlook Regional Park significantly differed with time ($F_{3,12} = 48.143$, $P<0.05$). The percentage of bare ground at Hemlock Overlook Regional Park increased from 2012-2014 in all treatment plots (Table 18). Mean percent coverage of bare ground was 1.15% at the beginning of the study in 2012, 32.00% in late 2012, 53.55% in 2013, and 71.00% in 2014. Significantly greater coverage of bare ground was found in 2014 compared to all other survey periods.

ANOVA with repeated measures found that mean percent coverage of bare ground at Sully Woodlands significantly differed with time ($F_{3,42} = 20.708$, $P<0.05$). The percentage of bare ground at Sully

Woodlands increased from 2012-2014 in 80% of treatment plots (Table 18). Mean percent coverage of bare ground was 1.28% at the beginning of the study in 2012, 23.18% in late 2012, 26.80% in 2013, and 33.98% in 2014. Significantly greater coverage of bare ground was found in 2014 compared to all other survey periods. Significantly lesser coverage of bare ground was found at the beginning of the study in 2012 compared to all other survey periods. Comparisons of mean percent coverage of bare ground among late 2012, 2013 and 2014 were non-significant.

Table 18. Percentage of bare soil collected inside circular fence plots from each 4-Poster location at both test sites from 2012 – 2014.

| | | % Bare Soil[b] | | | | Resample | % Bare Soil[b] | | | | Resample | % Bare Soil[b] | | | | Resample | % Bare Soil[b] | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Site[a] | Date | NE | NW | SE | SW | Date | NE | NW | SE | SW | Date | NE | NW | SE | SW | Date | NE | NW | SE | SW |
| H1 | 2/2/2012 | 1 | 1 | 2 | 1 | 10/17/2012 | 40 | 51 | 32 | 25 | 6/05/2013 | 42 | 50 | 38 | 28 | 6/04/2014 | 50 | 65 | 40 | 45 |
| H2 | 2/2/2012 | 2 | 1 | 1 | 1 | 10/17/2012 | 52 | 50 | 40 | 45 | 6/05/2013 | 72 | 77 | 68 | 63 | 6/11/2014 | 85 | 90 | 85 | 80 |
| H3 | 2/2/2012 | 1 | 1 | 1 | 1 | 10/17/2012 | 25 | 33 | 38 | 40 | 6/05/2013 | 40 | 48 | 55 | 60 | 6/11/2014 | 70 | 65 | 90 | 85 |
| H4 | 2/2/2012 | 2 | 2 | 1 | 3 | 10/17/2012 | 35 | 47 | 25 | 42 | 6/05/2013 | 77 | 83 | 48 | 66 | 6/11/2014 | 70 | 90 | 75 | 85 |
| H5 | 3/13/2012 | 0 | 1 | 0 | 0 | 10/17/2012 | 5 | 5 | 5 | 5 | 6/05/2013 | 42 | 40 | 45 | 29 | 6/11/2014 | 90 | 65 | 65 | 30 |
| S1 | 1/19/2012 | 3 | 2 | 2 | 3 | 10/10/2012 | 22 | 40 | 20 | 40 | 6/06/2013 | 42 | 45 | 55 | 48 | 6/10/2014 | 55 | 50 | 70 | 60 |
| S2 | 1/19/2012 | 1 | 1 | 1 | 1 | 10/10/2012 | 2 | 1 | 2 | 1 | 6/06/2013 | 6 | 12 | 4 | 2 | 6/12/2014 | 25 | 15 | 15 | 30 |
| S3 | 2/2/2012 | 2 | 1 | 4 | 4 | 9/12/2012 | 37 | 30 | 65 | 24 | 6/04/2013 | 67 | 40 | 77 | 60 | 6/12/2014 | 50 | 50 | 65 | 60 |
| S4 | 2/2/2012 | 4 | 3 | 2 | 2 | 9/12/2012 | 55 | 42 | 60 | 72 | 6/04/2013 | 45 | 57 | 42 | 60 | 6/05/2014 | 35 | 45 | 20 | 50 |
| S5 | 2/2/2012 | 1 | 1 | 1 | 1 | 9/12/2012 | 30 | 48 | 38 | 31 | 6/04/2013 | 55 | 42 | 50 | 47 | 6/05/2014 | 35 | 60 | 50 | 45 |
| S6 | 2/2/2012 | 6 | 3 | 1 | 1 | 9/12/2012 | 1 | 1 | 3 | 1 | 6/04/2013 | 1 | 1 | 3 | 1 | 6/10/2014 | 5 | 10 | 5 | 1 |
| S7 | 2/2/2012 | 1 | 0 | 0 | 0 | 10/10/2012 | 20 | 30 | 38 | 30 | 6/04/2013 | 35 | 28 | 38 | 22 | 6/12/2014 | 45 | 35 | 35 | 30 |
| S8 | 2/2/2012 | 0 | 0 | 0 | 0 | 10/10/2012 | 25 | 32 | 28 | 30 | 6/04/2013 | 8 | 4 | 5 | 4 | 6/10/2014 | 15 | 20 | 5 | 10 |
| S9 | 2/2/2012 | 1 | 1 | 1 | 2 | 10/10/2012 | 48 | 60 | 37 | 40 | 6/04/2013 | 55 | 45 | 35 | 37 | 6/10/2014 | 30 | 50 | 35 | 45 |
| S10 | 2/1/2012 | 0 | 0 | 0 | 0 | 10/10/2012 | 10 | 7 | 8 | 4 | 6/04/2013 | 33 | 37 | 39 | 35 | 6/12/2014 | 30 | 35 | 40 | 15 |
| S11 | 2/1/2012 | 1 | 1 | 1 | 1 | 10/10/2012 | 20 | 30 | 38 | 30 | 6/04/2013 | 20 | 35 | 30 | 45 | 6/13/2014 | 50 | 80 | 75 | 85 |
| S12 | 4/25/2012 | 2 | 3 | 3 | 4 | 10/10/2012 | 25 | 32 | 28 | 30 | 6/05/2013 | 15 | 20 | 12 | 25 | 6/13/2014 | 40 | 40 | 40 | 60 |
| S13 | 2/1/2012 | 0 | 1 | 0 | 1 | 10/17/2012 | 2 | 2 | 3 | 4 | 6/05/2013 | 3 | 4 | 3 | 4 | 6/13/2014 | 5 | 5 | 3 | 10 |
| S14 | 2/1/2012 | 0 | 0 | 0 | 0 | 10/17/2012 | 4 | 3 | 3 | 4 | 6/05/2013 | 17 | 11 | 4 | 7 | 6/13/2014 | 30 | 25 | 10 | 30 |
| S15 | 2/1/2012 | 1 | 1 | 0 | 0 | 10/17/2012 | 4 | 5 | 7 | 4 | 6/05/2013 | 4 | 7 | 12 | 8 | 6/13/2014 | 20 | 10 | 20 | 20 |

[a] 2 test sites: H = Hemlock Overlook Regional Park and S = Sully Woodlands.
[b] Circular fence plots were split into quadrants (NE = northeast, NW = northwest, SE = southeast, and SW = southwest) to collect ground cover data.

Surveys at Hemlock Overlook Regional Park found no significant difference in browse from 2012 and 2014 ($W = 0$, $n = 5$ plots, $P > 0.2$). Surveys showed an increase in browse damage at 20% of treatment plots located at both the fence and Plot A, although these results were not significant. Eighty percent of treatment plots showed no change in browse ratings. No plots at Hemlock Overlook Regional Park showed a decrease in browse levels over the study period (Table 19).

Browse levels at Sully Woodlands significantly differed from 2012 and 2014 ($W = 160$, $n = 33$ plots, $P < 0.05$). Overall, 37% of treatment plots showed an increase in browse damage, 8% of treatment plots showed a decrease, and 55% of treatment plots showed no difference in browse levels (Table 19).

