IDENTIFICATION OF THE LYME DISEASE VECTOR IN SOUTHWEST VIRGINIA

By

James Eric Sheppard

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APPROVED:

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Cynthia J. Denbow, Chairman

_____ _____

Sally L. Paulson D. Michael Denbow

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Lyme disease

Introduction

In the mid-1970s, fifty-one residents from the quaint little Atlantic seaside town of Lyme, Connecticut came down with something that resembled rheumatoid arthritis (Garrett, 1994). The ailment was dubbed Lyme disease and quickly spread to all fifty states. Once physicians became aware of the symptoms, the disease was diagnosed in many states of the Northeast, but there was a clear upward trend in Lyme disease found throughout the United States. By 1992, Lyme disease was the most reported vector-borne disease in the country (Steere, et al.). In fact, from 1995 to 2009, more than 300,000 cases of Lyme disease were reported to the Centers of Disease Control (CDC) by state health departments and the District of Columbia (http://www.cdc.gov/nc) (Appendix A). During this 14-year period, most of the cases were reported from northeastern states including Connecticut, Delaware, Massachusetts, Maryland, Minnesota, New Jersey, New York, Pennsylvania, and Rhode Island. In 1982, Lyme disease was first seen in Virginia and, following the nationwide trend, has steadily increased since that time (Lyme Disease, 2010b). The cases of Lyme disease in Virginia included 29,959 confirmed cases and 8,509 probable cases being reported just in 2009 (http://www.cdc.gov/nc).

Most people suffering from Lyme disease lived in wooded areas inhabited by common animals such as deer, squirrels, and chipmunks. It was reported that 80 percent of all cases of Lyme disease in North America were linked to either residing in a deer habitat or hiking through areas with populations of deer (Barbour and Fish, 1993). Unfortunately deer populations, including those in Virginia, have grown due to the lack

of natural predators, thus forcing large numbers of deer to invade suburban areas scouring for food thereby increasing the contact with not only people, but also their pet dogs and cats with infected ticks (Garrett, 1994). In Roanoke County, which borders the New River Valley, a noticeable increase in deer population has led local officials to allow out-of-season bow hunting permits to help reduce the deer herd. According to a local news station, WSLS, the city of Roanoke has tried to reduce the deer herd by 200 deer (2008, WSLS). This action clearly shows that the deer population and human contact are getting closer and closer.

Lindgren and Jaenson, (2006) noted that in Europe there were approximately 85,000 cases of Lyme disease a year; whereas in the United States between 15,000 and 20,000 cases were reported ().These cases were found mostly in the temperate zones of the northern hemisphere. The fact that the northern most part of the United States and Europe have larger numbers of reported Lyme disease cases than other geographical locations might indicate that the environment could impact the distribution of pathogens and/or their vectors. It is possible that global warming may be playing a role in moving the disease from one temperate zone to another. Could the tick be adapting to the global warming event?

Whether the increased numbers of Lyme disease are due to increasing and encroaching deer populations and/or warmer climates allowing wider distribution of vectors, it becomes extremely important that the population become educated about tick removal, self-diagnosis by recognizing symptoms, and what to do when symptoms occur. With that in mind, this project includes multiple sections and was conducted to provide a detailed summary of information about Lyme disease, especially in Virginia,

including the New River Valley. That information will be used to create a fact sheet for use by extension agents to better inform and educate the public. Interviews were carried out with area veterinarians in order to determine numbers of Lyme disease cases reported. Lastly, an effort was made to collect actual ticks to determine if they were one of the known vectors in Virginia to cause Lyme disease. The ticks were obtained by posting fliers around the New River Valley asking hunters to collect any ticks they found on deer or themselves. This information can and should help determine if the disease is continuing its southern track and what can be done to prevent the disease from continuing to spread into the southern region of the United States.

Definition and Characteristic Symptoms

According to the United States Environmental Protection Agency (EPA), Lyme disease is defined as, “A tick-borne disease that can cause a rash, fever, fatigue and headaches. If it is not treated it can cause infection in the joints, heart or nervous system. In the Northeastern United States, Lyme disease affects about 100,000 people every year, many of them children” (U.S. EPA, n.d.). The characteristic skin lesion of Lyme disease was originally known as erythema chronicum migrans (ECM) but is now called erythema migrans (Lyme Disease, 2010a). Later symptoms may include meningitis, progressive muscular and joint pains, and arthritic symptoms. If left untreated, the disease could lead to a range of neurological disorders, amnesia, behavioral changes, serious pain in bones and muscles, and even fatal heart disease or respiratory failure (Steere et al, 1993).

Causes of Lyme disease

The causative agent of Lyme disease is *Borrelia burgdorferi,* a species of gram-negative bacteria of the spirochete class (Burgdorfer et al, 1982). Several closely related *Borrelia* species are responsible for most of the cases of Lyme disease. The bactera that are associated with Lyme disease are *Borrelia burgdorferi* (*B. burgdorferi*), *Borrelia afzelii*, and *Borrelia garinii* (McDowell, et al., 2003).

Vectors of Lyme disease

Lyme disease is zoonotic, meaning the infectious bacteria are transmitted to humans from a natural non-human reservoir, either wild or domestic, by a vector. The vectors involved in transmission of Lyme disease are ticks that feed on both sets of hosts. Hard-bodied ticks of the genus *Ixodes* are the main vectors of Lyme disease. There are several closely related species of that are known vectors of Lyme disease (Schmid, 1984; Spielman 1985). These ticks are:

- *Ixodes ricinus* (*I. ricinus*), commonly known as sheep tick (Figure 1).

Figure 1. larva, nymph fasting and replete, male replete and fasting, female fasting and replete. (ISW Group)

Figure 2. Life Cycle of *Ixodes pacificus* in cm. SDNHM

Figure 3. Image of *Ixodes persulcatus*. Focosi, 2009

- *Ixodes pacificus,* commonly known as western black-legged tick (Figure 2).
- *Ixodes persulcatus*, commonly known as taiga tick (Figure 3),
- *Ixodes scapularis* commonly known as the deer tick (Figure 4).

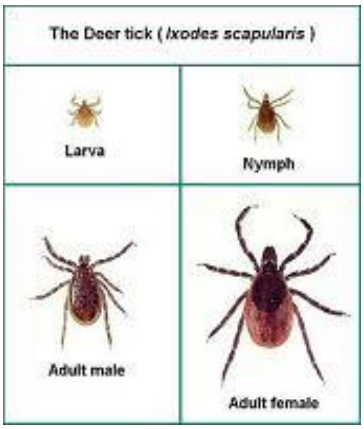

Figure 4. Life Cycle of *Ixodes scapularis*. American, 2010b

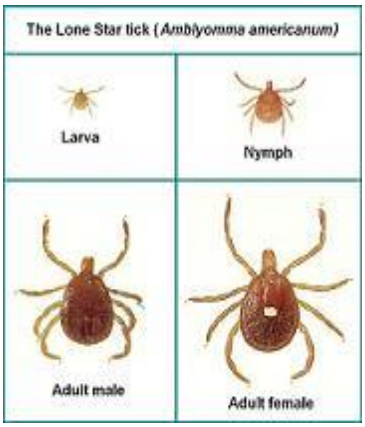

Figure 5. Life Cycle of *Amblyomma americanum*. American, 2010a

Additionally, *Amblyomma americanum* , commonly known as the Lone Star tick (Figure 5) is a vector of a Lyme disease-like illness (Barbour et al. DATE). With this illness, humans experience a rash that may occur along with headache, muscle pain, fever, fatigue, and joint pain (STARI, 2009). This rash is known as southern tick-associated rash illness (STARI).

Ticks in Virginia

Figure 6. Adult photo of *Dermacentor variabilis*. Day, 2009

According to Eric Day, there are four common ticks in Virginia (Day, 2009). These include the *Amblyomma americanum* (lone star tick), *Dermacentor variabilis (*American dog tick) (Figure 6), *Rhipicephalus sanguineus* (brown tick), and the *Ixodes scapularis* (deer tick). Of these, only the *Ixodes scapularis* has been shown to be a vector of Lyme disease in Virginia (Day, 2009). With the data from the ticks collected, this project hopes to show that there is a significant population of *Ixodes scapularis* established in the New River Valley. Unfortunately, observation of Lyme disease cases in southwest Virginia relies heavily on human cases being reported and tick specimens being submitted for identification (Troyano, 2009).

Studies have shown that global climate change may create an abundance of vectors, such as ticks (Brownstein, et al., 2005). As Brownstein, et al. explained, *Ixodes scapularis* is being redistributed as a result of multip[le factors including temperature change. Minimum temperatures are rising which is resulting in the expansion of *Ixodes scapularis* into higher latitudes. This can be explained according to these authors by an inverse relationship between the survival of the tick and the degree of exposure to subfreezing temperatures. The recent change in temperatures in the past decade may be a contributing factor to the spread of Lyme disease throughout the state of Virginia. They also mention that the structure of the landscape may influence white-tailed deer.

Sluss (2011) noted that the deer population is exploding in Virginia . This may account for the increase in Lyme disease cases in Virginia. There were approximately

52,000 deer hit by vehicles in Virginia in 2009, an increase of seven percent over the previous year and a twenty-eight percent increase over the past five years in the number of vehicle incidents involving deer (Ellis, 2010). There are a greater number of hosts for the vector to attach to since there is an increase in the deer population throughout Virginia. This can lead to a greater range of distribution for the disease since deer are a common host for adult ticks and the deer have a wider range of travel. Another common host, the white-footed mouse, does not travel as far as the deer (Troyana, 2009). Therefore the deer are more likely to carry the *Ixodes scapularis* greater distances than the white-footed mouse.

