Testimony for the Joint Hearing
Senate Health & Human Services Committee and Senate Aging and Youth Committee – Topic:
Impact of Lyme Disease on the Commonwealth and Update on Lyme Disease Task Force Report

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Chairpersons Baker, Schwank, Brooks, and Haywood, distinguished members of the Health and Human Services and Aging and Youth committees, it is a pleasure to discuss the status of blacklegged tick control on behalf of the College of Agricultural Sciences at Pennsylvania State University. Thank you for your interest in continuing the efforts to better understand blacklegged tick ecology and control.

Ticks are the most important arthropod vector in the United States. There are three primary ticks of concern in Pennsylvania: blacklegged (deer) ticks, the vectors for anaplasmosis, babesiosis, Powassan encephalitis virus, and Lyme disease; brown dog ticks that transmit Rocky Mountain spotted fever; and American dog ticks that are vectors for Rocky Mountain spotted fever and tularemia. In some locations, lone star ticks can also be found and are vectors for Tularemia, Ehrlichiosis, and southern tick associated rash illness (STARI). Therefore, it is essential to address the issue of tick control and tick-borne disease risk. However, tick ecology is complicated, and information is often oversimplified.

Of the many pathogens transmitted by ticks, Lyme disease is by far the most important and common. It is also the most prevalent vector-borne illness in the United States. The Centers for Disease Control and Prevention (CDC) estimates 329,000 cases occur in the United States each year. In recent years, **Pennsylvania has led the nation in the number of reported Lyme disease cases, with 7,351 in 2015, and is number 3 in the nation in number of cases per 100,000 people.**

To protect citizens of the Commonwealth of Pennsylvania by reducing the Lyme disease threat, it is important to understand:

a) Tick biology involves more than white-footed mice and white-tailed deer as the primary hosts,
b) options for tick control are limited, and
c) additional resources to expand our ecological understanding of complex relationships between ticks and their hosts, including long-term and comprehensive surveillance, is required.

The geographic distribution of Lyme disease, and many of the previously mentioned tick-borne diseases is increasing, presenting significant challenges for public health professionals and policy makers. The CDC has documented a westward progression of Lyme disease across Pennsylvania with many counties becoming high risk areas. The Pennsylvania Department of Environmental Protection (DEP) confirmed in 2015 that **every county in Pennsylvania has blacklegged ticks infected with *Borrelia burgdorferi*, the causative agent of Lyme disease.**

The ecology of blacklegged ticks and the associated Lyme disease cycle is complicated. Lyme disease is a zoonotic disease, meaning that the pathogen typically resides in one or more non-human vertebrate hosts, but can infect humans as well. These non-human hosts, called "reservoirs," maintain the pathogen in nature and become a source of infection. Creating further complexity, ticks can feed on many hosts. In biomedicine, there is a reductionist model to understand simpler levels of organization such as "*the* reservoir host" or "*the* vector arthropod." In many cases, this has been highly successful, yet in some cases such as the Lyme disease cycle, paring down the ecology of a system is inefficient and inadequate. Unfortunately, even though Lyme disease is the most common vector-borne illness in the United States despite its limited range, **relatively little is known about blacklegged tick and tick host ecology throughout the Lyme disease range**.

The primary reservoir for the Lyme disease pathogen, and host for *immature* stages of blacklegged tick feeding is considered to be white-footed mice. Initially, blacklegged tick larvae and nymphs require a blood meal, and this is typically from a smaller vertebrate host. It is at the larval stage of blacklegged ticks typically become infected with the Lyme disease pathogen. While **white-footed mice are highly competent reservoirs for *Borrelia burgdorferi* infection, other animal species such as eastern chipmunks, short-tailed and masked shrews, and American robins are also competent reservoir hosts. Vector biologists use the term** "competent" to mean that the pathogen can survive and sometimes reproduce within these species, and because individuals do not always "cure" themselves, the potential risk of subsequent tick infection is higher.

