Lyme Disease: Habitat Fragmentation and the Abundance of White-tailed Deer

by

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Abstract
Lyme disease is a prevalent vector disease that can be found in much of the United States. The tick that carries it, the blacklegged tick, is found in the Eastern part of the United States. This study will look at six counties within the State of Wisconsin to observe the correlation between white-tailed deer population, Lyme disease, and habitat fragmentation; specifically how cropland cover affects the population of white-tailed deer and the number of Lyme disease cases. These counties were chosen because they had a significant amount of Lyme disease cases in 2013. The results of the linear regressions that were ran did not support the hypothesis that in areas with increased cropland acreage there would be a higher population of white-tailed deer which would result in more reported cases of Lyme disease. The severity of Lyme disease is a cause for concern and why studying how it is spread is important.

Introduction
Lyme disease is the most commonly reported vector disease\(^1\) in North America (Lyme Disease: Introduction to Symptoms, Diagnosis and Treatment). It was first discovered in 1909 by a Swedish dermatologist, Arvid Afzelius. Afzelius noticed a ring-shaped rash on a patient who had been bitten by a tick (Daniels, Thomas J., and Richard C. Falco., 1989). It is believed that Lyme disease made its way to the United States from Europe on ships that carried livestock or birds that migrated to the U.S. (Daniels, Thomas J., and Richard C. Falco., 1989) and thrived on the hosts that it found here. It was later discovered again in 1975 in a group of Juvenile Arthritis patients in Lyme, Connecticut (Stafford, 2007). Although it is more common in the Eastern United States (Stafford, 2007), it can be found in the West as well. In 1988 Lyme disease was present in 43 states, compared to the reports now of 49 states. Due to the severity of its symptoms and the novelty of the disease, it was considered a very important disease to study in the country at the time. Since the blacklegged tick is so small, people do not

\(^1\) Definition: an infection transmitted to humans and animals by ticks, mosquitos and fleas (arthropods that feed off of blood).
usually recall being bitten or notice at the time, which is why it usually goes unnoticed (Daniels, Thomas J., and Richard C. Falco., 1989). Even though we know more about Lyme disease it can still go untreated which can lead to severe damage to the human host. However, a bite from the blacklegged tick does not always result in Lyme disease. The chances of actually getting Lyme disease after getting bitten by a tick are low (Prevent Lyme Disease, 2016). The disease is also easily treatable but one of the noticeable symptoms, the bull’s eye rash, doesn’t always appear.

The disease is transferred to humans through the bite of the blacklegged tick (*Ixodes scapularis*), more commonly known as the deer tick or bear tick. Blacklegged ticks can be found places where the white-tailed deer travel, such as tall grasses and forests. The number of Lyme disease cases reported nearly doubled between 1992 and 2006. There are about 30,000 cases reported each year to the Centers for Disease Control (CDC) and Prevention by state health departments. In 2014 there were 25,359 confirmed cases of Lyme disease found in the United States (*Lyme Disease Data Tables*, 2015). Wisconsin alone had 1,740 confirmed cases of Lyme disease reported in 2013 ("Lyme Disease Cases by County - 2013.", 2016).

As the number of cases of this disease rises it’s becoming more important to study the reasons behind the increase. There are many different factors involved in the spreading of ticks and Lyme disease. These factors include climate change, which would impact the behavior of the tick and or habitat fragmentation, which would directly affect the host community of the tick. Studies have shown that the change in landscape patterns, an abundance of white-tailed deer, and more people moving to forested areas
all increase the potential of coming into contact with the blacklegged tick (Stafford, 2007). There are also studies that show that in an area associated with small fragments of habitat a higher density of the host the white-footed mice can be seen (LoGuidice et al. 2008). The purpose of this study will be to explore the idea of how habitat fragmentation can increase the potential of people coming into contact with ticks. By focusing on the effects of habitat fragmentation on the population of the white-tailed deer (Odocoileus virginianus) and how people are moving closer to deer habitat, a correlation between the amount of deer, how much habitat fragmentation is occurring, and the number of reported cases of Lyme disease could possibly be found.