As shown in Figure 7, Southwest Virginia is thought to have a habitat that is suitable for *Ixodes scapularis*, but no established population has been reported (Brownstein, et al., 2005). Brownstein, et al. (2009) also said that the autologistic model predicted a forecast of suitable climate-based habitat in years 2020, 2050, and 2080 (Figure 8). Gaines showed that there are currently counties that are south and west of northern Virginia where there is Lyme disease (Figure 9) (Gaines, 2010). When looking at figure 9, one can determine that there are sections in the state of Virginia where Lyme disease occurs in greater

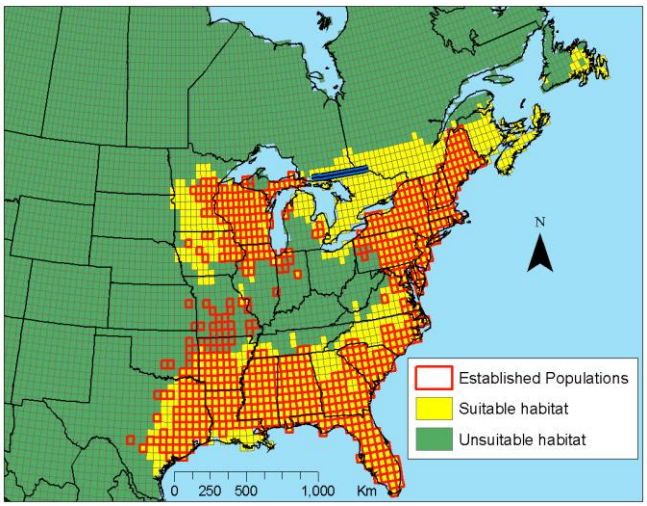

Figure 7. Climate based habitat suitable for *Ixodes scapularis*. (Brownstein, et al., 2005).

numbers. According to the figure, these areas include the Northern Virginia, Richmond area, and portions of Southwest Virginia. The main highways running through

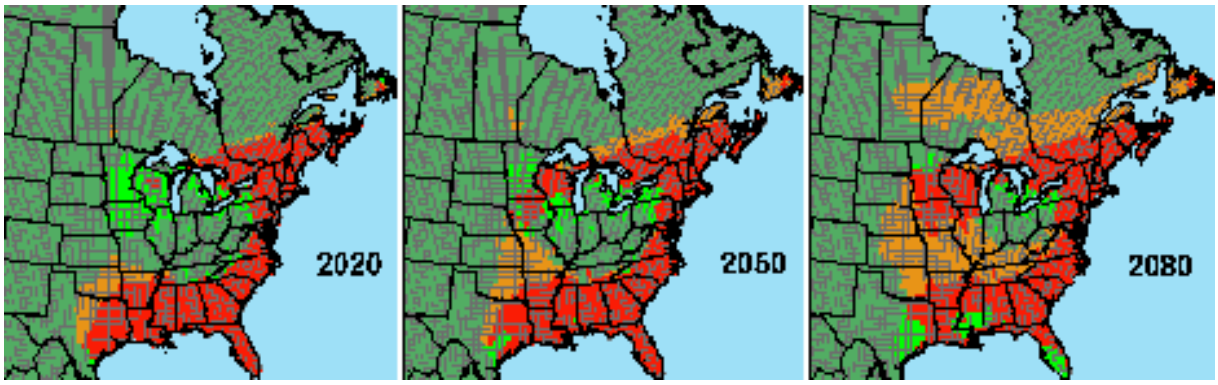

Figure 8. Projected bases of climate based suitability for *Ixodes scapularis*. (Brownstein, et al., 2005).

Virginia seems to be pathways for the disease to travel from one part of the state to another. This raises questions for further studies at a later date. Such questions include: are the ticks being transported by vehicles? Or are they being moved by way of white-tail deer that move alongside main highways? With this project, collecting data on the ticks obtained from citizens in the New River Valley, it is hoped to show conclusively that Ixodes *scapularis* does exist in Southwest Virginia earlier than what was projected (Figure 8).

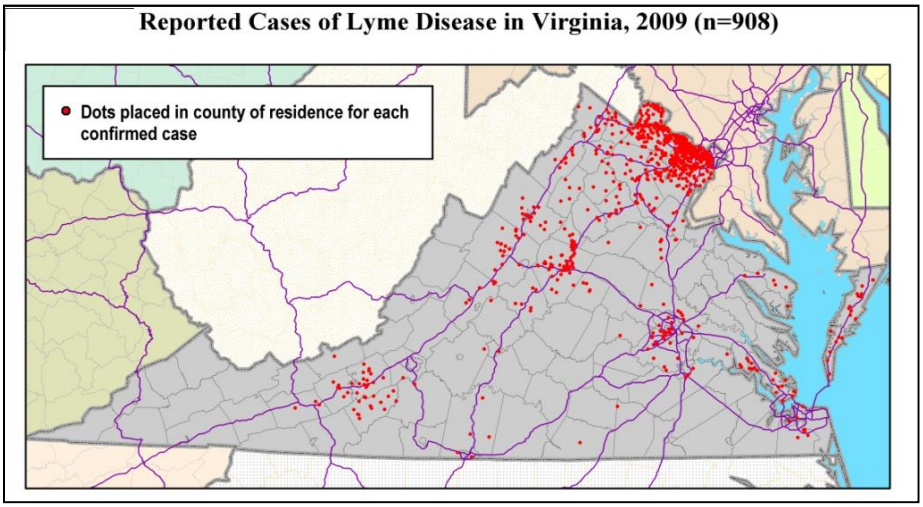

Figure 9. Reported cases of Lyme Disease in Virginia, 2009. Gaines, 2010

Life Cycle of a Tick

The ticks have four developmental stages (Figures 11 and 12) (Ostfeld and Keesing, 2000). The first stage is the egg which the female adult tick lays in the spring. This is followed by the second stage (larvae stage) in which the tick looks for a host,

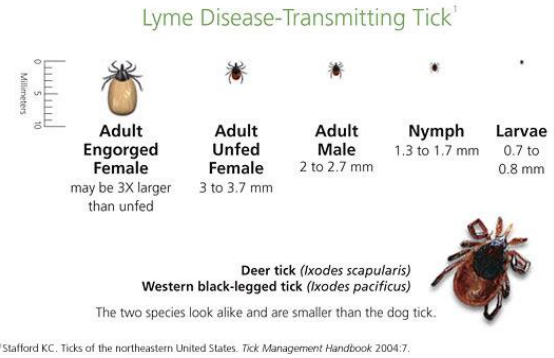

Figure 10. *Ixodes scapularis, Ixodes pacificus* (they look alike). Lyme Disease, n.d.

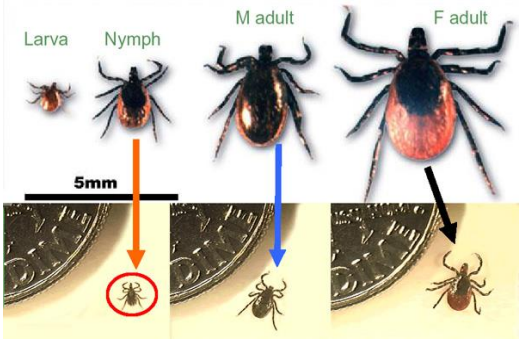

Figure 11. Developmental life cycle of ticks. April, n.d.

usually a bird or small mammal such as rats or mice; the size at this stage is between 0.7 and 0.8 mm. During this stage, the tick is not capable of infecting the host. The larva gets a single blood meal during the summer from a reservoir host, picking up the bacteria at that time which it carries for the rest of its life. It then falls off and molts into the third stage (nymphal). The size at this stage is between 1.3 and 1.7 mm. and the nymphal stage is when it is most likely to transmit Lyme disease due to its small size. During this stage, the tick overwinters and then looks for a host in the late spring or early summer. In this stage, the tick again takes a single blood meal, drops off, and then molts into the final stage of adult (4^{th} stage). The adult male is between 2 and 2.7 mm and the adult female is between 3 and 3.7 mm. Once engorged, the adult female can be up to 3 times larger than when it is unfed. The adult will then seek a host during the fall, usually a white-tailed deer for the final blood meal. The male and female tick mate while on the deer and then the female drops off to overwinter before laying eggs in the spring

(Ostfeld and Keesing, 2000). Humans are an accidental host of the tick, not an intended host.

Symptoms and Effects of Lyme disease – Animals

Unlike humans, where Lyme disease follows three identifiable stages, Lyme disease in animals does not follow specific stages. Instead, the animal exhibits symptoms of Lyme disease (Appel, et al., 1992). For dogs, horses, cattle, etc., the typical signs associated with Lyme disease include acute arthritis and arthralgia (Appel, et al., 1992). Less common side effects include central nervous system involvement, heart block, renal lesions, and uveitis (Appel, et al., 1992). As a pet owner, it is very important to be able to identify these potential signs of Lyme disease to ensure the health and safety of pets. As is the case with other diseases, early detection is essential to ensure that treatment is given to prevent the listed side effects. Although there are no clear stages of Lyme disease in animals, pet owners should be vigilant in checking their pets for ticks and in watching for any of the signs after a tick has been removed. The Idexx® Snap 4Dx® test was used by Troyano to test canines in southwest Virginia by taking a sample of their blood. Of the 412 dogs whose serum was tested by Troyano with the Idexx® Snap 4Dx® test, 4.1% tested positive for *B. burgdorferi* antibodies (Troyano, 2009). Cases of Lyme disease in humans have been associated with a prevalence of Lyme disease in dogs (Troyano, 2009). Dogs have been shown to be effective sentinels for Lyme disease as research has shown that there is a reciprocal or mutual relationship between the cases of the disease in dogs and the number of human cases (Troyano, 2009).

Stages of Lyme disease in Humans

In the first stage of Lyme disease in humans, called early Lyme disease there may be any combination of the following symptoms which may reoccur intermittently over several months for days to weeks after infection or disappear altogether. Symptoms include a spreading rash, nausea, fever, headache, fatigue, and aching joints and muscles (DNR, 2010). The red rash can be 2 to 20 inches in diameter and may appear anywhere from 3 to 32 days after a person is bitten (DNR, 2010). During the second stage, known as early disseminated Lyme disease, complications that involve the heart and/or nervous system may develop due to the spread of bacteria affecting other body functions. During this stage, meningitis, facial paralysis, encephalitis, heart block, painful muscles, joints, or tendons may be noticed (DNR, 2010). This stage can occur weeks, months, or years after the initial exposure. In the third stage, known as late or chronic Lyme disease repeated attacks of arthritis nervous system problems like memory loss, or chronic muscle pain, and restless sleep may occur.