White-footed mice have been incorrectly labeled as the principle hosts for immature blacklegged ticks. Some early studies have shown that white-footed mice are responsible for feeding over 95% of larvae that molt into infected adults in some areas, leading to the assumption that white-footed mice are responsible for the abundance of blacklegged ticks, and blacklegged tick infection. However, these studies did not sample other wildlife hosts, and therefore did not consider the impact that alternative hosts may play on blacklegged tick abundance, and Lyme disease risk. Observations of tick abundance on principally white-footed mice might be a result of the difficulty in identifying parasitic ticks under thick coats in some mammals. Blacklegged ticks primarily feed on flesh of the ears and head of white-footed mice which has limited hair cover. This makes recovery and counts of ticks on white-footed mouse hosts very accurate, whereas accurate counts on other potential hosts such as raccoons, robins, opossums, and skunks are nearly impossible, accounting for only 30% of tick presence. It is highly likely that inaccurate reporting of tick presence on alternative wildlife hosts has had an impact in the understanding of the role of these hosts in blacklegged tick ecology.

White-footed mice do not always carry the greatest number of blacklegged ticks. Analysis of other potential mammalian hosts in New York has found that counts of immature ticks of white-tailed deer, eastern chipmunks, squirrels, opossums, raccoons, skunks, and foxes exceeded that of white-footed mice. Intensive sampling showed that, except for ground-dwelling birds, each host species captured had more larval ticks per individual than white-footed mice. In fact, chipmunks fed more larval ticks than white-footed mice. These counts do not incorporate density of these hosts in the environment. Subsequent studies have demonstrated that mouse and chipmunk abundance in an area did not affect density of blacklegged tick nymphs or infected nymphs. A comprehensive genetic analysis found that short-tailed and masked shrews fed 30% of the population of blacklegged ticks, and infected 55% of them. White-footed mice were found to only feed 10% of the population of blacklegged ticks in an area and infect 30% of them. Overall, 80-90% of the ***infected*** nymphs had previously fed on shrews, mice, and chipmunks, but only 50% of the total population of blacklegged ticks had fed on these species. Other mammalian species in these forested habitats play a larger role in tick ecology than previously thought. Therefore, although rodent communities play a profound role in the epidemiology of Lyme Disease, it is critical to include shrews and chipmunks in the considerations for control. Along with shrews and chipmunks, white-footed mice may play a larger role in tick infection with *Borrelia burgdorferi* than other mammals; however, white-footed mice as the principal and primary host for immature blacklegged ticks in all areas cannot be supported.

As with white-footed mice, assumptions have been made of the exclusivity of white-tailed deer as the primary host for adult blacklegged ticks. The general dogma is that deer are responsible for feeding blacklegged ticks, and therefore are responsible for their abundance and distribution. **Deer do not infect blacklegged ticks with *Borrelia burgdorferi.*** Deer do not maintain *Borrelia burgdorferi* in their system, and less than 1% of the blacklegged ticks that have fed from deer have become infected with the Lyme disease pathogen. Deer have been considered the "definitive" or "keystone" host of adult blacklegged ticks, and the "primary" reproductive host. These designations were the result of quick calls to action in the 1970's and 1980's as Lyme disease became a health threat in the Northeastern United States. Hunter-killed deer were sampled for ticks, and the resulting numbers led the scientific community to assume that deer were used nearly exclusively by blacklegged ticks. This association even resulted in the alternative name of blacklegged ticks, "deer tick." Public perception of the blacklegged tick-deer association has caused aggressive demands of deer herd culling (removal by euthanasia) to reduce the risk of Lyme disease. However, **blacklegged ticks are not a specialist on white-tailed deer**. Although little is known about host preference in the field, over 27 mammalian hosts can be used by blacklegged ticks as hosts. Therefore, it is unwise to focus exclusively on white-tailed deer as the only target for blacklegged tick control.

Deer exclusion and deer culling has not resulted in consistent decreases in blacklegged tick populations. Deer exclusion has had inconsistent results at reducing tick populations. In New York, only one of two deer exclosures showed a reduction in tick numbers. In Connecticut, exclosure reduced immature blacklegged ticks by 50-80%, but did not affect adult tick numbers. In some cases, exlosures have resulted in increased abundance of host seeking ticks. In general, deer exclusion of 1 hectare has resulted in increased blacklegged tick numbers, 2-4 hectares has not demonstrated any difference, and 4+ acres have seen a reduction of numbers, but this reduction has not been tracked long-term. In Connecticut, deer populations were reduced by nearly 50% and the adult tick numbers were greater than before the reduction. Recent research from Connecticut has found that if culling programs do not reduce the risk of tick bites. In fact, unless the target population density is reduced to 10/km^2, the risk of blacklegged tick bite may increase as ticks seek alternative hosts.