Literature Review

Lyme Disease

Lyme disease is caused by a bacterium called Borrelia burgdorferi. Borrelia burgdorferi can infect a variety of invertebrates including lizards, and small mammals such as the white-footed mouse. Borrelia burgdorferi is a spirochete\(^2\) that is an obligate tick-borne parasite (Tilly et al. 2008). An obligate tick-borne parasite is a parasite that needs a host to complete its life cycle. If they cannot get a host then it cannot reproduce. These bacteria can infect a variety of hosts, mostly small mammals. These small mammals carry this bacteria but are not infected by the disease. However, ticks in their larval stage can contract it if they get their blood meal from an animal that is infected with Borrelia burgdorferi. The only method of transmission to humans of this bacterium is through the bite of the blacklegged tick. The blacklegged tick can attach

\(^2\) A bacteria with long helically coiled cells.
itself to any part of the human body but is found in mostly well-hidden places like the scalp and armpit. The tick must be attached to its host for 36 to 46 hours before Lyme disease can be transmitted (Transmission, 2015). The longer the tick is attached the higher the chance of getting the disease (Stafford, 2007). When a tick latches itself to a person and begins to take their blood meal the dormant spirochete begin to multiply and move to the salivary glands of the tick. Once they reach the glands they begin to alter the proteins on the outer surface (Stafford, 2007). The reason that humans are affected by this bacterium is because we have an immunopathological response to Borrelia burgdorferi and this response results in Lyme disease.

Lyme disease can induce many symptoms throughout multiple stages after the initial bite. It can take from three to thirty days for the early symptoms to start to show. These symptoms include a fever, rash, swollen lymph nodes, muscle and joint ache, fatigue, headaches, and chills. The type of rash that is common to appear on the skin is called the Erythema Migrans rash (EM). The rash can spread up twelve inches of the skin or more. The rash does not produce an itch but can possibly feel warm to the touch, and can happen anywhere on the body. This appears in about 70% to 80% of people infected with Lyme disease (Signs and Symptoms of Untreated Lyme Disease, 2015). These symptoms may not happen all at once.

Approximately thirty days after contraction, symptoms that can occur are stiff neck, worse headaches, more EM rashes, severe joint pain that can often cause arthritis in larger joints, and loss of muscle tone in the face that cause either one or both

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3 The disease has an impact on the immune system.
After a few months, if untreated, more severe symptoms can occur. Many times symptoms will go untreated because people do not recognize them as symptoms of Lyme disease. These include an irregular heartbeat (heart palpitations), inflammation of the brain and/or spinal cord and problems with short-term memory (*Signs and Symptoms of Untreated Lyme Disease, 2015*). With reported cases amounting to around 30,000 a year and the symptoms of the disease being so severe, extensive research is being done to figure out how to lower the risk of contracting Lyme disease. A factor that is prominent in these studies is the carrier of the disease- the blacklegged tick.

**Blacklegged Tick (*Ixodes scapularis*)**

The blacklegged tick is the prime carrier of Lyme disease. This tick goes through an incomplete metamorphosis: they start as eggs, move onto a larva stage then from their nymph stage in which they finally develop into their adult form. They can live up to three years and they feed very slowly. Their feeding process can take from three to five days, which is just enough time for Lyme disease to be transmitted to a human. It takes approximately one to two days for Lyme disease to infect a human host (*Tick-Transmitted Diseases, 2014*).
Figure 1. Life cycle of the Blacklegged tick Source: (Stafford, 2007)

Figure 1 shows the female blacklegged tick lays her eggs in the fall, once she has done this she has completed her life cycle. The eggs can now begin their life cycle where they will hatch between May and September and turn into larvae. The larvae are very small and do not carry any diseases at this point. They can however pick up the disease in their first blood meal if the host has the bacterium *Borrelia burgdorferi*. Once they feed from an infected host that larva becomes infected and is now able to transmit the disease to its next meal. Larvae usually feed on smaller mammals such as the white-footed mouse, which can infect the larvae who are not already infected (*Tick-Transmitted Diseases*, 2014).