Table 19. Deer Browse Impact Survey data collected from 4-Poster stations at Hemlock Overlook Regional Park and Sully Woodlands, 2012-2014.

| | Fence | | | Plot A | | | Plot B | | | Plot C | | | Plot D | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Site[a] | 2012 | 2013 | 2014 | 2012 | 2013 | 2014 | 2012 | 2013 | 2014 | 2012 | 2013 | 2014 | 2012 | 2013 | 2014 |
| H1 | 0 | 1 | 1 | 0 | 1 | 1 | 5 | 5 | 1 | 5 | 5 | 2 | 5 | 5 | 2 |
| H2 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| H3 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| H4 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| H5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| S1 | 2 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 4 | 4 | 5 |
| S2 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 1 |
| S3 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 1 | 4 | 3 |
| S4 | 4 | 5 | 5 | 5 | 5 | 5 | 4 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| S5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 4 | 4 | 5 |
| S6 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 1 |
| S7 | 5 | 3 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 2 | 3 | 5 | 5 | 5 |
| S8 | 5 | 0 | 1 | 5 | 5 | 1 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| S9 | 5 | 4 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| S10 | 4 | 0 | 1 | 0 | 0 | 5 | 1 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| S11 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 0 | 5 | 5 | 5 |
| S12 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| S13 | 0 | 0 | 5 | 0 | 0 | 0 | 5 | 1 | 0 | 4 | 5 | 5 | 2 | 4 | 5 |
| S14 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 3 | 0 | 0 | 0 |
| S15 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 5 | 0 | 0 | 0 | 0 | 0 | 0 |

[a] 2 test sites: H = Hemlock Overlook Regional Park and S = Sully Woodlands.
[b] Browse level estimated inside of the fence plot.
[c] Browse level for Plot A estimated within 1 $m^2$ circular plot at 1 meter from the outside of the fence plot.
[d] Browse level estimated within 1 $m^2$ circular plot 45.5 meters from Plot A.
[e] Browse level estimated within 1 $m^2$ circular plot 45.5 meters from Plot B.
[f] Browse level estimated within 1 $m^2$ circular plot 45.5 meters from Plot C.

### *4-Poster station maintenance and cost*

A total of 107,964 kg (238,020 lbs) of corn was supplied to feeders over the course of the study: 21,482 kg (47,370 lbs) in 2012, 34,636 kg (76,375 lbs) in 2013, 43,785 kg (96,550 lbs) in 2014 and 8,038 kg (17,775 lbs) in 2015.

A total of 90,962 kg (200,537 lbs) of corn was consumed during the study. Consumption rates were 16,890 kg (37,236 lbs), 29,096 kg (64,146 lbs), 38,269 kg (84,369 lbs) and 6,707 kg (14,786 lbs) in 2012, 2013, 2014 and 2015, respectively (Table 20; Figure 12). The difference in total corn supplied and the amount consumed was attributed to some corn becoming molded or clogged in the troughs and subsequently discarded and replaced.

One hundred forty-eight liters of pesticide were used to treat rollers at both test sites since April 2012; 34.5 liters, 47.1 liters, 55.1 liters and 11.1 liters in 2012, 2013, 2014 and 2015, respectively (Table 20).

Table 20. Total corn consumption (kg) and pesticide use (L) across all treatment sites by month from April 2012 - March 2015, excluding the acclimation period at the beginning of the study.

| Month | 2012 | | 2013 | | 2014 | | 2015 | |
|---|---|---|---|---|---|---|---|---|
| | Corn | Pesticide | Corn | Pesticide | Corn | Pesticide | Corn | Pesticide |
| January | | | 1567 | 3.12 | 1984 | 4.129 | 2260 | 5.716 |
| February | | | 1630 | 2.436 | 2921 | 4.222 | 2642 | 2.632 |
| March | | | 2370 | 3.658 | 3091 | 4.778 | 1845 | 2.79 |
| April | 351 | 4.516 | 2007 | 2.986 | 2955 | 3.748 | | |
| May | 1599 | 2.852 | 1161 | 2.56 | 3685 | 5.478 | | |
| June | 2968 | 5.618 | 2845 | 3.57 | 4125 | 6.598 | | |
| July | 3562 | 5.297 | 2841 | 6.265 | 5258 | 4.212 | | |
| August | 3317 | 4.796 | 3138 | 4.788 | 5730 | 9.066 | | |
| September | 980 | 2.2 | 3129 | 5.38 | 3555 | 3.744 | | |
| October | 1252 | 3.158 | 3379 | 4.113 | 980 | 1.574 | | |
| November | 1299 | 3.38 | 2592 | 4.526 | 1225 | 4.144 | | |
| December | 1562 | 2.64 | 3413 | 3.73 | 2760 | 3.428 | | |
| Total | 16,890 | 34.457 | 29,096 | 47.132 | 38,269 | 55.121 | 6,707 | 11.138 |

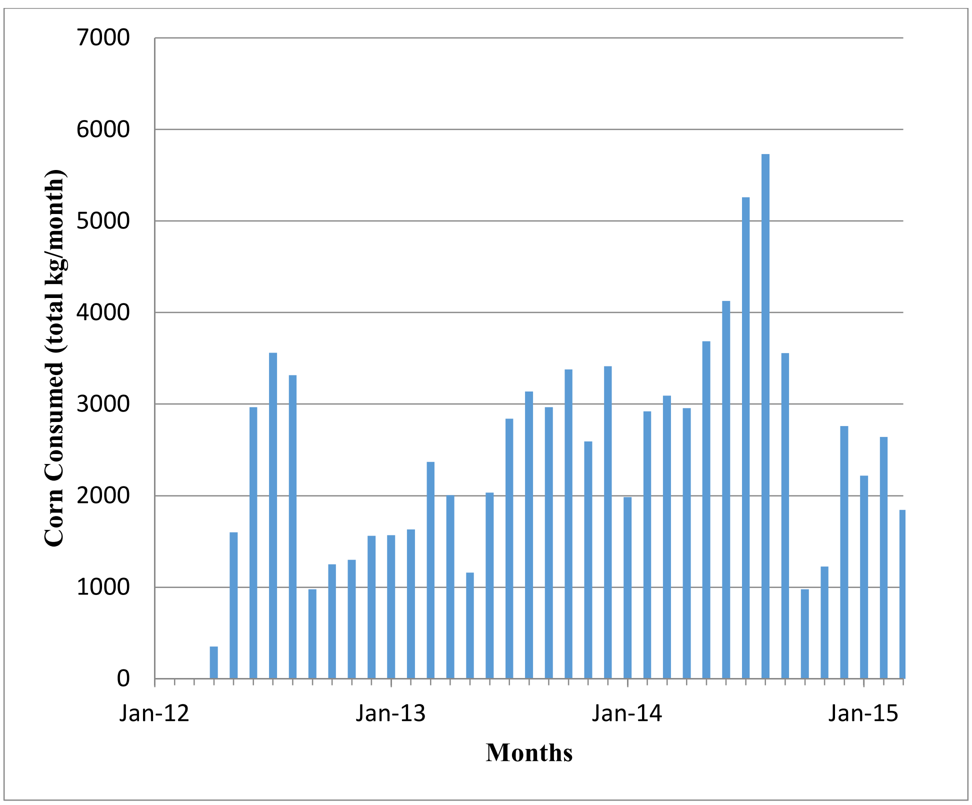



Figure 12. Total corn consumption (kg) across all treatment sites by month, April 2012 - March 2015.

In 2012, FCPD-WS personnel spent approximately 3,202 hours working to implement the Fairfax County 4-Poster pilot study including administrative duties, weekly monitoring of each station, biological data collection, and data analysis. From 1 February 2012 through 29 January 2013, FCPD-WS personnel spent 1,658 hours exclusively monitoring all 4-Poster devices. The average number of hours spent monitoring each 4-Poster device per month was 6.91 hours. The approximate number of hours spent monitoring the 4-Poster devices in 2013 was 1,854 hours. These hours are from the time period of 30 January 2013 until 28 January 2014. The average number of hours spent monitoring each 4-Poster device per month was 7.73 hours. For the calendar year of 2014, approximately 3,291 hours were spent maintaining the 4-Poster study. Total hours for 2014 included training of two part-time and one seasonal employee in the field. The average number of hours spent monitoring each 4-Poster device per month was 7.68 hours.

The cost for the purchase of the 4-Poster treatment stations was $10,000 (20 stations at $500 per station) excluding installation. Initial installation of fencing and aluminum signs cost approximately $3,500. Installation of electric fencing and signs cost an additional $2,700. Costs for maintenance of 4-Poster stations including corn purchases, permethrin, and labor are provided in Table 21. Based on average expenses for 2013 and 2014, the projected annual cost for maintaining twenty, 4-Poster stations after installation is $47,030 (including $16,756 for corn, $2,554 for permethrin, and $27,720 in labor costs for one staff position). Additional costs included periodic replacement of rollers ($38/dozen rollers), posts ($11/each), pesticide applicator guns ($120/each), game cameras for monitoring station use ($150-200/camera), PPE ($125) and supplies to repair damage to stations. Squirrels were found to inflict minor damage to several 4-Posters by chewing along the base of the stations. Galvanized wire mesh was drilled onto the base of the heavily chewed 4-Posters to prevent further damage. Other damage included holes punctured in the corn bin and lid that were sealed. The average cost for laboratory testing and pathology for deer herd health checks, including CWD testing, was $105/deer harvested. Processing of deer for donation to local food banks cost an additional $20/deer through the county's contracted rate.