Further complicating the Lyme disease cycle is the continuous fragmentation and land uses found in regions where blacklegged ticks are present. Fragmented habitats, such as suburban housing complexes, are suitable for white-footed mice and chipmunks, but not for many other potential mammalian tick hosts. This can produce what has been called the “dilution effect,” where the likelihood of a tick biting an infected mouse increases over the likelihood of a tick biting a host that likely isn’t infected with *Borrelia burgdorferi* because the mouse to alternative host ratio is higher. These suburban and urban areas also see a reduction in predators, such as foxes, that would naturally control the population. White-tailed deer also thrive in edge habitat that is common in suburban areas. While they may not be the exclusive host to blacklegged ticks in rural areas, the increase in density and reduced movement over the landscape is an easy target for local blacklegged tick populations. Furthermore, tick populations tend to occur in “hot spot” areas. In some cases, ticks are present in large numbers for several years, and in some seemingly suitable habitats very few ticks are found. Therefore**, it is likely that blacklegged tick control must be addressed in a localized way**, not area-wide until better tools are developed, or more evaluations on current tools are conducted.

Current Control Strategies and Limitations

One method of controlling ticks in the environment is by treatment of tick hosts with insecticides. Host-targeted treatment for the control of ticks in the environment has been developed for small mammals, and a passive treatment station have been developed for treating ungulates like white-tailed deer. **In some cases, chemical treatment of hosts has resulted in reductions of ticks in the environment.**

A rodent bait box (Select TCS Bait Box) that treats mice and chipmunks with fipronil (chemical found in frontline) has been shown to reduce the tick population in a large-scale island community trial. The bait boxes are available commercially through a licensed pesticide applicator. Exclusive use of bait boxes has been effective in some trials in New England at reducing blacklegged tick populations, and in some trials little effect has been seen. Maximum benefit is most likely if many residents within a neighborhood use the box, potentially treating the entire local population of white-footed mice. However, new information suggests that proper placement of bait boxes in mouse habitat is important, and territorial mice may not permit others to use bait boxes inside their home range.

Damminix tubes include permethrin-treated cotton balls target blacklegged ticks on white-footed mice. Product effectiveness is dependent upon the collection of the cotton as nesting material from distributed tubes. No reduction in the number of infected, host-seeking deer tick nymphs in woodland and residential areas of about 4 acres or less was found in CT and NY trials. However, a reduction in nymphal ticks was reported in a Massachusetts study with the treatment of one 18-acre site. The effect of the Damminix tubes on tick populations relies heavily on white-footed mouse behavior, and uses permethrin which is both toxic and repellent to blacklegged ticks. The tubes may treat mice, but does not treat any additional animals that may be serving as hosts. Thus, blacklegged ticks repelled by the permethrin treatment may seek these alternative hosts.

The 4-Poster self-treatment bait station is a similar passive feeding station targeting ticks parasitizing white-tailed deer. The 4-Poster feeder works by baiting deer with corn and passively treating the head and neck as the deer feed with permethrin-coated paint rollers. This has been the mostly widely used deer-targeted tick treatment device in the United States, likely due to its commercial domestic availability. **While the 4-Poster feeder has been found to be successful in reducing tick populations in some cases, the feasibility of use is situational.** The 4-Poster feeder had been found to reduce the abundance of blacklegged ticks in some cases, but not others. A review study in 2009 concluded that the feeders generally reduce populations by 70%, however there were no replications conducted on any of these field tests. In some evaluations, tick density was not affected using 4-posters. In Virginia, the use of the 4-poster was not recommended to Fairfax county due to the lack of efficacy in field trials. Local tick numbers were reduced, but the effect on the population was ambiguous. Because of size, design, and the frequent addition of corn, multiple units are difficult to move and maintain.

While the use of the device has had positive results in many cases, there are some problems and concerns with execution of the 4-Poster system that has precluded the widespread use of this device in areas with high tick risk.

Cost to maintain the 4-Poster stations can be high. Annual corn and permethrin cost estimates range from $7,064 to 17,859, depending on the number of feeders and deer use. Annual costs for 4-Poster feeders were estimated at $47,030 per year for ten feeders including the cost of corn, permethrin, and labor for one staff member. Projected costs for corn per 4-poster bait station was approximately $1,675 annually excluding replacement parts. It is estimated that these costs would be significantly higher accounting for inflation, and including these additional repair and maintenance costs. Many municipalities and local governments or parks and recreation groups have forgone the use of 4-poster feeders due to these high labor and maintenance costs.