The larvae then molt into the next stage of their life, which is a nymph. Once their molting process is finished they go dormant throughout the winter. As you can see in Figure 1 between May and early July nymphs take their second meal from a mammal. From this feeding they can transmit the disease. If at this point the nymph didn’t receive...
the disease in their larva stage they can pick it up from their first feeding as a nymph (Tick-Transmitted Diseases, 2014).

In their adult stage females become larger than males. Their color can either be orange or red and their bodies will start to enlarge once they fill with blood after their feedings. The female tick will get their blood meal from a large mammal such as the white-tailed deer. Up to 90% of ticks feed on deer and these ticks can lay up to 3,000 eggs (Stafford, 2007). They will also mate on the mammal. If they do not feed in the fall then they will go dormant throughout the winter and wait until spring for their next blood meal. Once a female finds a host the feeding process will take several days to happen. The end of the female’s life is mating, laying her eggs, and then dying. She can only lay her eggs once she has received a blood meal. A male blacklegged tick will attach to a host but they do not take a blood meal and are therefore unable to transfer any diseases. A frost will not kill a tick and sometimes ticks can be seen being active during winter if the temperature is above freezing (Tick-Transmitted Diseases, 2014). Female ticks feed by inserting their mouthparts into the skin of their host and taking the blood. This can take three to five days because they are slow feeders (Tick-Transmitted Diseases, 2014).

The blacklegged tick can be found in wooded areas with lots of brush and grass that they can cling on to. They can also be found close to homes and parks. White-tailed deer will carry ticks to yards, those ticks will cling to the top of grass where they wait for an animal or human to walk by that they can grab onto. The blacklegged tick is located in the Northeastern and Midwestern part of the United States (Figure 2).
the geographic range of the blacklegged tick is quite large. It covers all of the east coast, half of the south, and a section of the midwest. It is unclear why there is a band in southern Illinois and areas surrounding it without ticks. In the west, a different tick species *Ixodes pacificus*, carries the spirochete.

*Figure 2.* This map strictly shows the range of Blacklegged tick in the United States.

Source: http://www.cdc.gov/

The white-tailed deer shares a similar geographic range with the blacklegged tick, which is why it’s a common host.

**White-tailed Deer (*Odocoileus virginianus*)**

The white-tailed deer lives in wooded areas and forages for food in tall grasses during the early parts of the day and into the afternoon (White-tailed Deer - Odocoileus Virginianus). They can carry the adult form of the *Ixodes scapularis* and spread it throughout different areas causing an increase in Lyme disease. The white-tailed deer
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can be found almost everywhere in the United States and in the southern areas of Canada. There is high density of deer in Wisconsin and surrounding areas (Figure 3). Some areas of the state even have greater than 45 deer per square mile. The range that they live in can usually be measured at less than a square mile. (White-tailed Deer - *Odocoileus virginianus*). These animals have two different mating seasons depending on where they live. The northern deer tend to mate later in the year around the month of November. While the southern deer tend to mate earlier in the year during the months of January and February. After finding a suitable mate, the doe is pregnant for six months before giving birth to about one to three fawns. These fawns then stay with their mother until they are around one to two years old before going off on their own (White-tailed Deer - *Odocoileus virginianus*).

The white-tailed deer is highly suitable to study when looking at the spread of Lyme disease because they are important hosts to the blacklegged tick. Studies have shown that the decrease of deer populations can lower the amount of larvae and nymphs found on mice. A study done in Great Island, Massachusetts showed that reducing deer population by 97% resulted in a 50-55% reduction in the larvae and nymphs of the tick (Stafford, 2007). In Bluff Point Coastal Preserve in Connecticut, data showed that reducing deer population down from 200/mi² to around 30/mi², an 84% decrease, resulted in a >90% decline in tick abundance. That’s 100/mi² down to 1/100mi² (Stafford, 2007). However, as much as reducing deer populations lowers the amount of ticks in an area, it is unclear if we can reduce deer populations enough to lower the amount of amount ticks and Lyme disease cases to the point that is wanted.
This point being a vague lowering of the Lyme disease cases. Total eradication of the disease is unlikely, however lowering the numbers is a reasonable goal.