Table 21. Corn and permethrin supplied to 4-Poster stations and estimated monthly costs for labor and station maintenance.

| Year | Corn Supplied Total lbs | Corn Supplied Total kg | Corn Cost/Yr $[1] | Average Monthly Corn Cost $[1] | Permethrin mL | Permethrin Cost/Yr $[2] | Average Monthly Permethrin Cost $[2] | Labor Cost/Month $[3] |
|---|---|---|---|---|---|---|---|---|
| 2012 | 47,370 | 21,482 | $9,180.31 | $1,020.03 | 34,457 | $1,721.13 | $191.24 | $2,070.00 |
| 2013 | 76,375 | 34,636 | $14,801.48 | $1,233.46 | 47,132 | $2,354.24 | $196.19 | $2,310.00 |
| 2014 | 96,550 | 43,785 | $18,711.39 | $1,559.28 | 55,121 | $2,753.29 | $229.44 | $2,310.00 |
| 2015 | 17,725 | 8,038 | $3,435.11 | $1,145.04 | 11,138 | $556.34 | $185.45 | $1,800.00 |

[1] Based on an average corn cost of $9.69/50lbs
[2] Based on an average permethrin cost of $185.00/gallon
[3] Based on average workload and $15.00/hr payrate for one employee

# DISCUSSION

***Tick control using 4-Poster stations***

Although lone star ticks and blacklegged ticks are opportunistic feeders, the white-tailed deer is an important host for adult blacklegged ticks (Wilson *et al.*, 1990) and all stages of the lone star tick (Childs and Paddock, 2003). Previous 4-Poster studies (Carroll *et al.*, 2002, 2009a; Schulze *et al.*, 2009) indicated a decrease in lone star tick abundance due to 4-Poster treatment. Due to generally low numbers of blacklegged ticks collected, analysis in this study also focused on lone star ticks. More lone star ticks were collected throughout the study and they were also collected more consistently than blacklegged ticks.

Ear examination was used as sampling method to look at ticks on harvested deer since they were consistent and could be removed as a part of the routine necropsy that was being done for the herd health check. With the exception of male gulf coast ticks, the number of ticks found on deer ears did not differ significantly between treatment and control areas. Some individual deer within the treatment area had low tick loads on their ears. However, finding ticks on deer ears from deer taken within the treatment area and the lack of an overall reduction in the number of ticks on deer ears from deer harvested within the treatment area suggest that some deer within the treatment area were not being treated. During deer harvesting activities, the primary targets within the treatment sites were deer that either had pink ears or were seen at the 4-Posters. Within the treatment area, ticks were found on both deer that had pink ears and deer that did not have pink ears. Deer harvested in treatment areas without pink ears (Tables 2-3) could mean deer were present that were not using the feeders or that they were not using the feeders during the time the pink dye was applied to the rollers since the dye was only applied to the rollers for a short period prior to deer harvesting activities. The angle at which the deer approached the feeding troughs and 4-Poster may not have allowed for direct application of the dye to the ears or if deer only approached the feeder from one side, they may have applied dye directly to only one ear. When paired ear samples were processed for ticks, there were samples with pink dye on only one ear. Pink-eared deer with ticks may have only used the 4-posters during a time when the dye, and not the acaricide, was applied or the pesticide may not have reached the ticks. Treatment rollers were also observed out of position off the vertical axis. If the posts were not in proper position, pesticide or dye may not have been applied to deer that were feeding at the stations. Ticks were also found on deer within the treatment area during other deer management activities (i.e., managed hunts at Sully Woodlands) during the study (not shown).

Carbon dioxide-baited tick traps were used to collect ticks from the study sites throughout the entire study (Tables 7, 8). The only difference seen in the numbers of blacklegged ticks on the tick traps between years and within treatment type occurred prior to the deployment of the 4-Posters. During the first pre-treatment year, the number of blacklegged tick nymphs was significantly higher at the treatment sites than it was for the remaining years at the treatment sites. No significant differences were seen for the adult stages in the treatment area or for the adult or nymphal stages within the control area. Although the numbers of blacklegged ticks were low, no significant difference or reduction was seen within the treatment sites after the introduction of the 4-Poster. More variability was seen in the numbers of lone star ticks on tick traps between years within the type of site. No significant changes were seen in the numbers of adult lone star ticks collected within the treatment area after the 4-Posters were deployed, although significantly less were collected at the control sites after the 4-Posters were deployed when compared to the second pre-treatment year. Significantly fewer lone star nymphs were collected at both the treatment and control sites when compared to the second pre-treatment year. The significant reduction in the treatment area was seen by the fifth year of the study, which was the third year of 4-Poster deployment. The significant reduction at the control sites was seen in the third year of the study and remained lower through the fifth year of the study. A significant reduction was seen in the number of lone star larvae within the treatment area during the deployment of the 4-Poster. This reduction was seen between years three and four of the study. A significant reduction was also seen in lone star larvae within the control area, but that was followed by a significant increase in the number of larvae collected the following year. Reductions in the numbers of lone star ticks collected were seen within the treatment areas of the study during the 4-Poster deployment, but reductions in numbers of lone star ticks collected were also seen within the control areas which suggest that other factors were also contributing to the changes in tick abundance during the study (Table 13).

The Henderson-Tilton calculation has been used in other 4-Poster studies to look at the impact of the pesticide application on tick abundance (e.g., Carroll *et al.*, 2002; Grear *et al.*, 2014; Miller *et al.*, 2009; Schulze *et al.*, 2008). These calculations were performed beginning with year two of the study since it was the year prior to 4-poster deployment and pesticide application. The calculations were also performed starting with year one (not shown) and when years one and two were compared, "control" was achieved in the absence of any pesticide treatment. The reduction between those two years was presumably due to natural fluctuations in the tick populations. Variations in tick abundance from year-to-year has been noted for the lone star tick (Davidson *et al.*, 1994) and blacklegged tick (Schulze and Jordan, 1996; Stafford and Magnarelli, 1993). The results of the Henderson-Tilton calculations were inconsistent within the same species and over time, with most results from tick collections showing no control on the target life stages (Table 14). Pound *et al.* (2009) stated that "measurable reductions in free-living nymphal blacklegged and lone star tick densities typically occurred with a lag of 1 or 2 years after device deployments, and maximal control required 4 or more years of treatment." Reductions based on the Henderson-Tilton calculations were not seen or appeared inconsistent in the first three years after the deployment. Although a reduction was seen in the larval lone star tick stages, reduction was not observed in the nymphal or adult stages of the lone star tick. In female blacklegged ticks where results indicated a reduction, similar reductions were not seen in the male or nymphal blacklegged ricks. It is also important to note the low numbers of blacklegged ticks collected in general (Table 8).

The higher levels of acorn mast during Fall 2012 and Fall 2014 (according to DGIF) could have been one of the reasons for the reduction in 4-Poster use as seen by the reduction in corn consumption during this time (Figure 12). Adult blacklegged ticks are most active during the fall, although they are also active during the winter and early spring, and a reduction in the use of the 4-Poster during the fall could make it difficult to control this target species. Variable use of the 4-Posters by deer could have also impacted their ability to reduce the tick abundance in the treatment areas. The presence of the bear for several months during 2012 was unexpected and also affected 4-Poster use by the deer. The removal of corn from several stations in order to deter the bear left several 4-Posters offline for a period of time. Many stations were offline until electric exclusion fencing could be put into place. After the fencing modifications were completed in April 2013, corn consumption remained low at those stations until the fencing was removed. The 4-Posters that were closest to the tick trapping site were not visited by bears and the exclusion fencing was not used at those sites.

Although tick collection methods were different in previous studies (flagging or dragging) and the current study (carbon dioxide-baited tick traps), the trapping methods used in this study were consistent throughout the project and the traps were able to pick up changes in host-seeking activity across sites (e.g., increased lone star activity at the end of pre-treatment year two after a milder winter). Daily temperature data were collected at the beginning of each month from two National Weather Service Stations (Reagan National Airport, Dulles International Airport) at opposite sides of the county (National Weather Service, 2010-2015). Average monthly temperatures (average of Dulles and National temps) in year two were mostly warmer than the 5-year study average, especially in winter or latter part of year two (not shown). This was also a time when earlier activity in the lone star ticks was detected (Figures 4-6) which may help explain why year two mean ranks for nymphal and adult stages of this tick were different than most other years.

Blacklegged tick larvae were not included in data analysis for the traps due to no pre-treatment collections of this stage; however, their presence at both treatment and control sites (not shown) during all three treatment years is worth noting.