Concerns regarding the impact of nutritive bait such as corn with 4-Poster feeder use on deer population growth have been raised. Dressed weights of white-tailed deer were seen to steadily increase over a three year 4-Poster use period. Corn use reports have been an average of 5,242 pounds of corn is ingested per feeder per year. This can be extrapolated into calories added to the environment per year by multiplying corn consumption by 290 (the approximate number of calories in 1 pound of whole-kernel corn), which is 1,520,180 calories into the environment per feeder, per year. This is a serious concern from both a wildlife nutrition and population management perspective.

As an alternative to direct host-targeted control, **landscape features can be modified to reduce tick presence in an area, although they do not necessarily result in tick control by reduction of populations**. A clearly defined wood chip or stone border between lawn and woods, removing leaf litter at the lawn perimeter, grass mowing, tree pruning, and removal of wildlife harborage areas such as wood piles, stone walls, and Japanese Barberry plants can reduce the risk of tick presence. Deer may not be the exclusive host of blacklegged ticks, but they are hosts that can transport adult females into residential areas to lay eggs, so reducing deer resistant plants and discouraging deer browsing may help reduce tick presence in an area.

Synthetic chemical applications can reduce tick presence, either by directly killing them or by residual repellent effects. Applications of pyrethroids, carbamate insecticides either in granular or spray form can be applied to the perimeter of high use areas such as lawns or athletic fields by license applicators. Applications do not need to be made on lawns, as 82% of blacklegged ticks have been recovered within 9 feet of the lawn edge. These have been shown to be highly effective at reducing tick presence in an area with multiple applications. However, there are concerns regarding increased insecticide applications in the environment, and pyrethroids are highly toxic to aquatic wildlife.

An alternative to synthetic chemical insecticides is the use of a biopesticide, or essential oils. There are biopesticides registered for residential use for tick control. Met52 is a fungal pesticide that is relatively specific with no concerning effects on pollinators, and no negative effects on humans. While the biopesticide requires several days to become effective as the fungus grows and subsequently kills the tick host, several studies have shown high success rates with reducing tick numbers after applications of this biopesticide. Even greater reduction was realized in combination with the rodent bait boxes as part of an integrated pest management program in residential areas. However, this product is also toxic to aquatic wildlife in its current formulation. Several essential oils, such as cedar oil and garlic, have been successful at repelling ticks in the laboratory, but the oils are unstable in the field and often require weekly or more application as there is no residual effect.

Current research is focused on integrated pest management using currently available tools, and development of vaccines and other treatment for white-footed mice and white-tailed deer. A USDA and Pennsylvania State University collaboration with the Connecticut Experimental Station has established an area-wide tick control project in Maryland and Connecticut to address control of blacklegged ticks in suburban areas adjacent to large county parks using bait boxes, biopesticides, and 4-poster feeders. A similar project was developed for tick control in school settings in Maryland using 4-Poster feeders and rodent bait boxes. Similar projects could be developed in Pennsylvania.

Through the USDA-Penn State collaborative project, an anti-tick vaccine for white-tailed deer is in the early stages of screening. This would prevent ticks from biting white-tailed deer and taking a blood meal. For deer treatment, we have developed a modified deer feeder that eliminates many of the problems associated with the 4-Posters and would be suitable for homeowner use. This product is currently in the patent process. A granular bait containing a vaccine for *Borrelia burgdorferi* infection in white-footed mice has been developed by the University of Tennessee and found to be successful for up to a year in clearing mouse infection. The aforementioned bait boxes are currently being evaluated by the CDC to include antibiotics in the bait to both treat mice and cure them of *Borrelia* infection. However, **more information on the local ecology and host use of ticks in Pennsylvania is required to understand how control differs by region and landscape use in order to effectively control the tick population.** In addition, other technologies for alternative hosts need to be developed to address host feeding on a landscape level, not just “one house at a time.”

In conclusion, it is important to understand that tick biology involves more than white-footed mice and white-tailed deer as the primary hosts. The ecology of blacklegged ticks is complex, and our options for tick control are limited. Finally, additional resources to expand our ecological understanding of complex relationships between ticks and their hosts, **including long-term and comprehensive tick surveillance**, in the Commonwealth of Pennsylvania is required to develop more effective tools to protect citizens from the increasing threat of Lyme disease, and other tick-borne diseases.