Effects on Humans

The first symptom of Lyme disease in humans is typically the rash which begins as a small red spot at the site of the tick bite. Over days or weeks, the spot gets larger and forms a red rash in the shape of a circle or oval (Figure 12) (Lyme, 2008a). Other symptoms include fever, stiff neck, tiredness, body aches, and headache. Arthritis may develop after several months. Some neurological symptoms that can occur include stiff neck, meningitis, Bell's palsy, poor muscle movement, numbness, pain, or weakness in

the limbs, memory loss, difficulty with concentration, and change in mood or sleep habits (Lyme, 2008a). A few people, less than 1 out of 10, will develop heart problems such as an irregular heartbeat. Rarely, eye inflammation, liver disease, and severe fatigue can occur (Lyme, 2008a). If left untreated, Lyme disease can lead to death. In pregnant women it can also lead to fetal death.

Figure 12. Images of Reported Lyme disease rash. Cwandless, 2010

Outlook for those diagnosed with Lyme disease

The prognosis for those that are diagnosed with Lyme disease in the early stages is good. The disease can be cured with antibiotics (Vorvick and Vyas, 2010). If treatment is not received in the early stages, however, then complications can result that involve the joints, heart, and nervous system (Vorvick and Vyas, 2010). For those patients that continue to have symptoms which interfere with their daily lives (post-Lyme disease syndrome) there is no effective treatment (Vorvick and Vyas, 2010).

Risk factors for contracting Lyme disease

There are several risk factors for contracting Lyme disease. Having pets that might carry ticks is one risk factor (Vorvick and Vyas, 2010). Another risk factor is participating in activities which may increase exposure to ticks such as hunting, hiking,

gardening, or any other outdoor activity (Vorvick and Vyas, 2010). It is essential that after participating in outdoor activities, the body and scalp are checked for ticks and that the ticks are carefully removed. This is important for both humans and animals as this will help to reduce the risks for contracting Lyme disease.

Treatment of Lyme disease

To prevent complications from Lyme disease, it is necessary to receive prompt diagnosis and treatment with antibiotics (DNR, 2010). The standard treatment is between fourteen and twenty-one days of antibiotics (Report to Congressional Requester, 2001). If Lyme disease is diagnosed during later stages, it is often necessary to use more intensive antibiotic therapy (DNR, 2010). During later stages, two to four weeks of intravenous antibiotics are necessary which can be repeated a second time (Report to Congressional Requester, 2001).

Prevention of Lyme disease

Exposure to ticks can be limited by several methods. This includes spraying clothes with insect repellants, such as Deet (Report to Congressional Requester, 2001). Long pants should be worn and tucked into boots. Shirts should be long-sleeved and buttoned at the cuff (DNR, 2010). Wearing lighter colored clothing (Lyme, 2009) can help aid in the detection of ticks. Clothing, skin, and pets should be checked for ticks and any ticks found should be removed (DNR, 2010) within the first thirty-six hours. Removing the ticks quickly and carefully can aid in not contracting Lyme disease, even when bitten by an infected vector.

Vaccine for Lyme disease

The Food and Drug Administration (FDA) approved a vaccine for Lyme disease in December 1998 (Report). The vaccine was L-OspA and was given as a series of three injections (Steere, et al., 1998). The vaccine was approved for patients between the ages of fifteen and seventy (Report to Congressional Requester, 2001). After two doses, the vaccine was fifty percent effective and after three doses it was seventy-eight percent effective (Report to Congressional Requester, 2001). The vaccine was marketed by GlaxoSmithKline in the United States (Abbott, 2006). There was a class action lawsuit filed in December 1999 and the vaccine was withdrawn from the market in February 2002 (Abbott, 2006).

How is information on Lyme disease disseminated?

There have been several journal articles written on Lyme disease and its effects. Some health departments also have publications about Lyme disease. Some Extension offices have published fact sheets about the disease. In Virginia, only Extension offices in northern and eastern parts of the state have actually published information for the general public. To date, nothing has been published in southwest Virginia through the local Extension offices. As of today's date, none of the Extension offices have the facts sheets published on the Virginia Cooperative Extension website. There have been four publications that are on the Virginia Cooperative Extension website, but none of these are actual fact sheets on Lyme disease.

Number of Lyme disease cases in the New River Valley since 2005

According to the Virginia Department of Health, the number of cases of Lyme disease in humans has been increasing since 2005 (Annual Reports, 2010). In 2005, there were only two confirmed cases of Lyme disease in the New River Health District. In 2009, there were 39 confirmed cases, see Appendix B (P. Bordwine, District Epidemiologist, New River Health District, personal communication, January 19, 2011). In 2010, there were 96 cases, although this is provisional data and subject to change, it shows a significant increase from 2009, see Appendix B (P. Bordwine, District Epidemiologist, New River Health District, personal communication, April 12, 2011).

According to the Companion Animal Clinic, the number of cases of Lyme disease they have seen has increased over the past two years (Companion Animal Clinic, personal communication, January 18, 2011). North Main Small Animal Clinic saw about three cases of Lyme disease yearly from 2005 until 2009 (North Main Small Animal Clinic, personal communication, January 18, 2011). In 2010, they saw about one case every three months, the last of those being in December. They saw only one case in January of 2011. Riner Animal Hospital reported an increase in the number of cases they have seen (Riner Animal Hospital, personal communication, January 18, 2011), but no further information was given. The West End Animal Clinic had 84 positive test results for Lyme disease in 2009 and 117 positive test results in 2010 (Kerry Jamerson, West End Animal Clinic, personal communication, January 18, 2011). The Virginia-Maryland Regional College of Veterinary Medicine reported that they do not see many cases of Lyme disease, nor do they keep a record of the number of cases they see (VMRCVM, personal communication, January 18, 2011).

Data collection of ticks in the New River Valley

This portion of the project dealt with disseminating fliers (Appendix D) throughout the New River Valley to encourage participants to collect deer ticks from game killed during the hunting season of fall 2010. Also collected were ticks found on the individuals themselves as well as household pets. The location of the fliers were determined to be best suited in locations that included game check stations, local gun shops, and various convenience stores where hunters would check in game or purchase hunting necessities before and during the hunting season. The fliers had tags that listed a name, phone number, and e-mail address for individuals to have a contact person to collect baggies in which the ticks were to be placed. The areas within the New River Valley that were studied include the counties of Floyd, Giles, Montgomery, and Pulaski as well as the city of Radford. Participants were given a resealable plastic bag that contained the following items (Appendix F):

- Resealable plastic bags labeled with:
    - Name
    - Contact number
    - Location
    - Type of animal
    - Date
- Vial containing 80% ethanol
- Pencil

The spreadsheet (Appendix G) was used to track the resealable plastic bags that were distributed. There were a total of 100 vials distributed. Sixteen of the vials were

distributed to residents in Floyd County, twenty-seven to residents in Giles County, forty-four to residents in Montgomery County, and thirteen to residents in Pulaski County. On the spreadsheet was the number of the resealable plastic bag, the person that the plastic bag was given to, the date the tick was collected, the species from which the tick was removed, the location, and a contact number, if the tick tested positive or negative for Lyme disease and the type of tick taken to the lab. Once the resealable plastic bag was collected, it was then brought to the Entomology department at Virginia Tech and placed in a box marked with 'Dr. Paulson Lyme Disease Project' for later analysis.

Results

The data collected from the tick collection from hunters and residents within the New River Valley show that the vector *Ixodes scapularis* has indeed spread into the southwestern Virginia region ahead the schedule predicted by Browstein, et al. (2005). In this collection, the data showed that out of the 100 vials distributed, a total of seventy-four ticks were collected throughout the New River Valley (Table 1). Of those collected, a total of thirty-four were adult female *Ixodes scapularis*. The locations where these ticks were collected included three from Floyd County, fifteen from Giles County, fifteen from Montgomery County, and one from Pulaski County. Eight of these were retrieved from deer, twenty-four from dogs, one from a pony, and one from a human. A total of twenty-one of the ticks collected were adult male *Ixodes scapularis*. Of these, three were from Floyd County, sixteen were from Giles County, and two were from Montgomery County. Ten of these were collected from deer, ten from dogs, and one

from a pony. The nineteen remaining ticks were adult female *Ixodes*, with no mouth parts intact so species could not be determined. Of these, four were from Floyd County, ten were from Giles County, and five were from Montgomery County. Three of these came from cats, eleven from deer, and five from dogs.

New River Valley Tick Collection (Fall 2010 – Spring 2011)					
County	**Host**	**Ixodes Scapularis**		**Ixodes (no mouthparts)**	
		Male	**Female**	**Male**	**Female**
Floyd	Cat	0	0	0	3
	Deer	0	0	0	1
	Dog	2	1	0	0
	Human	0	1	0	0
	Pony	1	1	0	0
Giles	Deer	10	8	0	10
	Dog	6	7	0	0
Montgomery	Dog	2	15	0	5
Pulaski	Dog	0	1	1	0

Table 1: Numbers, location of ticks collected in the New River Valley from various hosts.

A general fact sheet was prepared that was designed to educate citizens of the New River Valley about ticks and the control of Lyme disease. Once approved by the appropriate authorities, this fact sheet will be offered for dissemination by extension agents and other government agencies throughout the Commonwealth of Virginia to educate the public on Lyme disease symptoms, spread, and prevention.

Conclusion

In conclusion, I feel that further study on Lyme disease and possible vaccinations are needed. Further research needs to be done on the disease and how scientists and government organizations can halt the movement of this disease in the United States.