***Deer density and environmental impacts***

From 2012-2014, deer density estimates at Hemlock Overlook Regional Park and Sully Woodlands increased over 1.6 times since the initial population surveys were conducted. A density of ≤ 20 deer per square mile is recommended to maintain diverse and healthy forested ecosystems (Tilghman, 1989; Anderson, 1994; DeCalesta, 1994; Healy, 1997). Results of these camera surveys indicated local deer population densities over 15 times the recommended density at Hemlock Overlook Regional Park and over 8 times the recommended density at Sully Woodlands for a healthy, sustainable deer population without cascading damage to the environment. An increase in the number of deer at treatment sites is likely a combination of the high reproductive potential of white-tailed deer coupled with potential immigration into the area by deer attracted to bait over time. At Sully Woodlands, public managed hunts and an archery program were conducted as part of the Fairfax County Deer Management Program but there remains a large deer population at the park. At Hemlock Overlook Regional Park, hunting was prohibited during the study and no legal lethal deer management activity occurred beyond the sharpshooting operations conducted to collect biological data for the pilot study. Poaching has been reported at both test sites, although the prevalence of illicit deer hunting activity or its impact on the local deer population is unknown. Archery was also used for deer management at Laurel Hill Golf Course during the study period; however, deer density data were not collected at this site.

Potential damage to native plants and plant communities in close proximity to 4-Posters over the course of the pilot study was a significant concern. Year-round baiting of deer at test sites may attract more deer to the area than can be sustained without causing damage to that habitat (Dunkley and Cattet, 2003; Lewis and Rongstad, 1998; Kilpatrick and Stober, 2002; McBryde, 1995; Porter *et al.*, 1991). Vegetation sampling was conducted to provide a baseline assessment of plant health and identify potential impacts to habitat associated with operation of the 4-Poster treatment stations. Browse damage is generally correlated with deer population density as a function of how much vegetation the population requires to survive (i.e. higher density deer population correlate to greater browse damage).

In this study, field surveys indicated a history of heavy to severe browse across study sites with lack of native plant regeneration in most areas, indicative of a high deer population. At Hemlock Overlook Regional Park, there was no difference in the level of browse damage detected during the study; however, 80% of survey plots had already sustained severe browse damage prior to the beginning of the study. This level of damage remained consistent over study years with little to no recovery of native vegetation and was attributed to consistent foraging by deer attracted to 4-Poster stations.

Browse levels at Sully Woodlands differed significantly over study years with variable results depending on survey plot. At Sully Woodlands, 48% of survey plots had sustained heavy to severe browse damage prior to implementation of the 4-Poster stations. Of these plots, only 8% (4 plots) showed a decrease in browse damage throughout the study. These plots were concentrated inside the fence plot or within 1 m from the fence plot. While these individual plots showed some measure of vegetative recovery during the study, additional plots at greater distances from the fence showed either an increase in damage to severe levels or no change in browse damage for plots that were already severely impacted prior to the study. Thirty-one percent of survey plots at Sully Woodlands showed no browse damage at the beginning of the study. These plots were located in a field setting with minimal woody vegetation compared to forested plots. Eighty-seven percent of these plots showed an increase in browse damage to at least light browse levels by the end of the study.

Treatment locations also saw a significant increase in damage to ground cover and soil exposure associated with 4-Poster station use by deer. Mean percent coverage of bare ground increased by 70% at Hemlock Overlook Regional Park and 32% at Sully Woodlands from 2012-2014. This increase is primarily attributed to deer travelling to and from the 4-Posters to consume corn, sufficient to expose and impact the soil. Impacts to soil and ground vegetative cover are of concern due to potential for soil erosion, damage to native regenerating seedlings and saplings, and spread of non-native invasive species.

***Supplemental feeding of deer***

For the 4-Poster stations to be effective, it was essential to provide a consistent supply of supplemental corn to increase reliable application of the acaricide while the 4-Posters were deployed during the pilot study (Carroll *et al.*, 2009a; Carroll *et al.*, 2009b). The rate of corn consumption has been found to vary considerably within and between years (Schulze *et al.* 2009). Deer rely on supplementary food sources in the presence of increased competition if native food is scarce, high-density deer herds are present, and/or minimal hunting pressures exist (Dunkley and Cattet, 2003; Grenier *et al.*, 1999; Kilpatrick and Stober, 2002; Schmitz, 1990). Other factors include availability of hard mast, such as white oak acorns (*Quercus alba*), which are a heavily browsed food source for deer.

In this study, deer quickly became acclimated to the 4-Posters and showed variable consumption of corn through each study year. In both 2012 and 2014, corn consumption peaked during summer months (June – August) and declined during fall and winter. In 2013, high corn consumption rates were noted from August-October and again in December. These seasonal differences and annual variation in corn consumption were likely related to productivity of the annual acorn crop. According to the DGIF, acorn mast in 2012 and 2014 was high. Availability of acorns as an alternative, preferred food source might account for the change in corn consumption rates as deer sought out available hard mast during fall and winter. Conversely, acorn production in 2013 was at its lowest levels since 2008. This decrease in availability of natural forage during the fall and winter may account for the increased consumption of corn as deer sought out supplemental food during this time period. Bear activity at Sully Woodlands may also have contributed to lower corn consumption by deer at some treatment stations in 2012 and 2013 when corn was temporarily removed or electric fences were in use.

### ***Wildlife disease concerns***

Year-round feeding of deer during this study was conducted with caution due to risk of increased disease transmission associated with the supplemental feeding of wildlife (Joly *et al.*, 2003; Miller and Kaneene, 2006; Van Deelen, 2003). In Virginia, deer populations are at risk for a range of wildlife diseases and parasites including bovine paratuberculosis, CWD, hemorrhagic diseases, Johne's disease, meningeal worms, and internal and external parasites such as ticks, mites and lice.

In our study, the most frequently diagnosed conditions included verminous pneumonia, entercolitis, multiple organ inflammation and variable internal parasites. Verminous pneumonia is common in white-tailed deer and is consistent with lungworm. Enterocolitis indicates inflammation of the gastrointestinal tract which is not uncommon considering the parasite loads carried by deer (M. Kirchgessner, DGIF, personal communication). Organ inflammation did not appear severe enough to be clinically significant. The specific cause of inflammation was not determined through additional testing but suggested a contribution by parasites or an immune-mediated response.

Although none of the deer tested in our study were found to be positive for CWD there are serious concerns regarding the potential spread of CWD in Virginia. CWD is a slow, progressive and fatal neurological disease of deer, elk, and moose. CWD is transmitted within a high-density population by direct and indirect contact between deer. CWD has a dormancy period before symptoms are first exhibited. A disease outbreak can decimate a local deer population. Abnormally shaped proteins (prions) are shed in the saliva, fecal matter and urine of infected deer. These prions can remain in certain soils over prolonged periods of time (Gross and Miller, 2001; Van Deelen, 2003; Weismann *et al.*, 2002). Ten confirmed cases of CWD-positive deer have been documented in VA since 2009, including three new cases of CWD detected during the 2014 hunting season.

A primary objective of DGIF is to prevent the spread of CWD into new areas in Virginia. A CWD response plan developed by DGIF outlines the concerns associated with disease transmission in the deer population in the Commonwealth (DGIF, 2009). In response to the three new cases of CWD detected in 2014, including the first CWD-positive deer documented in Shenandoah County, VA, DGIF expanded a CWD Containment Area to include Frederick, Clarke, Shenandoah, and Warren counties, effective in fall 2015. As a part of the response plan, it is illegal to feed deer from September 1 through the first Saturday in January of each year or through any designated hunting season. In Fairfax County, this prohibition on feeding deer extends from September through April due to the liberal hunting season approved for the county in efforts to reduce the overabundant deer population. A special permit would be required from DGIF to allow for supplemental feeding of deer if 4-Poster stations were implemented in Fairfax County. While necropsies and histological examinations of harvested deer did not detect CWD in this study, the ability of feeding stations to congregate animals that may allow for rapid disease spread if an infected deer were present remains a paramount concern.

### ***Non-target wildlife***

Wildlife other than deer can also be attracted to the corn dispensed into the troughs of each 4-Poster (Hoen *et al.*, 2009; Pound *et al.*, 2000a). The same concerns exist in terms of potential for disease transmission for non-target wildlife that are attracted to 4-Poster feeding stations as with deer. Concentration of animals over a short period of time can spread disease within that population more readily than would occur in a natural environment. During this study, several non-target wildlife species were observed inside the circular fence plots surrounding each 4-Poster including black bear (*Ursus americanus*), red fox (*Vulpes vulpes*), groundhog (*Marmota monax*), raccoon (*Procyon lotor*), gray squirrel (*Sciurus carolinensis*), Virginia opossum (*Didelphis virginiana*), Canada goose (*Branta canadensis*), and turkey vulture (*Cathartes aura*). A primary concern with providing supplemental food to wildlife in Fairfax County is the frequent visitation of rabies vector species, primarily raccoons and foxes, to 4-Poster stations. Additional public health concerns may arise due to accumulation of feces at feeding stations with potential for spread of wildlife zoonotic infections to humans and domestic animals, such as the intestinal roundworm, *Baylisascaris procyonis*, commonly found in raccoons. Special consideration must also be taken in areas where black bears are active. In Virginia, it is illegal to feed bears on both public and private lands, whether deliberate or inadvertent. These regulations have been enacted to reduce habituation of bears to people and minimize conflicts associated with nuisance bears, which can result in safety concerns and serious property damage for landowners and potentially loss of life for the animal.