![Map of deer population density released in 2008 by the Quality Deer Management Association (QDMA)](http://www.i-maps.com)

**Figure 3.** Map of deer population density released in 2008 by the Quality Deer Management Association (QDMA)

Source: [http://www.i-maps.com](http://www.i-maps.com)

There is plenty of data available on white-tailed deer and not so much on the other mammals that can carry this disease. This is because deer are much easier to track and count because of their size and abundance, while smaller mammals are harder to track. There has been a lot of research done on how regulating deer populations are helpful in regulating tick abundance. Another important factor to study is habitat fragmentation, to see how that affects the deer and tick populations. Deer move
from place to place for a variety of reasons. Two of them are to find resources and avoid any kind of danger. Many deer find food in gardens or farms and avoid the risk of cars by taking advantage of the edge effect caused by forest fragmentation. In a paper written on how landscape structures influence how white-tailed deer use their space mentioned that a forested landscape with patches edging urban areas are a suitable habitat for deer because of their productivity and structural complexity. They found that deer populations are about 67% in forests and 29.6% in agricultural areas because these areas have important resources for deer. Another study implicated that the edge effect was prevalent in the increase of parasitism (Alverson et al. 1988).

**Habitat Fragmentation**

Habitat fragmentation is defined as larger chunks of habitat being divided into smaller, more isolated areas, leading to loss of habitat in those areas. There are many factors that can cause habitat fragmentation. The building of roads can cut through a habitat; the building of cities and other urban areas can cause the loss of habitat, agriculture is another form of habitat fragmentation. This habitat loss happens at landscape levels. Habitat fragmentation is one of the leading causes of extinctions and declines in species (Stafford, 2007).

When talking about cropland, the original vegetation is removed and replaced with another type of vegetation. For deer this can be helpful for them because of the edge effect that is caused by this form of habitat fragmentation. And while it was mentioned earlier that the regulating of deer population can be a helpful thing this study will focus more on how habitat fragmentation increases the possibility of people coming
into contact with ticks and getting Lyme disease.

Habitat fragmentation can be very complex. If the shape of the habitat is more complex then there can be an increase in edge-affected habitat. Edge-affected habitat is looking at the change in between two different habitats. And an edge-affected habitat accompanies a reduced core area in that same habitat. Edge-affected habitat is a very suitable form of habitat fragmentation for white-tailed deer to strive. An example of edge-affected habitat is when a forest meets cropland. This is a very good environment for the deer because they can eat the crops and then quickly move back into the safety of the forest that is nearby. This could possibly result in bringing white-tailed deer closer to human populations, which in turn can bring Lyme disease closer to human population.

Another example of the edge-effect that would bring would bring deer populations closer to humans would be parks and nature preserves. Many of these areas allow humans to walk along trails throughout the woods where deer live. These trails can be wide or narrow but they create fragments in the forest that are considered “islands”. This is based off of the theory of island biogeography. The number of species in these “islands” all depend on the island’s area and how isolated these areas are (Bennett, Andrew F., and Denis A. Saunders., 2011). Therefore, a larger forested area may have more trails running through it but may have larger fragmented areas. More species can live in these areas but also more trails possibly mean more foot traffic.

These parks or preserves also might have a parking lot or multiple parking lots running through them. These could cut directly through a forested area of the park
and cause fragmented areas. Deer are unlikely to cross these areas because of human presence and the risk of danger caused by cars passing through. This will lead to areas of the forest having a denser population of deer and this can increase the chance of people coming into contact with a blacklegged tick. This is because if there are more deer in an area then there is a higher chance of a tick latching onto a deer for a meal than some other animal. If this deer is confined to one area because of the humanmade fragments then they will carry the tick around in this area other than traveling to a new area and the tick dropping off there.