Further research on ticks to ensure that more tick species are not carriers of the disease is also needed. In this project, I have documented through both local veterinarians and health organizations that Lyme disease is increasing in the New River Valley (southwest Virginia). Appendix B clearly shows the increase of Lyme disease in the New River Valley. The fact sheet can also be used to disseminate information about Lyme disease to increase awareness and prevention. From identification of the ticks that were collected, *Ixodes scapularis* has definitely moved into the Southwest Virginia region in higher numbers than previously thought. Grants for research should be pursued in an effort to fund more studies which may possibly assist in the reduction or elimination of Lyme disease. Further studies into the use of dogs as sentinels or early warning for humans should also be considered. Further studies also need to be done on the variations of climate and the effect this has on the spread of the Lyme disease vectors.

Lyme Disease Fact Sheet

Fact Sheet for Masters of Agricultural and Life Sciences Project and Report

What is Lyme disease?
Lyme disease is the most common vector-borne illness in the United States (Figure 1). The causative agent is a corkscrew shaped bacterium called *Borellia burgdorferi*.

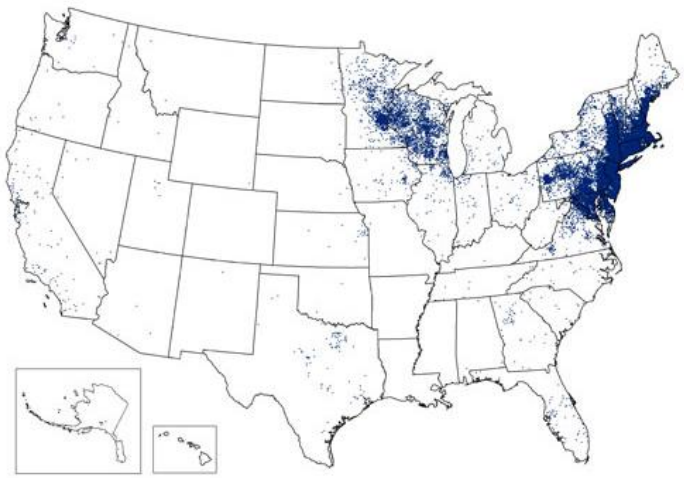

Figure 1: Reported cases of Lyme disease, 2009 (CDC).

How is Lyme disease spread?
Lyme disease is transmitted by the bite of the tick *Ixodes scapularis*, sometimes called the deer tick or blacklegged tick
(Figure 2).

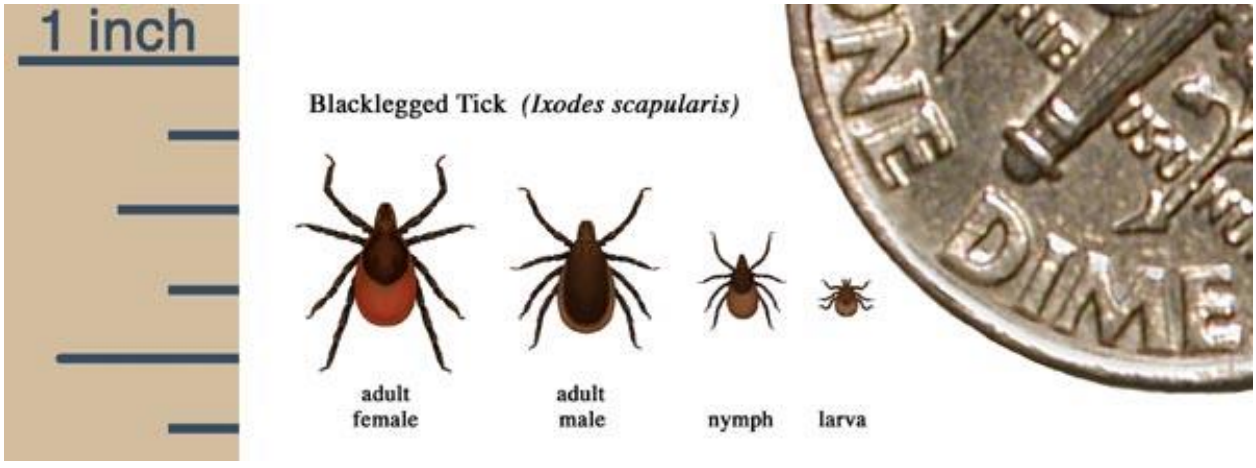

Figure 2: The blood-feeding stages of the deer tick (CDC).

What is the life cycle of the tick?
It is important to study the life cycle of the tick vector to understand the seasonal risk pattern of Lyme disease. Deer ticks have 4 life stages (egg, larva, nymph, adult) and it takes 2 years to complete their life cycle (Figure 3). Larval ticks hatch from the egg in the summer and feed on small animal hosts such as rodents. Upon feeding on an infected animal, the tick ingests the bacteria along with the blood and becomes infected for life. The larva drops off its host, becomes inactive, and molts into the nymph. The following spring, the infected nymphs become active and feed on a wide variety of hosts, including people. Because the tiny nymph often goes unnoticed, this is the stage that is most likely to transmit Lyme disease to people. That is why human cases are more common in the late spring and early summer when the nymphs are most active. After feeding, the nymph molts into the adult. The adult ticks feed on large animals such as deer, but will also feed on humans. In the spring, the female tick lays her eggs and completes the life cycle.

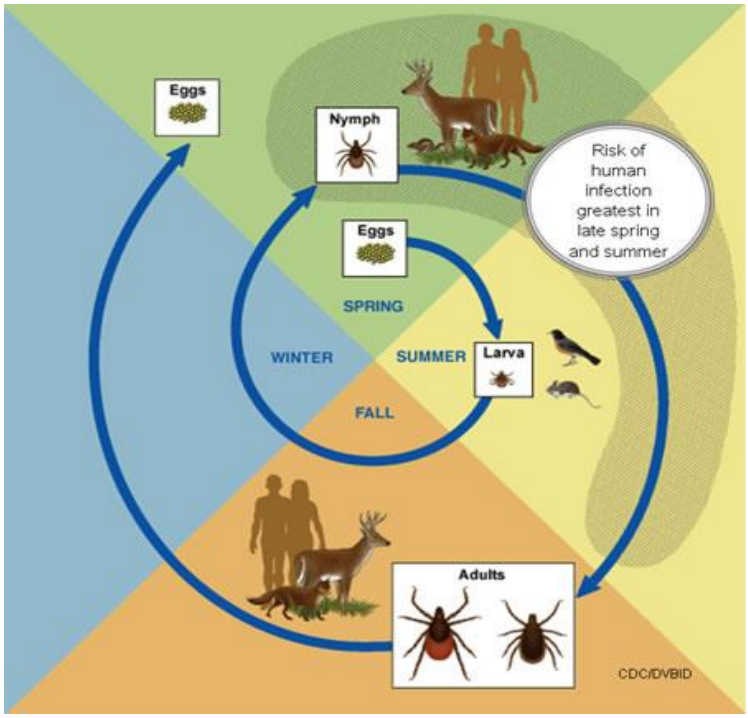

Figure 3: The life cycle of the deer tick (CDC).

Who can get Lyme disease?
Anyone can get Lyme disease at any age. Those that spend significant time outdoors (either working or leisure) have an increased risk of coming in contact with infected ticks.

Are there other ways to get infected with Lyme disease?
Lyme disease is not spread from person-to-person. Although *B. burdorferi* bacteria do occur in the blood of infected people, no case of Lyme disease has ever been linked to blood transfusion. Infection of a pregnant woman can lead to complications, including possible stillbirth, but these can be avoided by appropriate antibiotic treatment of the

mother. Dogs and cats can get Lyme disease (there is a vaccine for dogs) but there is no evidence that they can spread the disease to their owner. However, pets should be treated with tick control products to prevent them from bringing ticks into your home and yard. You cannot get Lyme disease from eating venison or squirrels. However, as a general precaution, meat should always be cooked thoroughly. There is no evidence to suggest transmission by other means such as food, water, or the bites of other blood-feeding insects like mosquitoes or fleas.

Does Lyme disease occur in Virginia?

Lyme disease has been mostly localized to the northeastern, mid-Atlantic, and upper north-central regions of the United States. In the southeast, a wider range of hosts for the immature ticks effectively decreases the potential for contact with infected rodent reservoirs, resulting in a lower prevalence of disease. In the past decade, however, there has been an increase in the number of reported cases in Virginia (Figure 4).

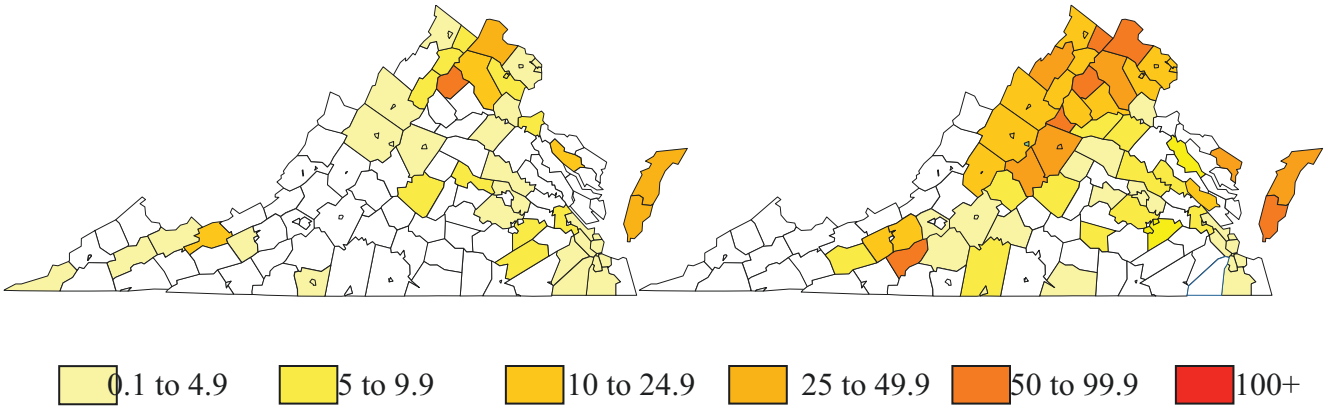

Figure 4: The expanding distribution and increasing prevalence of Lyme disease in Virginia (VDH).