***Station placement and operation***

Label restrictions for the application of permethrin limit the availability of suitable 4-Poster station locations making them impractical for use in large-scale developed areas and many public parks in Fairfax County. Permethrin is highly toxic to fish and is prohibited from being applied directly to water or within 100 feet of streams, rivers or lakes. Water can be contaminated if disposal of equipment and equipment “washwaters” is not done properly. In addition to restrictions near water bodies, label restrictions prohibit use of 4-Poster stations with permethrin within 100 yards of any residence, playground, or other area where children may be present without supervision. Additional restrictions were required by DGIF prohibiting placement of stations within 100 yards of public roads. Pesticide applicator licenses would need to be acquired by VDACS for personnel to operate 4-Poster stations in Virginia. Stations are labor-intensive and require frequent service (at least once a week per station).

***Project implementation***

Although efforts were made to ensure quality study design, issues that arose during project implementation and during the project itself may have impacted the study. Treatment site selection was based primarily on finding sites that had high recorded and/or observed deer populations, were large enough to accommodate a large number of 4-Posters sites that could comply with the label requirements, and their conduciveness to safely harvest deer. Once the areas had been pre-identified for 4-Poster use by the Wildlife Biologist office, tick surveillance sites were established in 2010. The 4-posters were originally supposed to be split equally among the treatment sites (10 4-Posters at each site). However, when the site selection for the 4-posters began within each treatment area in the months leading up to deployment of the feeding stations, it was realized that the Hemlock Overlook Regional Park site would not be able to accommodate the planned number of 4-Posters and the number of feeding stations was reduced to five stations. The balance of the 4-Posters were then added to the Sully Woodlands treatment area. The original Sully Woodlands study area was intended to be the Richard Jones Property. However, with the addition of more 4-Posters that area needed to be expanded. After initial site selection was completed, several 4-Posters were re-located within the Sully Woodlands area at the beginning of the study in order to comply with the label and DGIF requirements. The tick collection sites in the areas identified as control sites had been previously used as tick collection sites. However, control and treatment sites varied in terms of size, habitats, and land use making it difficult to directly compare among sites. Within the treatment areas, the tick trap collection sites were located at variable distances from the 4-Posters, but they were located within the average home range of deer. At Hemlock Overlook, the closest 4-Poster sites were located approximately 275 and 358 meters from the tick collection site. At Sully Woodlands, the closest 4-Poster sites were located approximately 675 and 1,135 meters from the tick collection site. Deer density was only estimated at 4-Poster test sites and not the control sites; therefore, it is unclear whether the increase in deer density at treatment sites over study years was indicative of supplemental feeding or other causes. Bear activity and subsequent project design modifications likely impacted 4-Poster use by deer at Sully Woodlands; however, the bear did not visit the stations at the Richard Jones Property which were closest to the routine tick sampling site. Similarly, environmental surveys for browse damage and bare soil were also only completed on 4-Poster test sites and not the control sites. Other deer management activities (managed hunts and archery) continued at the Sully Woodlands site during the study period. The impact of these deer management activities on the use of the 4-Posters by deer was not analyzed, but could have had an impact on the ability of its use as a management tool.

# MANAGEMENT IMPLICATIONS

Based on this study's results, implementation of 4-Poster stations in Fairfax County is not recommended. The 4-Poster deer treatment station may have helped reduce tick loads on individual deer within the treatment area, but the impact on the tick population as a whole is not clear. The results of the Henderson-Tilton calculations performed on tick trap data were highly variable and inconsistent within each species and stage. In most instances, the results of the calculation did not show a reduction in the treatment areas versus the control areas. While the 4-Poster has been used to help reduce tick abundance in some studies, the impact in this study appears to be minimal. Possible, but incomplete, explanations for this minimal observed impact when compared to other studies may include the openness of the study area, length of the study, density of 4-Posters, and various project implementation issues.

In addition to the limited efficacy for tick control, year-round operation of 4-Poster stations resulted in negative environmental effects including sustained high levels of deer browse, damage to ground cover and increased soil exposure as the result of deer activity at feeding stations.

Selecting sites that maintain the integrity of the 4-Poster and still meet the label and DGIF requirements (e.g., distance from aquatic resources, distance from roads, distance to houses, areas in close proximity to unsupervised children) would be difficult. Other landscape/terrain issues that were encountered with site selection in the pilot study could also make it difficult to identify suitable sites.

The potential for disease spread at feeding stations is a serious concern for deer and non-target wildlife. Implementation of 4-Poster stations would directly conflict with current laws that prohibit feeding of deer in the Commonwealth and would require approval by DGIF and consistent monitoring of health effects on deer. Given the close proximity of the CWD Containment area to Fairfax County and the high-density herds present within the county, it is not advisable to implement a method that would require year-round supplemental feeding of deer and increase potential for spread of the disease through either direct contact or environmental contamination at the feeding site. Supplemental feeding also has potential to alter species ecology and increase potential for disease transmission among non-target wildlife, including rabies vector species such as raccoons and foxes, that were frequently documented at 4-Poster stations.

Feeding of deer conflicts with current management objectives for deer population reduction in Fairfax County. The deer population in Fairfax County is already well-above desired population objectives. Fairfax County has invested heavy resources to implement the Deer Management Program on public lands to address safety, health and environmental concerns related to overabundant deer. It would be counter-productive to current deer control efforts to introduce practices that may encourage population growth in local deer herds through provision of an ample, year-round food source. A special permit would be required from DGIF to authorize supplemental feeding during most of the year. Since many parks in the county are being utilized for other deer management activities, it is highly unlikely that 4-Poster stations could be operated in parks where archery or managed hunts are conducted. If 4-Poster station use was restricted during the hunting season, which currently extends from September through April in Fairfax County, station operation would not be optimal as this time period coincides with peak activity for adult blacklegged ticks.

# LITERATURE CITED


Abbott, W.S. 1925. A method for computing the effectiveness of an insecticide. *Journal of Economic Entomology* 18: 265-267.

Abu-Qare, A. W. and Abou-Donia, M. B. 2001. Combined exposure to DEET (N, N-diethyl m-toluidamide) and permethrin induced the release of rat brain cytochrome c. *Journal of Toxicology and Environmental Health* Part a 63: 243–52.

Agency for Toxic Substance and Disease Registry. 2001. Toxicological profile for pyrethrins and pyrethroids, Atlanta: US Department of Health and Human Services, ATSDR. http://www.atsdr.cdc.gov/

Agency for Toxic Substance and Disease Registry. 2005. Toxicological information about insecticides used for eradicating mosquitoes (West Nile virus control). www.atsdr.cdc.gov/

Anderson, R.C. 1994. Height of white-flowered trillium (*Trillium crandiflorum*) as an index of deer browsing intensity. *Ecological Applications* 4:104-109.

Brei, B., Brownstein, J. S., George, J. E., Pound, J. M., Miller, J.A. 2009. Evaluation of the United States Department of Agriculture northeast area wide tick control project by meta-analysis. *Vector-Borne and Zoonotic Diseases* 9 (4): 423–430.

Carroll, J.F. 2003. Survival of larvae and nymphs of *Ixodes scapularis* (Acari: Ixodidae) in four habitats in Maryland. *Proceedings of the Entomological Society of Washington* 105: 120–126.

Carroll, J. F., Allen, P. C., Hill, D. E., Pound, M. J., Miller, J. A and George, J. E. 2002. Control of *Ixodes scapularis* and *Amblyomma americanum* through use of the '4-poster' treatment device on deer in Maryland. *Experimental and Applied Acarology* 28: 289–296.

Carroll, J. F., Pound, M. J., Miller, J. A., Kramer, M. 2009a. Sustained control of Gibson Island, Maryland, populations of *Ixodes scapularis* and *Amblyomma americanum* (Acari: Ixodidae) by community-administered 4-poster deer self-treatment bait stations. *Vector-Borne and Zoonotic Diseases* 9(4): 417–421.

Carroll, J. F., Hill, D. E., Allen, P. C., Young, K. W., Miramontes, E., Kramer, M., Pound, M. J., Miller, J. A., and George, J. E. 2009b.The impact of 4-poster deer self-treatment devices at three locations in Maryland. *Vector-Borne and Zoonotic Diseases* 9(4): 407–416.