Is there a relationship between habitat fragmentation, white-tailed deer population and the amount of Lyme disease cases reported in an area? My hypothesis is that in areas with higher acreage of cropland coverage near forested areas, compared to areas with lower acreage of cropland coverage, will have a higher white-tailed deer population and in turn have a higher amount of Lyme disease cases reported.

Methods

The data used was collected from data.gov, cdc.gov and the United States Department of Agriculture. Deer populations around the year of 2013 were used along with reported cases of Lyme disease and the acreage of three different cropland covers in the six counties chosen.

The data for habitat fragmentation comes from the USDA cropland cover website, https://nassgeodata.gmu.edu/CropScape/. The three crops with the highest coverage (by acreage) were chosen. The acreage of these areas was counted by
number and not by percentage. These three crops are corn, deciduous forest and grass/pasture. Next the amount of reported cases of Lyme disease in the counties of Wisconsin was pulled from the CDC website where they release the data; this data was from 2013 as well. And finally data for white-tailed deer population was taken from the Wisconsin DNR. It was found in the White-tailed Deer Population Status from 2014, this population status report contained deer population numbers from 2013 and 2014. The population numbers from the year 2013 were selected to match the other data.

Data was collected across different southern counties in Wisconsin. The counties were chosen based off of the number of Lyme disease cases reported in them. The counties with 30 cases or more have been picked. These counties, as seen in Figure 4 below, include Columbia, Dane, Sauk, Vernon, Richland and Waukesha. All of these counties are in the southern farmlands of Wisconsin. These counties have a high number of white-tailed deer population, Lyme disease cases and cropland coverage, hence why they were picked. First a linear regression analysis was ran to determine if there is a significant relationship between the reported Lyme disease cases and the population of white-tailed deer in an area. The independent variable is the number of white-tailed deer and the dependent variable is the amount of reported Lyme disease cases. Three separate linear regressions will be done on deer population, corn, deciduous forest and pastures/grass. For the first regression it will be deer population, the dependent variable and corn, the independent variable. This regression will show if there is a correlation between how much corn acreage there is and the amount of white-tailed deer present. The second regression will show the same thing except with
deciduous forest. Deciduous forest will become the independent variable. And finally a third regression will show the relationship between pasture/grass acreage and white-tailed deer population. And in the future a multiple regression will be ran on all four variables.
Figure 4. Images of all six of the counties in southern Wisconsin with more than 30 cases of Lyme disease reported and agriculture and non-agriculture shown from 2013.

(Source: “CropScape - Cropland Data Layer”, 2017)
Results

There is no correlation between number of Lyme disease cases and deer population (Figure 5, $p=.592$). That means that there is a probability of 59% that Lyme disease cases and deer populations are correlated. However, since the $p$-value is above .05 we are unable to reject the null hypothesis and the data is found statistically insignificant. The $r^2$ indicates that there is a 7% chance that the population of deer has an effect on the variance in Lyme disease.

![Lyme Disease Cases vs White-tailed Deer Population](image)

**Figure 5.** Lyme Disease Cases vs White-tailed Deer Population, this graph shows the correlation between white-tailed deer population (source: Rolley, Robert E., 2014) and Lyme disease cases (source: "Lyme Disease Cases by County - 2013.", 2016).
The factors compared were population and corn acreage. The scatter plot shows the relationship between white-tailed deer population and corn acreage. The $r^2$ (Figure 6) shows that there is a 4% chance that corn acreage has an effect on the variance of white-tailed deer population. Since the p-value is above .05 then we fail to reject the null hypothesis and the data was found statistically insignificant. There is, however, a 69% probability that the two variables are related.

![White-tailed Deer Population vs. Corn](image)

**Figure 6.** White-tailed Deer Population vs. Corn, this graph shows the correlation between the deer population (source: Rolley, Robert E., 2014) and the acreage of corn (source: *CropScape - Cropland Data Layer, 2013*) in the counties.
The next two factors compared were population and deciduous forest acreage. A scatterplot was created to show the statistical relationship between deer population and the acreage of forest. The $r^2$ is .58874 (Figure 7) meaning that there is a 58% chance that the acreage of deciduous forest has an effect on the variance of white-tailed deer population. Since the p-value (.075) is above .05 then we fail to reject the null hypothesis and the data was found statistically insignificant.