What are the symptoms of Lyme disease?

Early symptoms include flu-like illness with headache, fever, muscle and joint aches, and fatigue. In about 70-80% of the cases, a characteristic circular rash will form that gradually enlarges over the course of about a week. Eventually, the rash may be as large as 12 inches in diameter with a clear center, giving it a bull's-eye appearance (Figure 5). If untreated, the disease will spread to other parts of the body and cause a variety of symptoms such as tiredness, body aches, and headache. Arthritis may develop after several months. Some neurological symptoms that may occur include stiff neck, meningitis, Bell's palsy, poor muscle movement, numbness, pain, or weakness in the limbs, memory loss, difficulty with concentration, and change in mood or sleep habits. A few people, less than 1 out of 10, will develop heart problems such as an irregular heartbeat. Rarely, eye inflammation, liver disease, and severe fatigue can occur.

Figure 5: The characteristic bull's-eye rash of Lyme disease. (Cwandless, 2010)

What is the treatment for Lyme disease?
Lyme disease can be cured by treatment with antibiotics but it is important to start treatment early to avoid complications. A small number of patients may continue to show symptoms for months to years after antibiotic treatment. These chronic symptoms include muscle and joint pain, arthritis, fatigue, cognitive impairment, and sleep disturbance (CDC). The cause of these symptoms is not known and treatment is controversial

What is the timeline of disease?
If the tick is removed within the first twenty-four hours, Lyme disease cannot be transferred. The tick must be attached to the skin for at least twenty-four hours for transmission to occur The rash occurs between three and thirty days after a person is bitten (CDC). Anyone developing a rash or flu-like illness after a tick bite should see a physician.

How can Lyme disease be prevented?
The best way to avoid Lyme disease is to prevent tick bites. This can be accomplished by employing a number of simple steps.

Step 1: Avoid contact with ticks:
- Take extra precautions during the warm weather months.
- Limit exposure to tall grasses, wooded areas, bushes and leaf piles.
- Walk in the center of trails while hiking.
- Wear long-sleeved shirts fastened at the cuff and long pants tucked into boots or socks.

Step 2: Repel ticks with permethrin or DEET:
- Clothing and gear can be treated with permethrin.
- Spray an insect repellent containing Deet (≥ 20%) on the skin. Be sure to follow label instructions.
- The Environmental Protection Agency (EPA) has a list of other repellents that can be used (http://cfpub.epa.gov/oppref/insect/).

Step 3: Detection and prompt removal of ticks:
- Wear light colored clothing for easy detection of ticks.
- Check yourself and others (including pets) after any outdoor activities.

- Shower within 2 hours of coming indoors.

Step 4: Prevent ticks in the yard:

- Treat your yard with pesticides to kill the ticks. Be sure to first familiarize yourself with the rules and regulations related to pesticide application on residential properties as determined by the EPA and your state.
- Create a tick-safe zone. Remove habitat for ticks and their rodent hosts by cutting tall grass and brush, mowing frequently, stacking wood neatly in a dry area, and getting rid of any old furniture, mattresses or trash. Discourage unwelcome animals such as deer and raccoons from entering your yard by constructing fences. Create barriers with wood chips or gravel between your yard and wooded areas to prevent tick migration.

How can I protect my pet from Lyme disease?

Both dogs and cats can contract Lyme disease. Methods to reduce the risk of your pet being exposed are similar to those for people. Check your pet for ticks daily and remove any found quickly. Talk to your veterinarian about treating your pet with acaricides and repellents. A vaccine for Lyme disease is available for dogs, but its use is controversial. Any efforts to reduce ticks in your yard will also benefit your pet.

How should a tick be removed?

Use gloves to protect your fingers with a tissue while removing the tick to decrease further possible contamination. Gently grip the tick with fine-tipped tweezers as close to the skin as possible. Use a gentle and steady pulling action. Try not to squeeze the tick as this may cause the tick to regurgitate, increasing the risk of infection. Don't twist or jerk the tick because this may cause the mouthparts to break off in the skin. After removal, disinfect the bite wound and your hands with alcohol or soap and water. Place the tick in alcohol or in a closed container to kill it. There are many folklore methods such as coating the tick with petroleum jelly or using heat to make the tick detach from the skin. These are not recommended because it is important to remove the tick as quickly as possible to reduce the chance of disease transmission.

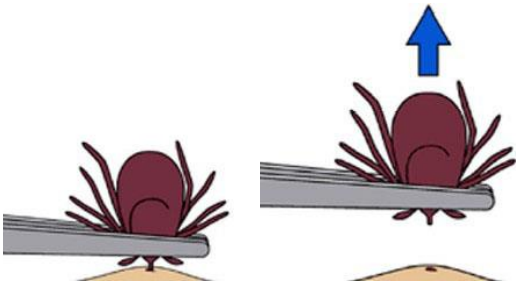

Figure 6. Safe removal of a tick. (CDC)

References: Cwandless. (2010, December 11). Lyme Disease Rash Pictures 2 | Lyme Disease Rash Pictures. *Lyme Disease Rash Pictures*. Retrieved February 8, 2011, from http://lymediseaserashpictures.com/lyme-disease-rash-pictures-2/.

For additional information on Lyme disease, visit the Virginia Department of Health (http://www.vdh.state.va.us)or the Centers for Disease Control and Prevention (http://www.cdc.gov) websites.

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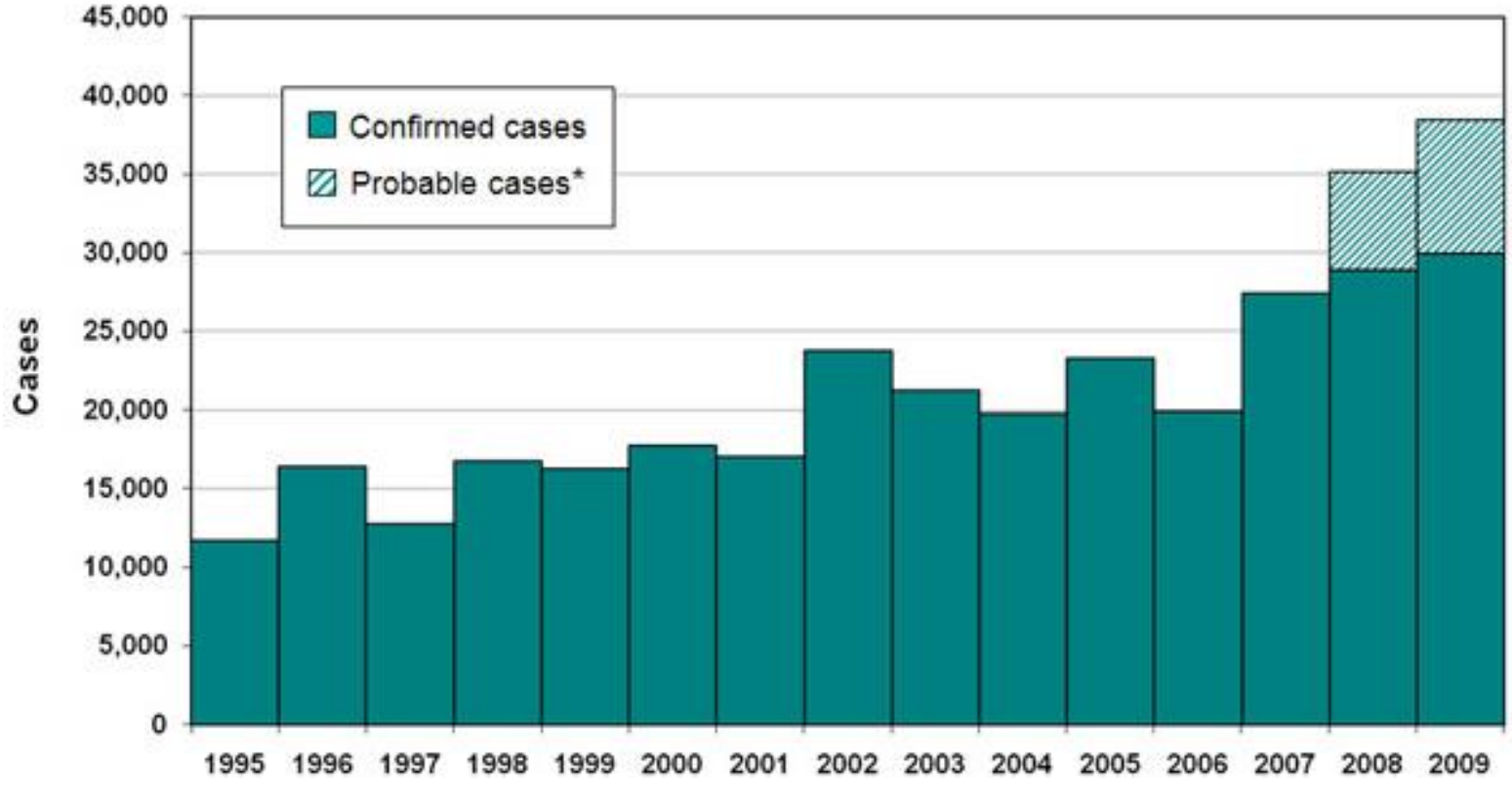
Appendix A