Childs, J. E. 2009. Low tech versus high tech approaches for vector-borne disease control. Vector *-Borne and Zoonotic Diseases* 9 (4): 355–356.

Childs, J.E. and Paddock, C.D. 2003. The ascendancy of *Amblyomma americanum* as a vector of pathogens affecting humans in the United States. *Annual Review of Entomology* 48:307-337.

Daniels, T. J.; Falco, R. C.; Mchugh, E. E.; Vellozzi, J.; Boccia, T.; Denicola, A. J.; Pound, J. M.; Miller, A. J.; George, J. E. and Fish, D. 2009. Acaricidal treatment of white-tailed deer to control *Ixodes scapularis* (Acari: Ixodidae) in a New York Lyme disease-endemic community. *Vector-Borne and Zoonotic Diseases* 9 (4): 381–387.

Davidson, W.R., Siefken, D.A., and Creekmore, L.H. 1994. Seasonal and annual abundance of *Amblyomma americanum* (Acari: Ixodidae) in Central Georgia. *Journal of Medical Entomology* 31(1):67-71.

DeCalesta, David S. 1994. Effect of white-tailed deer on songbirds within managed forests in Pennsylvania. *Journal of Wildlife Management* 58(4):711-718.

Dunkley, L. and Cattet, M. R. L. 2003. A comprehensive review of the ecological and human social effects of artificial feeding and baiting of wildlife. Canada Cooperative Wildlife Health Centre, Department of Veterinary Pathology, University of Saskatchewan, Canada.

Fish, D. 2008. Why we do not understand the ecological connections between the environment and human health: The case for vector-borne disease. *In*: *Vector-borne diseases: Understanding the environmental, human health, and ecological connections.* Institute of Medicine, Washington, D.C. The National Academies Press: 65–69.

Fish, D. and Childs, J. E. 2009. Community-based prevention of Lyme disease and other tick-borne diseases through topical application of acaricide to white-tailed deer: background and rationale. *Vector-Borne and Zoonotic Diseases* 9(4): 357–364.

Grear, J.S., Koethe, R., Hoskins, B., Hillger, R., Dapsis, L., and Pongsiri, M. 2014. The effectiveness of permethrin-treated deer stations for control of the Lyme disease vector *Ixodes scapularis* on Cape Cod and the islands: a five-year experiment. *Parasites and Vectors*. 7: 292.

Grenier, D, Barrette, C. and Crete, M. 1999. Food access by white-tailed deer (*Odocoileus virginianus*) at winter feeding sites in eastern Quebec. *Applied Animal Behavior Science* 63: 323–337.

Gross, J. E. and Miller, M. W. 2001. Chronic wasting disease in mule deer: Disease dynamics and control. *Journal of Wildlife Management* 65: 205–215.

Healy, William M. 1997. Influence of deer on the development of forest structure and composition in Central Massachusetts, *in* McShea, w., H.B. Underwood, and John H. Rappole, eds. The Science of Overabundance: The Ecology of Unmanaged Deer Populations. Smithsonian Institution Press.

Henderson, C.F. and Tilton, E. W. 1955. Tests with acaricides against the brown wheat mite. *Journal of Economic Entomology* 48:157-161.

Hoen A. G., Rollend, L. G., Papero, M. A. 2009. Effects of tick control by acaricide self-treatment of white-tailed deer on host-seeking tick infection prevalence and entomologic risk for *Ixodes scapularis*-borne pathogens. *Vector-Borne and Zoonotic Diseases* 9 (4):431–438.

Jacobson, H. A., J. C. Kroll, R. W. Browning, B. H. Koerth, and M. H. Conway. 1997. Infrared-triggered cameras for censusing white-tailed deer. *Wildlife Society Bulletin* 25:547–556.

Joly, D. O., Ribic, C. A., Langenberg, J. A., Beheler, K., Batha, C. A., Dhuey, B. J., Rolley, R. E., Bartelt, G., Van Deelen, T. R. and Samuel, M. D. 2003. Chronic wasting disease in free-ranging Wisconsin white-tailed deer. *Emerging Infectious Diseases* 5: 599–601.

Kilpatrick, H. J. and Stober, W. A. 2002. Effects of temporary bait sites on movements of suburban white-tail deer. *Wildlife Society Bulletin* 30: 760–766.

Lewis, T. L. and Rongstad, O. J. 1998. Effects of supplemental feeding on white-tailed deer, *Odocoileus virginianus*, migration and survival in northern Wisconsin. *Canada Field Naturalist* 112: 75–81.

McBryde, G. L. 1995. Economics of supplemental feeding and food plots for white-tailed deer. *Wildlife Society Bulletin* 23: 497–501.

Miller, N. J., Thomas, W. A., and Mather, T. N. 2009. Evaluating a deer-targeted acaricide applicator for area-wide suppression of blacklegged ticks, *Ixodes scapularis* (Acari: Ixodidae), in Rhode Island. *Vector-Borne and Zoonotic Diseases* 9(4): 401–406.

Miller, R. and Kaneene, J. B. 2006. Evaluation of historical factors influencing the occurrence and distribution of *Mycobacterium bovis* infection among wildlife in Michigan. *American Journal of Veterinary Research* 67 (4): 604 –615.

National Weather Service. 2010-2015. Preliminary Monthly Data. Accessed monthly from http://w2.weather.gov/climate/?wfo=lwx.

Piesman, J. and Eisen, L. 2008. Prevention of tick-borne diseases. *Annual Review of Entomology* 53: 323–343.

Porter, W. F.; Matthews, N. E.; Underwood, H. B.; Sage, R. W. and Behrend, D. F. 1991. Social organization in deer: Implications for localized management. *Environmental Management* 15: 809–814.

Pound, J. M., Miller, J. A. and George, J. E. 2000a. Efficacy of amitraz applied to white-tailed deer by the '4-poster' topical treatment device in controlling free-living lone star ticks (Acari:Ixodidae). *Journal of Medical Entomology* 37: 878–884.

Pound, J. M., Miller, J. A., George, J. E. and LeMeilleur, C. A. 2000b. The '4-poster' passive topical treatment device to apply acaricide for controlling ticks (Acari: Ixodidae) feeding on white-tailed deer. *Journal of Medical Entomology* 37: 588–594.

Pound, J. M., Miller, J. A., George, J. E., Fish, D., Carroll, J. F., Schulze, T. L., Daniels, T. J., Falco, R. C., Stafford III, K. C., and Mather, T. N. 2009. The USDA Northeast area-wide tick control project – Summary and conclusions. *Vector-Borne and Zoonotic Diseases* 9(4): 355–356.

Schmitz, O. J. 1990. Management implications of foraging theory: Evaluating deer supplemental feeding. *Journal of Wildlife Management* 54: 522–532.

Schulze, T.L. and Jordan, R.A. 1996. Seasonal and long-term variations in abundance of adult *Ixodes scapularis* (Acari: Ixodidae) in different coastal plain habitats of New Jersey. *Journal of Medical Entomology* 33(6):963-970.

Schulze, L., Jordan, R.A., Dolan, M.C., Dietrich, G., Healy, S.P., and Piesman, J. 2008. Ability of 4-Poster passive topical treatment devices for deer to sustain low population levels of *Ixodes scapularis* (Acari: Ixodidae) after integrated tick management in a residential landscape. *Journal of Medical Entomology* 45(5):899-904.

Schulze, T. L., Jordan, R. A., Hung, R. W. and Schulze, C. J. 2009. Effectiveness of the 4-Poster passive topical treatment device in the control of *Ixodes scapularis* and *Amblyomma americanum* (Acari: Ixodidae) in New Jersey. *Vector-Borne and Zoonotic Diseases* 9(4): 389–400.

Solberg, V. B.; Miller, J. A.; Hadfield, T.; Burge, T.; Schech, J. M.; and Pound, J. M. 2003. Control of *Ixodes scapularis* (Acari: Ixodidae) with topical self-application of permethrin by white-tailed deer inhabiting NASA, Beltsville, Maryland. *Journal of Vector Ecology* 28: 117–134.

Stafford, K.C. and Magnarelli, L.A. 1993. Spatial and temporal patterns of *Ixodes scapularis* (Acari: Ixodidae) in Southeastern Connecticut. *Journal of Medical Entomology* 30(4):762-771.

Stafford III, K. C., Denicola, A. J., Pound, J. M., Miller, A., and George, J. E. 2009. Topical treatment of white-tailed deer with an acaricide for the control of *Ixodes scapularis* (Acari: Ixodidae) in a Connecticut Lyme Borreliosis hyper-endemic community. *Vector-Borne and Zoonotic Diseases* 9(4): 371–379.