![White-tailed Deer Population vs. Deciduous Forest](image.png)

**Figure 7.** White-tailed Deer Population vs. Deciduous Forest, this graph shows the correlation between the deer population (source: Rolley, Robert E., 2014) and the acreage of deciduous forest (source: CropScape - Cropland Data Layer, 2013) in the counties.

The final two factors compared were population and pasture/grass acreage. The $r^2$ (Figure 8) indicates there is a 32% chance of pasture/grass acreage having an effect on the variance of deer population. The p-value shows that there is a 24% chance of the
two being related, however since the p-value is over .05 the data was found statistically significant and we fail to reject the null hypothesis.

![White-tailed Deer Population vs. Pasture/Grass](image)

**Figure 8.** White-tailed Deer Population vs. Pasture/Grass, this graph shows the correlation between the deer population (source: Rolley, Robert E., 2014) and the acreage of pasture/grass (source: CropScape - Cropland Data Layer, 2013) in the counties.

**Discussion**

The results of the regressions did not support my hypothesis that where there was more habitat fragmentation there would be a higher population white-tailed deer and more cases of Lyme disease in that area. The data also showed that there was no correlation between Lyme disease cases and white-tailed deer population. 7% is a very low chance of white-tailed deer having an effect on the variance of Lyme disease. Assuming this is the case, then there are many other factors that could come into play. Factors such as farmers having preventative measures in place to keep deer out of their
crops, leading to deer finding safer places to find food away from human populations. Contrary to belief deer have a hard time digesting grass and therefore must find food sources elsewhere, crops being an important source (“Preventing Deer Damage”, 2016). With this in mind, farmers having ways to keep deer away from their crops is a reasonable idea that could come into play. These measures could include fences (electric and nonelectric), repellents, dogs and shooting (“Preventing Deer Damage”, 2016). Also, if these areas of cropland are in a low populated or low foot traffic area then there can be a high population of deer that carry the blacklegged tick around but cases of Lyme disease won’t spread.

Hunting is another possible reason why the data did support my hypothesis. In these areas that the population numbers were collected the hunting season could have affected those numbers. If it was a more successful hunting season then the number of deer that year would have been lower; leading to the possibility of a decreased number of Lyme disease cases.

Also not enough data could have been a reason that no statistically significant relationships were found in the variables of this study’s data. Being able to look at all of the state of Wisconsin’s white-tailed deer population, Lyme disease cases and all different forms of habitat fragmentation would have given more thorough data results.

Another factor that would have skewed things away from supporting my hypothesis would be that some cases of Lyme disease were not reported in that county. There are many reasons why this could be, the main reason however would be that people did not know that they had Lyme disease at the time and therefore did not go in
to get it treated. Another reason would have been that not all of the cases reported were included in the data that I used.

Another factor would be that the white-tailed deer population numbers were off. Deer are an easier animal to track and there are many hunting groups out there that make keeping track of population easy, however it is not a perfect system and numbers may be off compared to the real number of deer population. Also, the white-tailed deer is not the only host of the blacklegged tick. There are many other animals that are able to carry this tick around. Animals such as the white-footed mouse, lizards, foxes and even birds are capable of carrying these ticks to other places. The hosts are easily capable of bringing the tick closer to human populations. These hosts are also affected by habitat fragmentation differently. For example the white-footed mouse, which is also a prevalent blacklegged tick host, prefer smaller fragments to live in. There are many factors to include in the weaknesses of this study.

Overall, based on the data that was analyzed in this study there is no significant connection to Lyme disease and white-tailed deer population in fragmented areas. However, my experiment set up a solid base for future studies. It gives multiple variable to look at such as habitat fragmentation and opens up a lot of new ideas on how to look at the spread of Lyme disease. Future studies that have more time and resources could build off of this experiment and know what to look for and how to do things in a more improved way. For these future studies to be improved they should include more data and data that is more relevant. And all of the factors that are mentioned should be taken into account. These factors include the location of the cropland or habitat fragmentation
that is being studied. Is it in a highly populated area or in a more rural area? Does this area have a high population of hunters and how successful was that hunting season? Do the farmers in that area have preventative measures set up? And finally how close are these croplands to deer inhabited forests?