Reported Cases of Lyme Disease by Year, United States, 1995 – 2009

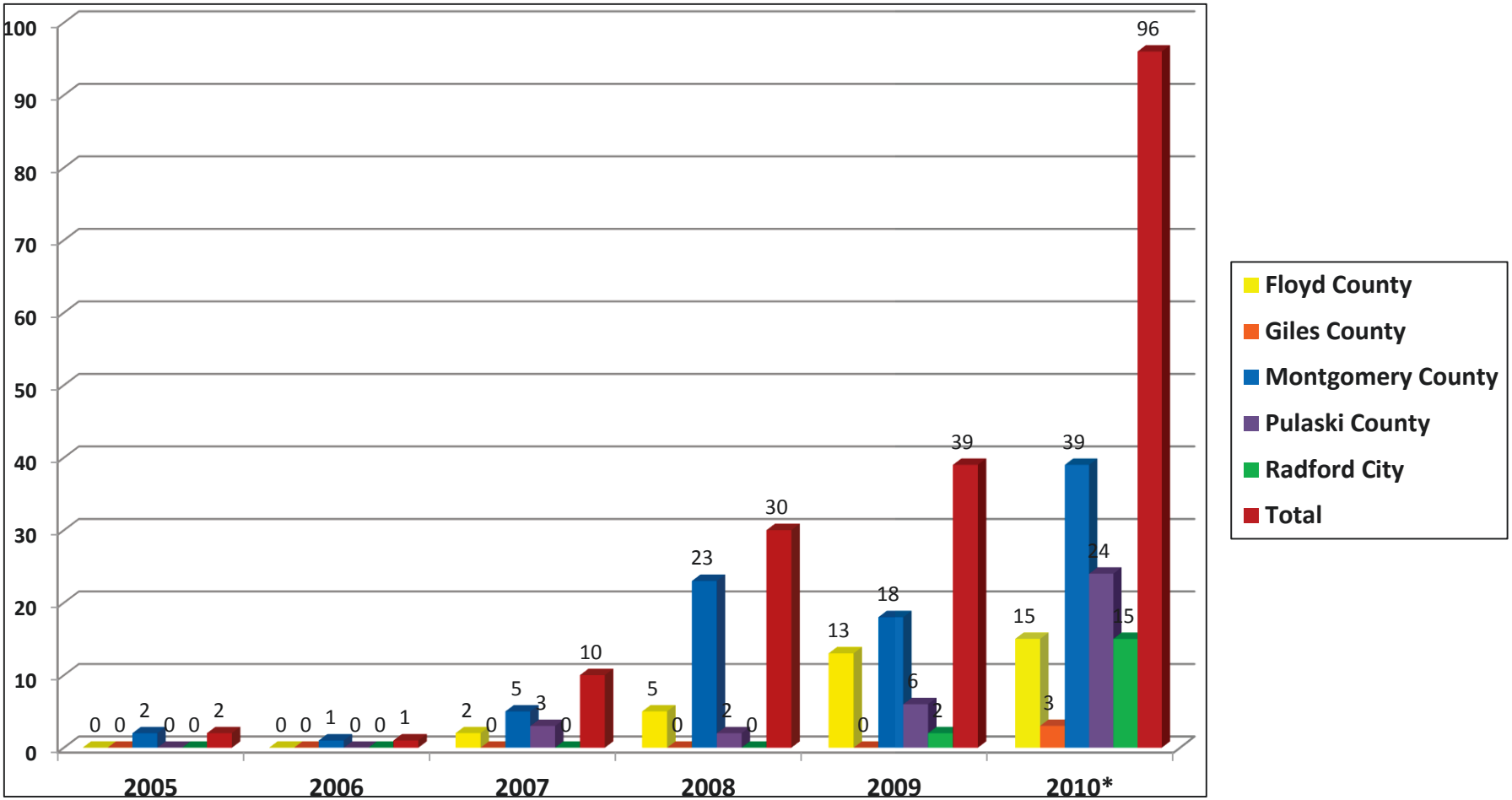


*National Surveillance case definition revised in 2008 to include probable cases:

Details at http://www.cdc.gov/ncidod/dvbid/lyme/ld_UpClimbLymeDis.htm

Appendix B

Number of Lyme Disease Cases per County/City for the New River Health District 2005 – 2010



*2010 statistical information is provisional and therefore subject to change

Lyme Disease Fact Sheet

Fact Sheet for Masters of Agricultural and Life Sciences Project and Report

What is Lyme disease?
Lyme disease is the most common vector-borne illness in the United States (Figure 1). The causative agent is a corkscrew shaped bacterium called *Borellia burgdorferi*.

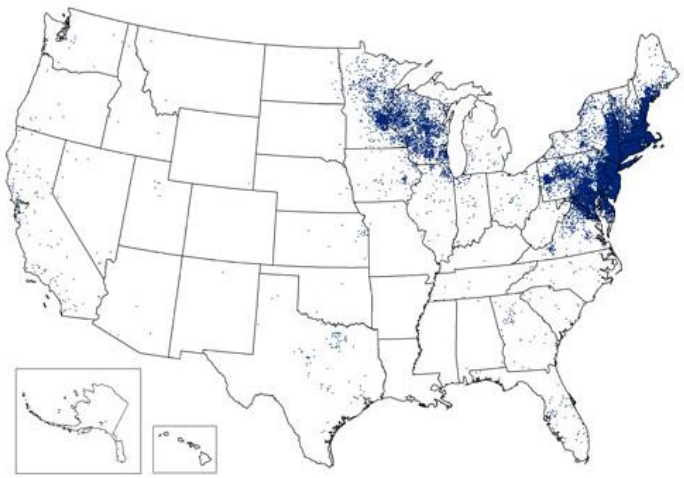
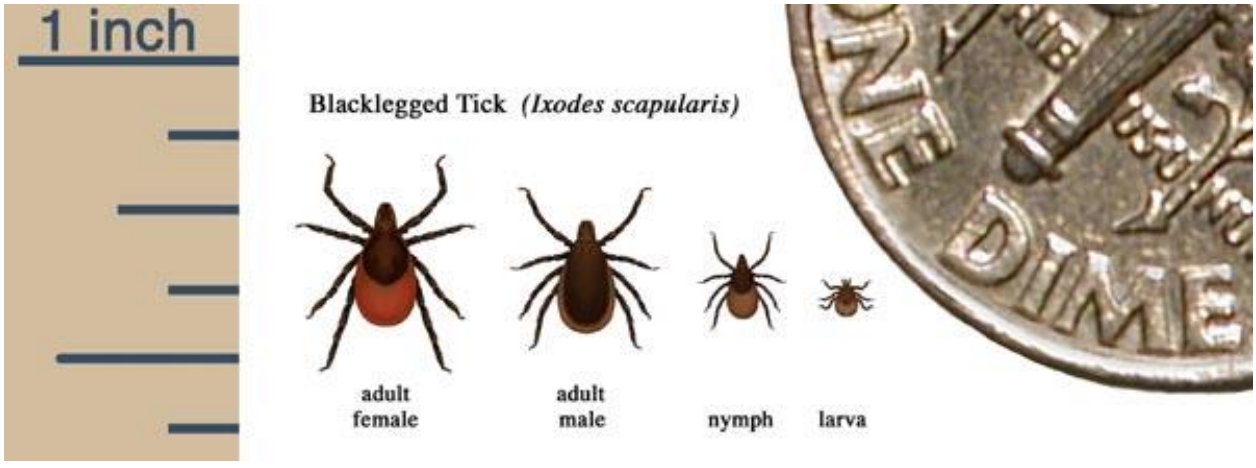


Figure 1: Reported cases of Lyme disease, 2009 (CDC).

How is Lyme disease spread?
Lyme disease is transmitted by the bite of the tick *Ixodes scapularis*, sometimes called the deer tick or blacklegged tick
(Figure 2).



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What is the life cycle of the tick?
It is important to study the life cycle of the tick vector to understand the seasonal risk pattern of Lyme disease. Deer ticks have 4 life stages (egg, larva, nymph, adult) and it takes 2 years to complete their life cycle (Figure 3). Larval ticks hatch from the egg in the summer and feed on small animal hosts such as rodents. Upon feeding on an infected animal, the tick ingests the bacteria along with the blood and becomes infected for life. The larva drops off its host, becomes inactive, and molts into the nymph. The following spring, the infected nymphs become active and feed on a wide variety of hosts, including people. Because the tiny nymph often goes unnoticed, this is the stage that is most likely to transmit Lyme disease to people. That is why human cases are more common in the late spring and early summer when the nymphs are most active. After feeding, the nymph molts into the adult. The adult ticks feed on large animals such as deer, but will also feed on humans. In the spring, the female tick lays her eggs and completes the life cycle.

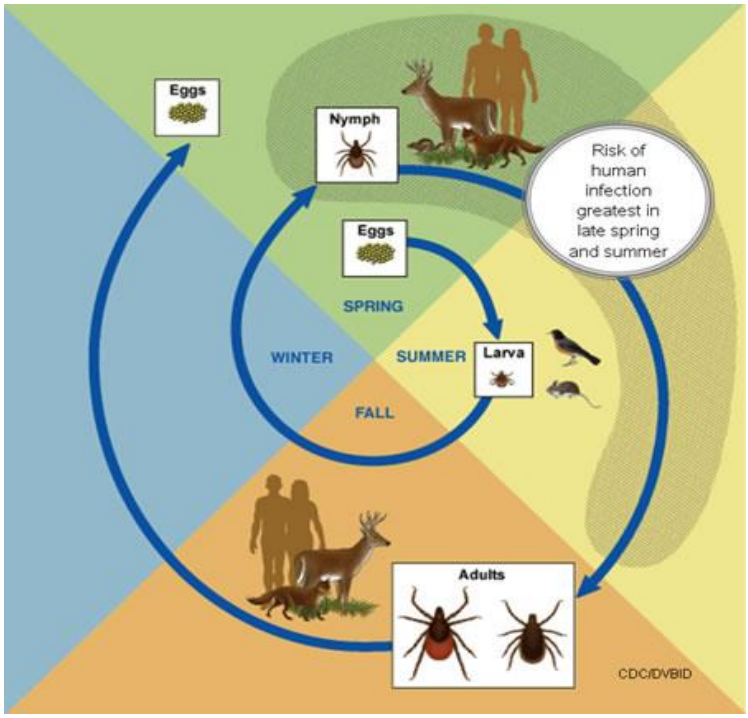

Figure 3: The life cycle of the deer tick (CDC).

Who can get Lyme disease?
Anyone can get Lyme disease at any age. Those that spend significant time outdoors (either working or leisure) have an increased risk of coming in contact with infected ticks.