Tilghman, N.G. 1989. Impacts of white-tailed deer on forest regeneration in northwestern Pennsylvania. *Journal of Wildlife Management* 53(3):524-532.

United States Environmental Protection Agency. 2006. Permethrin facts (Reregistration eligibility decision (RED) fact sheet). www.epa.gov/pesticides/reregistration/REDs.

Van Deelen, T.R. 2003.Chronic wasting disease and the science in support of the ban on baiting and feeding deer. www.cwd-info.org/pdf/ FeedingDeer.pdf

Van Deelen, T. R. Wilson, M. L., Telford III, S. R., Piesman, J. and Spielman, A. 1988. Reduced abundance of *Ixodes dammini* (Acari: Ixodidae) following elimination of deer. *Journal of Medical Entomology* 25: 224–228.

Virginia Department of Game and Inland Fisheries. 2009. Surveillance and management plan for Chronic Wasting Disease 2009-2010. http://www.dgif.virginia.gov/wildlife/diseases/cwd/ cwd-surveillance-and-management-plan.pdf.

Weissmann, C.; Enari, M.; Klohn, P. C.; Rossi, D. and Flechsig, S. 2002. Transmission of prions. *Proceedings of the National Academy of Sciences* 99: 16378–16383.

Wilson, M.L., Litwin, T.S., Gavin, T.A, Capkanis, M.C., Maclean, D.C., and Spielman, A. 1990. Host-dependent differences in feeding and reproduction of *Ixodes dammini* (Acari: Ixodidae). *Journal of Medical Entomology* 27(6):945-954.

# APPENDIX A

## Scientific Collection Permits

# *Virginia Department of Game and Inland Fisheries*

**4010 West Broad Street, P.O. Box 11104, Richmond, VA 23230-1104**
**(804) 367-1000 (V/TDD)**
*Under Authority of § 29.1-412, § 29.1-417, & § 29.1-418 of the Code of Virginia*

## Scientific Collection Permit

Permit Type: **Renewal** Fee Paid: **$40.00** VADGIF Permit No. **050260**

Permittee: **Victoria G Monroe**
Address: **Fairfax Co. Police Dept./Animal Services Division**
**4500 West Ox Road**
**Fairfax, VA 22030**

Office: **(703) 324-0240**
City/County:

**Control Tick Infestation on White-Tailed Deer in Fairfax County**

**Authorized Collection Methods: By Hand/Sharpshooting/Nocturnal (i.e. shining w/high-power spot light)/Visual Encounter (turning over rocks/logs)**
**Authorized Waterbodies: N/A**

Authorized Counties / Cities:
**Fairfax**

**SEE ATTACHED PAGE FOR SPECIAL CONDITIONS**

**Permittee MUST notify VDGIF a minimum of 4 days prior to any sampling activity (per the standard conditions which accompany this permit). Notification must be made via email to: collectionpermits@dgif.virginia.gov**

**Report Due: 31 January 2015, 31 January 2016**

**ALL PERMIT REPORTS MUST CONTAIN COORDINATES; PERMITTEE CAN USE THE VIRGINIA FISH AND WILDLIFE INFORMATION SERVICE (VAFWIS) TO OBTAIN COORDINATES BY VISITING: HTTPS://FWISWEB1.DGIF.VIRGINIA.GOV/FWIS/INDEX.HTML**

**STANDARD CONDITIONS ATTACHED APPLY TO THIS PERMIT.**

Authorized Species:

| Description | ID Number | Scientific Name |
|---|---|---|
| White-tailed Deer | | *Odocoileus virginianus* |

Annual Report Due End of Each Year

Authorized Sub-Permittees:

**Dr. Jorge R Arias, Fairfax County Health Department**

**Joshua D Smith, Fairfax County Health Department**

**Jeremy Everitts, Fairfax County Police Dept./Animal Services Division**

**Christina Banker, Fairfax County Police Dept./Animal Services Division**

**Approved by:**

Applicants may appeal permit decisions within 60 days of issuance. The appeal must be in writing to the Director, Department of Game and Inland Fisheries.

**Title:** **James E. Husband - Permits Manager** **Date:** **1/13/2014**

*Virginia Department of Game and Inland Fisheries*

**4010 West Broad Street, P.O. Box 11104, Richmond, VA 23230-1104**

**(804) 367-1000 (V/TDD)**

*Under Authority of § 29.1-412, § 29.1-417, & § 29.1-418 of the Code of Virginia*

## Scientific Collection Permit

Permit Type: **Renewal** Fee Paid: **$40.00** VADGIF Permit No. **050260**

**20** Permit Effective **1/13/2014** through **12/31/2015** **15**

*Virginia Department of Game and Inland Fisheries*
**4010 West Broad Street, P.O. Box 11104, Richmond, VA 23230-1104**
**(804) 367-1000 (V/TDD) FAX (804) 367- 9147**

*Under Authority of § 29.1-412, § 29.1-417, & § 29.1-568 of the Code of Virginia and Policy E-1-90*

Special Conditions SCSV Permit # 50260

# Permit Conditions for 4-poster devices

- All activities conducted under this permit must follow all applicable federal, state, and local laws
- 4-poster devices shall not be placed at a density greater than 1 device per 50 acres
  - individual landowners with less than 50 acres may develop a cooperative agreement with their neighbors to satisfy this condition
  - cooperative agreements among neighbors shall be in writing
- Label restrictions must be followed:
  - No feeder may be placed within 100 yards of any residence, playground, or place where children might be present without adult supervision.
  - Cautionary signs must be posted 100-200 yards around feeder location
- Feeder must be 100 yards away from a public road or waterway
- Use of individual 4-poster devices must cease when the feeding of any wildlife at the device results in property damage, endangers any person or wildlife, or creates a public health concern.
- The public should be notified of device use and precautions for hunters and others coming into contact with deer carcasses should be noted to minimize pesticide exposure when handling treated carcasses (i.e., rubber gloves)
- The number and GPS coordinates for each devices should be recorded
- The amount of pesticide and corn used with each device should be recorded
- The number of hours necessary to maintain each device (charging rollers, filling with corn, repairs, etc) should be recorded
- Remote trail cameras should be placed at each device location to monitor species use of the devices
- Research sites and records should be available for inspection by DGIF at any time

# *Virginia Department of Game and Inland Fisheries*

**4010 West Broad Street, P.O. Box 11104, Richmond, VA 23230-1104**
**(804) 367-1000 (V/TDD) FAX (804) 367-9147**


Under Authority of § 29.1-412, § 29.1-417, & § 29.1-418 of the Code of Virginia

## Scientific Collection Permit -- Standard Conditions

**• This permit, or a copy, must be carried by the above named individuals during collection activities.**

**• The permittee is required to submit to this Department a report of all specimens collected under this permit by the report due date. Report form may be found at http://www.dgif.virginia.gov/permits/guide.asp. FAILURE TO RETURN THIS REPORT WILL RESULT IN NON-ISSUANCE OF FUTURE PERMITS. If no activity occurs under this permit, an email should be sent to collectionpermits@dgif.virginia.gov containing the following statement: No activity occurred under Permit #insert permitID during insert year (i.e. 2006). Permit reports are due by January 31.**

• Permittee MUST notify VDGIF within the seven (7) day period prior to EACH sampling event. Notification must be made via email to: collectionpermits@dgif.virginia.gov.)

• This permit does not support any activities outside of those associated with the application and proposal submitted to and approved by DGIF.

• No species currently listed by the U.S. Fish and Wildlife Service or the Virginia Department of Game and Inland Fisheries as threatened or endangered may be intentionally collected under this permit. If incidental *death or injury* of threatened or endangered species does occur, the permittee is required to notify this Department at collectionpermits@dgif.virginia.gov within twenty-four (24) hours of occurrence. The following information must be reported: collector, date, species, location (county, quad, waterbody, and latitude and longitude to nearest second), and number collected.

• If incidental *observation or collection and live release* of threatened or endangered species occurs, the permittee is required to notify this Department at collectionpermits@dgif.virginia.gov within seven (7) days, providing the same information as the above condition.

• If incidental *mortality or injury of specimens intended to be taken live* occurs, the permittee is required to notify this Department at collectionpermits@dgif.virginia.gov within 48 hours, providing the same information as the above conditions. In addition, the permittee must provide the cause of mortality or injury and steps that are being taken to address the problem.

▪No species may be retained unless specifically authorized by this permit.

• Game birds/game mammals/game fish protected by State and/or Federal laws must be taken during authorized hunting and trapping seasons and under applicable daily and seasonal bag/number limits by properly licensed persons unless otherwise specifically authorized. A valid Virginia fishing license is required for each person collecting samples by hook-and-line.