Based on data from other studies on the same subject, there is a significant connection between Lyme disease and white-tailed deer population in fragmented areas. Like the study done in Great Island, Massachusetts that showed that reducing deer population by 97% resulted in a 50-55% reduction in the larvae and nymphs of the tick (Stafford, 2007). And the other location In Bluff Point Coastal Preserve in Connecticut, data showed that reducing deer population down from 200/mi² to around 30/mi², an 84% decrease, resulted in a >90% decline in tick abundance. That’s 100/mi² down to 1/100mi² (Stafford, 2007). These studies show that there is a significant relationship between the white-tailed deer and Lyme disease.

With these two studies in mind, more future studies removing or placing deer elsewhere so they aren’t as abundant in areas with high Lyme disease cases would be a good place to continue. For these studies a location with a high amount of Lyme disease cases, and a large population of deer would be the best to look at. Then removing those deer from that area and recording the amount of ticks present before and after removing the deer would be the first half of the data that would be studied. Removing the deer could be done in multiple ways such as hunting or moving them to another location, however hunting would seem to be the best method of removal. The second half of the data would then be the amount of Lyme disease cases, looking at the
numbers before the deer were removed and after the deer were removed. This would show us if there is a correlation between lowering deer population and the amount of Lyme disease cases. By doing this it would take what the other two studies, that were mentioned before, a step forward.

However, ideally another route would be to have accurate and recent deer population data that includes adult and adolescents males and females. There would be two data sets, pre-hunt and post-hunting season. To gather this data on the deer tracking and tagging would be the best possible method. It has to be taken into account that not all of the deer may be possible to track and tag and if necessary an estimate would then have to be taken of the deer population. Once the data is collected then two different studies could be done with these data sets, looking at post-hunting deer populations could show if hunting deer and lowering populations lowers Lyme disease cases in that area.

Another data set that would be looked at would be human population. This could be found on local government sites that would have a recent population record. Once the locations are chosen high traffic areas that record the amount of people coming in out would be the main focus. These places would include nationals parks, national forests and metroparks. This would be the best possible scenario because then you can have a more specific idea of how many people are coming in and out of the area and if those people reside in that area. It is possible however for people to get bitten by a tick and get Lyme disease somewhere and get treated for it elsewhere. That case would then be recorded wherever the person was treated. If people can identify that they were
bitten early enough and get it treated where they were bitten then the data would be more accurate. Also for the human population data to be more precise, instead of going by case number it would be by individuals in each area.

The final variable would be to look at habitat fragmentation. As mentioned before habitat fragmentation is defined as larger chunks of habitat being divided into smaller, more isolated areas, leading to loss of habitat in those areas. This study would look at parks and deer habitat that is close to human populations. This would be to see if human activity, such as building parks or neighborhoods near forests, increases the chance of coming into contact with ticks. The study could also take a closer look at how deer travel and their habitats to see how often they visit areas that are highly populated by people.

With all of these data sets collected then statistical tests such as linear regressions and multiple regressions can be ran to see if there is any correlation between the variables and how strong that correlation is. The tests will also show how the independent variable (habitat fragmentation) would affect the dependent variables (deer population and Lyme disease cases). The results will basically say if habitat fragmentation causes a higher number of Lyme disease cases in an area.

Overall, this experiment would take my original experiment and enhance it to its fullest. By doing this it would hopefully tell us that there is a strong correlation between white-tailed deer population, habitat fragmentation and cases of Lyme disease. A strong correlation between the three variables is what should have come out of the data from my original study. And this would allow others to be able to build upon these
experiments and learn knew things about how Lyme disease spreads. However, with limited resources and time this was not able to happen. With the results from the ideal study hopefully showing a connection would then help us start to think of ways to lower the chances of people coming into contact with the blacklegged tick and getting Lyme disease.

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