Are there other ways to get infected with Lyme disease?
Lyme disease is not spread from person-to-person. Although *B. burdorferi* bacteria do occur in the blood of infected people, no case of Lyme disease has ever been linked to blood transfusion. Infection of a pregnant woman can lead to complications, including possible stillbirth, but these can be avoided by appropriate antibiotic treatment of the

mother. Dogs and cats can get Lyme disease (there is a vaccine for dogs) but there is no evidence that they can spread the disease to their owner. However, pets should be treated with tick control products to prevent them from bringing ticks into your home and yard. You cannot get Lyme disease from eating venison or squirrels. However, as a general precaution, meat should always be cooked thoroughly. There is no evidence to suggest transmission by other means such as food, water, or the bites of other blood-feeding insects like mosquitoes or fleas.

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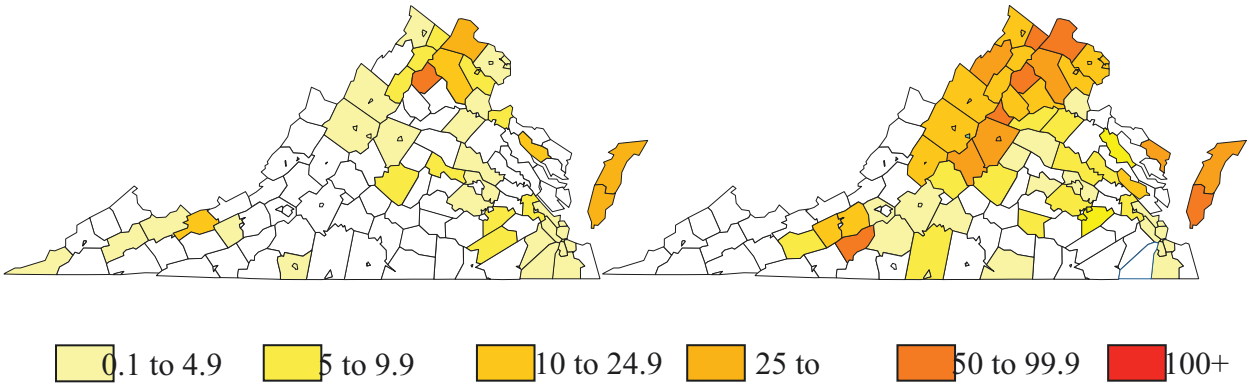

Figure 4: The expanding distribution and increasing prevalence of Lyme disease in Virginia (VDH).

What are the symptoms of Lyme disease?

Early symptoms include flu-like illness with headache, fever, muscle and joint aches, and fatigue. In about 70-80% of the cases, a characteristic circular rash will form that gradually enlarges over the course of about a week. Eventually, the rash may be as large as 12 inches in diameter with a clear center, giving it a bull's-eye appearance (Figure 5). If untreated, the disease will spread to other parts of the body and cause a variety of symptoms such as tiredness, body aches, and headache. Arthritis may develop after several months. Some neurological symptoms that may occur include stiff neck, meningitis, Bell's palsy, poor muscle movement, numbness, pain, or weakness in the limbs, memory loss, difficulty with concentration, and change in mood or sleep habits. A few people, less than 1 out of 10, will develop heart problems such as an irregular heartbeat. Rarely, eye inflammation, liver disease, and severe fatigue can occur.

Figure 5: The characteristic bull's-eye rash of Lyme disease. (Cwandless, 2010)

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How can Lyme disease be prevented?
The best way to avoid Lyme disease is to prevent tick bites. This can be accomplished by employing a number of simple steps.

Step 1: Avoid contact with ticks:
- Take extra precautions during the warm weather months.
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- Wear long-sleeved shirts fastened at the cuff and long pants tucked into boots or socks.

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- Spray an insect repellent containing Deet (≥ 20%) on the skin. Be sure to follow label instructions.
- The Environmental Protection Agency (EPA) has a list of other repellents that can be used (http://cfpub.epa.gov/oppref/insect/).

Step 3: Detection and prompt removal of ticks:
- Wear light colored clothing for easy detection of ticks.
- Check yourself and others (including pets) after any outdoor activities.

- Shower within 2 hours of coming indoors.

Step 4: Prevent ticks in the yard:

- Treat your yard with pesticides to kill the ticks. Be sure to first familiarize yourself with the rules and regulations related to pesticide application on residential properties as determined by the EPA and your state.
- Create a tick-safe zone. Remove habitat for ticks and their rodent hosts by cutting tall grass and brush, mowing frequently, stacking wood neatly in a dry area, and getting rid of any old furniture, mattresses or trash. Discourage unwelcome animals such as deer and raccoons from entering your yard by constructing fences. Create barriers with wood chips or gravel between your yard and wooded areas to prevent tick migration.

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How should a tick be removed?

Use gloves to protect your fingers with a tissue while removing the tick to decrease further possible contamination. Gently grip the tick with fine-tipped tweezers as close to the skin as possible. Use a gentle and steady pulling action. Try not to squeeze the tick as this may cause the tick to regurgitate, increasing the risk of infection. Don't twist or jerk the tick because this may cause the mouthparts to break off in the skin. After removal, disinfect the bite wound and your hands with alcohol or soap and water. Place the tick in alcohol or in a closed container to kill it. There are many folklore methods such as coating the tick with petroleum jelly or using heat to make the tick detach from the skin. These are not recommended because it is important to remove the tick as quickly as possible to reduce the chance of disease transmission.

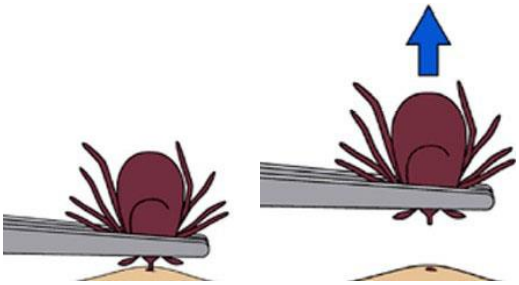


Figure 6. Safe removal of a tick. (CDC)

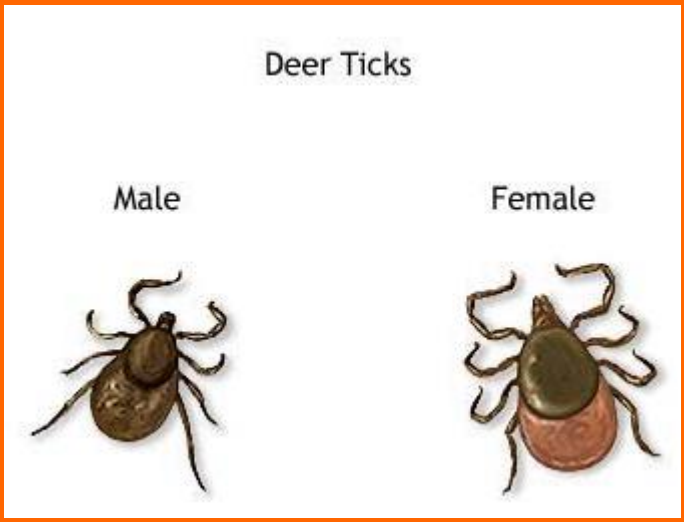
References: Cwandless. (2010, December 11). Lyme Disease Rash Pictures 2 | Lyme Disease Rash Pictures. *Lyme Disease Rash Pictures*. Retrieved February 8, 2011, from http://lymediseaserashpictures.com/lyme-disease-rash-pictures-2/.

For additional information on Lyme disease, visit the Virginia Department of Health (http://www.vdh.state.va.us)or the Centers for Disease Control and Prevention (http://www.cdc.gov) websites.

Appendix D

LYME DISEASE

HUNTERS NEEDED



I am resident of the New River Valley and I am doing a project at Virginia Tech involving the study of ticks for Lyme disease. I need the assistance of local hunters. I need hunters who will agree to check any game killed (and themselves) for ticks. I will provide you with a vial in which to place the tick. Labels and a pencil are also provided to fill in needed information to conduct the study. Please contact: Eric Sheppard at 540-231-6836 or eshepp20@vt.edu.

Eric Sheppard
540-231-6836
eshepp20@vt.edu

Eric Sheppard
540-231-6836
eshepp20@vt.edu
Eric Sheppard
540-231-6836
eshepp20@vt.edu
Eric Sheppard
540-231-6836
eshepp20@vt.edu
Eric Sheppard
540-231-6836
eshepp20@vt.edu
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540-231-6836
eshepp20@vt.edu
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eshepp20@vt.edu
Eric Sheppard
540-231-6836
eshepp20@vt.edu
Eric Sheppard
540-231-6836
eshepp20@vt.edu
Eric Sheppard
540-231-6836
eshepp20@vt.edu
Eric Sheppard
540-231-6836
eshepp20@vt.edu