▪ All traps must be marked with the name and address of the trapper or an identification number issued by the Department (Code of Virginia §29.1-521.7). Steel foothold traps, Conibear-style body gripping traps, and snares must be marked with a nonferrous metal tag bearing this information (Virginia Administrative Code 4 VAC 15-40-170).

• All traps must be checked at least once a day and all captured animals removed, except completely submerged body-gripping traps which must be checked at least once every 72 hours (Code of Virginia §29.1-521.9).

▪The permittee is required to report any incidences of wildlife deaths or diseases observed during the course of collection activities. Reports should be made to: collectionpermits@dgif.virginia.gov within seven (7) days.

• This permit satisfies only the Department's requirement for collection permits and is issued with the understanding that no collections will be made on federal, state, or private property without the prior approval and necessary permits from the landowners involved. The permittee is responsible for obtaining any additional permits required for collection.

• Sampling gear, boats, or trailers which have been used in states harboring zebra mussels must be cleaned and prepared following accepted guidelines for removal of zebra mussels, prior to being used in Virginia.

• For safety reasons, it is recommended that all permittees display at least 100 square inches of solid blaze orange material at shoulder level within body reach and visible from 360 degrees, especially during hunting season.

FAIRFAX COUNTY PARK AUTHORITY
12055 Government Center Parkway, Suite 927 • Fairfax, VA 22035-1118
703-324-8700 • Fax: 703-324-3974 • www.fairfaxcounty.gov/parks

Fairfax County Police Department
Animal Services Division, Wildlife Section
4500 West Ox Rd.
Fairfax, VA 22030

July 8, 2013

To the Fairfax County Wildlife Biologist and Biological Technicians:

Thank you for your interest in completing a stewardship activity on Fairfax County Park Authority property. This letter serves as evidence of your written permission to conduct the following activity:

1. Installation and maintenance of fifteen 4-Poster Deer Treatment Stations, to include circular fencing, signage, infrared digital game camera, corn bait, and 10% Permethrin acaricide to control ticks on treated deer.

2. Installation and maintenance of electric fencing around thirteen 4-Poster Deer Treatment Stations to deter black bear visitation. Installation and maintenance will adhere to VDGIF guidelines and recommendations.

3. Conduct periodic vegetation surveys within each 4-Poster Station fence plot to assess the environmental impact of deer to the surrounding area.

4. Conduct camera surveys of the deer population using trail cameras deployed at each 4-poster station.

5. Deer culling using sharpshooting at each test and control site, not to exceed six deer per culling event. Deer culling will take place three times per year at the test sites and control sites (approximately spring, summer and fall). Deer marked with pink dye will be preferentially culled from the test sites.

6. Installation, maintenance and removal of the electric fencing and of its constituent parts is solely the responsibility of FCPD Animal Services Division and must be conducted as approved and directed by the Virginia Department of Game and Inland Fisheries, Fairfax County Risk Management and the Fairfax County Health Department.

at these specific sites:

Throughout Sully Woodlands to meet specific criteria such as distance from stream and road. The Fairfax County Wildlife Biologist will work with Park Authority staff to determine station locations and adjust if necessary. Laurel Hill Park and Twin Lakes Golf Course will be control sites (no stations). See Attachment 1.

Electric Fences: Thirteen 4-Poster Treatment stations at Sully Woodlands. See Attachment 2.

for a period from the date of this letter through **July 8, 2014**, unless you are notified by the Park Authority to cease. This permission is renewable. Please have a copy of this letter with you whenever you are on Park Authority property. This letter is not a state or federal permit; all required permits are your responsibility. If you fail to comply with the conditions of this permit, state and federal laws or Park Authority Rules and Regulations, your permission is revoked until you obtain and verify valid permits and permissions to conduct your activity.

Please note that the Park Authority has a commitment to provide a natural resource to the entire Fairfax community, and therefore it is important when you are working in the park to:

1. Minimize any impact that you have to the park resources, for example, all stations and associated equipment should be removed at the end of the pilot study. ATV use should be confined to designated trails.

2. Any structures that are not integral to your activity will be removed by you at the conclusion of the project.

3. Adhere to any other conditions set below.

Please also document your activity and provide us with the following types of documentation:

Culling data following each sharpshooting event on parkland
Unusual activity in the park
Notification of any rare or unusual species discovered on parkland
Copy of any valid, relevant state and federal permits for the period of activity

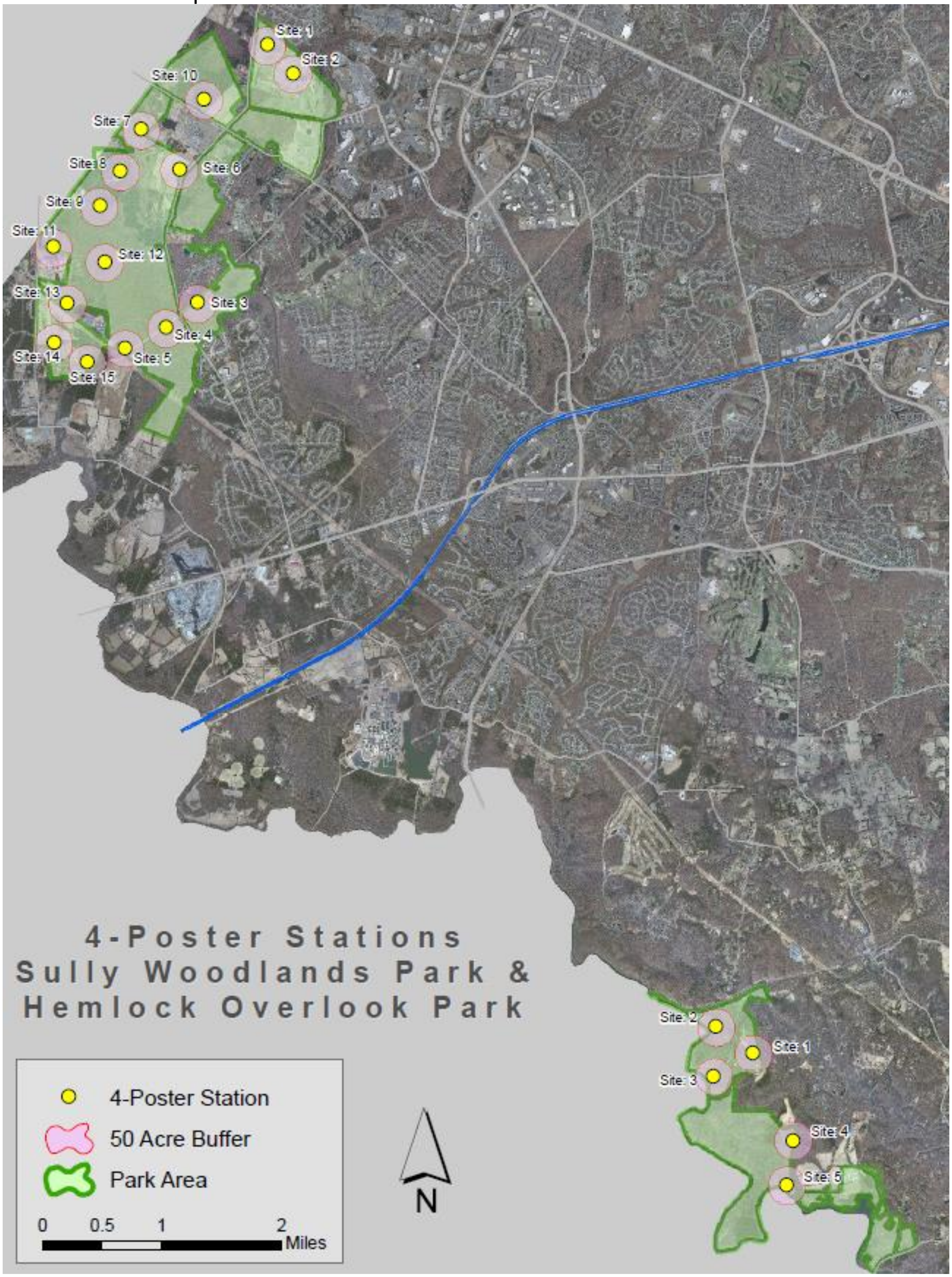
We appreciate your consideration of Park Authority property for your stewardship activity. Please adhere to our minimal requests to ensure a long and successful resource partnership.

Thank you,
Kristen Sinclair
Senior Natural Resource Specialist

Additional special conditions.

(1) Please inform Kristen Sinclair (703 324 8586 or Kristen.Sinclair@fairfaxcounty.gov) of activity and work schedule.

Attachment 1: Map of 4-Poster Treatment Station Locations for 2013/2014



Attachment 2: Map of Electrified 4-Poster Treatment Stations at Sully Woodlands