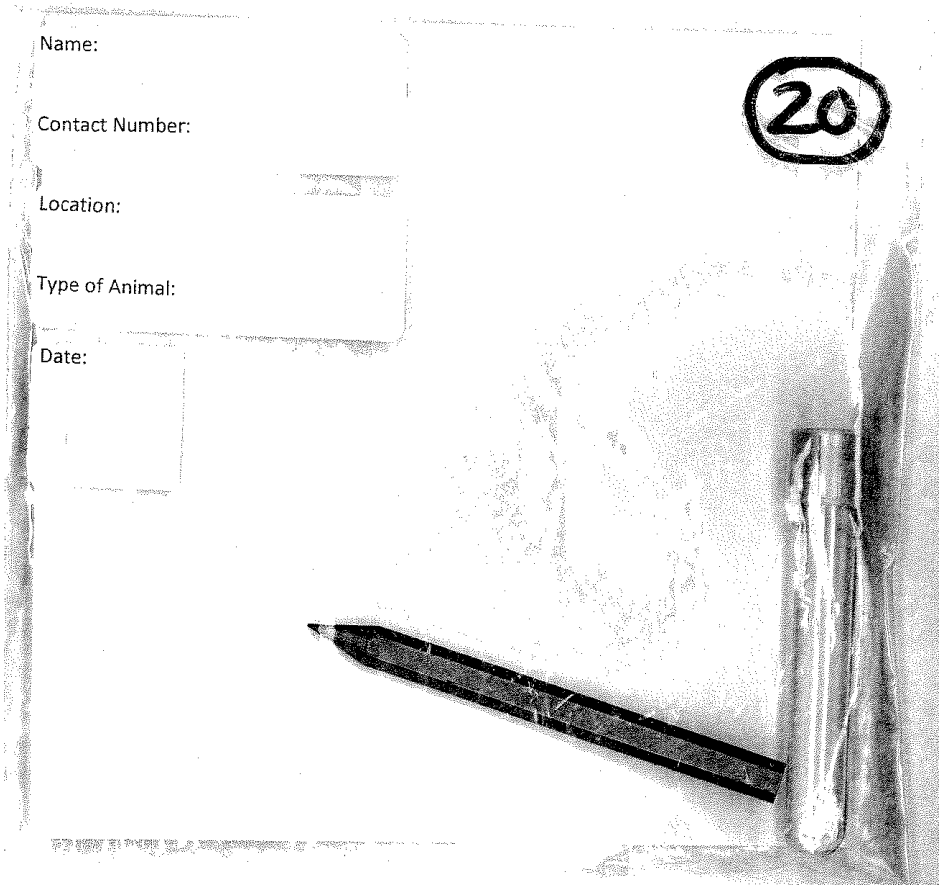
Appendix E

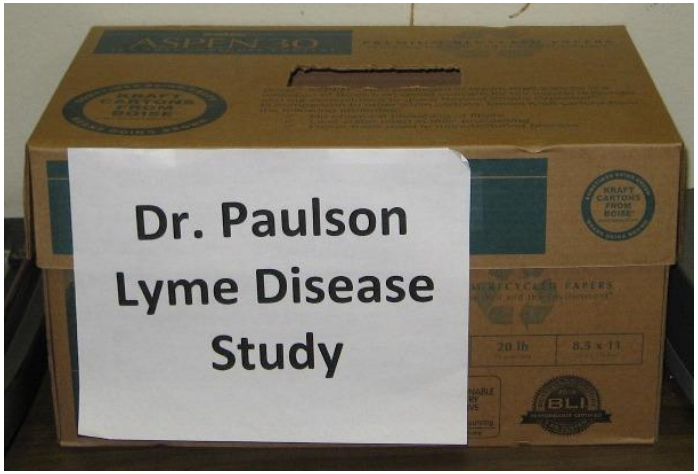
Locations for Fliers

1. Moore's Body Shop ..... Blacksburg, VA
2. Miller's Gun Shop ..... Christiansburg, VA
3. Sidekick Gunsmith ..... Christiansburg, VA
4. J&J Market ..... Floyd, VA
5. West End Market ..... Floyd, VA
6. Super Val-u ..... Newport, VA
7. Hilltop Grocery ..... Pembroke, VA
8. Little Giant ..... Pembroke, VA
9. Pembroke Stop & Save ..... Pembroke, VA
10. Pilot Mountain Grocery ..... Pilot, VA
11. 5C Farm & Home Supply ..... Pulaski, VA
12. Cougar Xpress ..... Pulaski, VA
13. Deli Mart ..... Pulaski, VA
14. Tractor Supply ..... Pulaski, VA
15. Whitetail Outfitters ..... Riner, VA

Appendix F

Data Collection Package





Appendix G

Spreadsheet used to Track Data

Date	Location	Host	Engorged yes/no	N/A	Male/Female	Species
10/31/2010	Giles	Dog	Yes	Adult	Female	I. scapularis
11/1/2010	Floyd	Pony	No	Adult	Female	I. scapularis
11/1/2010	Floyd	Pony	No	Adult	Male	I. scapularis
11/1/2010	Montgomery	Dog	Yes	Adult	Female	I. scapularis
11/1/2010	Montgomery	Dog	Yes	Adult	Female	I. scapularis
11/1/2010	Montgomery	Dog	Yes	Adult	Female	I. scapularis
11/1/2010	Montgomery	Dog	Yes	Adult	Female	I. scapularis
11/1/2010	Montgomery	Dog	Yes	Adult	Female	I. scapularis
11/1/2010	Montgomery	Dog	Yes	Adult	Female	Ixodes (no mouthparts)
11/4/2010	Giles	Deer	Yes	Adult	Female	I. scapularis
11/4/2010	Giles	Deer	Yes	Adult	Female	I. scapularis
11/4/2010	Giles	Deer	No	Adult	Male	I. scapularis
11/4/2010	Giles	Deer	No	Adult	Male	I. scapularis
11/4/2010	Giles	Deer	No	Adult	Male	I. scapularis
11/4/2010	Giles	Deer	No	Adult	Male	I. scapularis
11/4/2010	Giles	Deer	No	Adult	Male	I. scapularis
11/4/2010	Montgomery	Dog	Yes	Adult	Female	I. scapularis
11/4/2010	Montgomery	Dog	Yes	Adult	Female	I. scapularis
11/4/2010	Montgomery	Dog	Yes	Adult	Female	I. scapularis
11/4/2010	Giles	Deer	Yes	Adult	Female	Ixodes (no mouthparts)
11/4/2010	Giles	Deer	Yes	Adult	Female	Ixodes (no mouthparts)
11/4/2010	Giles	Deer	Yes	Adult	Female	Ixodes (no mouthparts)
11/4/2010	Giles	Deer	Yes	Adult	Female	Ixodes (no mouthparts)
11/4/2010	Montgomery	Dog	Yes	Adult	Female	Ixodes (no mouthparts)
11/6/2010	Giles	Dog	Yes	Adult	Female	I. scapularis
11/6/2010	Montgomery	Dog	Yes	Adult	Female	I. scapularis
11/6/2010	Montgomery	Dog	Yes	Adult	Female	I. scapularis
11/6/2010	Montgomery	Dog	Yes	Adult	Female	Ixodes (no mouthparts)
11/7/2010	Giles	Dog	No	Adult	Female	I. scapularis
11/7/2010	Giles	Dog	No	Adult	Female	I. scapularis
11/7/2010	Giles	Dog	No	Adult	Male	I. scapularis
11/7/2010	Giles	Dog	No	Adult	Male	I. scapularis

11/7/2010	Giles	Dog	No	Adult	Male	I. scapularis
11/7/2010	Giles	Dog	No	Adult	Male	I. scapularis
11/8/2010	Giles	Deer	Yes	Adult	Female	I. scapularis
11/8/2010	Giles	Deer	Yes	Adult	Female	I. scapularis
11/8/2010	Giles	Deer	Yes	Adult	Female	I. scapularis
11/8/2010	Giles	Deer	Yes	Adult	Female	I. scapularis
11/8/2010	Giles	Deer	Yes	Adult	Female	I. scapularis
11/8/2010	Giles	Deer	Yes	Adult	Female	I. scapularis
11/8/2010	Giles	Deer	No	Adult	Male	I. scapularis
11/8/2010	Giles	Deer	No	Adult	Male	I. scapularis
11/8/2010	Giles	Deer	No	Adult	Male	I. scapularis
11/8/2010	Giles	Deer	No	Adult	Male	I. scapularis
11/8/2010	Giles	Deer	No	Adult	Male	I. scapularis
11/8/2010	Giles	Deer	Yes	Adult	Female	Ixodes (no mouthparts)
11/8/2010	Giles	Deer	Yes	Adult	Female	Ixodes (no mouthparts)
11/8/2010	Giles	Deer	Yes	Adult	Female	Ixodes (no mouthparts)
11/8/2010	Giles	Deer	Yes	Adult	Female	Ixodes (no mouthparts)
11/8/2010	Giles	Deer	Yes	Adult	Female	Ixodes (no mouthparts)
11/8/2010	Giles	Deer	Yes	Adult	Female	Ixodes (no mouthparts)
11/11/2010	Montgomery	Dog	No	Adult	Female	I. scapularis
11/13/2010	Floyd	Dog	No	Adult	Female	I. scapularis
11/13/2010	Floyd	Human	No	Adult	Female	I. scapularis
11/13/2010	Floyd	Dog	No	adult	Male	I. scapularis
11/13/2010	Floyd	Deer	Yes	Adult	Female	Ixodes (no mouthparts)
11/14/2010	Giles	Dog	Yes	Adult	Female	I. scapularis
11/14/2010	Giles	Dog	No	Adult	Male	I. scapularis
11/14/2010	Giles	Dog	No	Adult	Male	I. scapularis
11/15/2010	Pulaski	Dog	Yes	Adult	Female	I. scapularis
11/23/2010	Montgomery	Dog	Yes	Adult	Female	I. scapularis
11/23/2010	Montgomery	Dog	Yes	Adult	Female	Ixodes (no mouthparts)
11/26/2010	Montgomery	Dog	No	Adult	Male	I. scapularis
11/26/2010	Montgomery	Dog	Yes	Adult	Male	I. scapularis
11/27/2010	Montgomery	Dog	Yes	Adult	Female	I. scapularis
11/27/2010	Montgomery	Dog	Yes	Adult	Female	Ixodes (no mouthparts)
11/28/2010	Floyd	Dog	No	adult	Male	I. scapularis

12/5/2010	Montgomery	Dog	Yes	Adult	Female	I. scapularis
12/13/2010	Montgomery	Dog	Yes	Adult	Female	I. scapularis
3/1/2011	Giles	Dog	Yes	Adult	Female	I. scapularis
3/1/2011	Giles	Dog	Yes	Adult	Female	I. scapularis
11/1/2012	Floyd	Cat	Yes	Adult	Female	Ixodes (no mouthparts)
11/1/2012	Floyd	Cat	Yes	Adult	Female	Ixodes (no mouthparts)
11/1/2012	Floyd	Cat	Yes	Adult	Female	Ixodes (no mouthparts)