Introduction and Purpose
Lyme disease is the most common vector-borne disease (that is, infectious transmitted by the bite of infected arthropod species, such as mosquitoes, ticks, or fleas) in the United States. In recent years, approximately 20,000-30,000 confirmed cases of Lyme disease per year have been reported to the Centers for Disease Control and Prevention (CDC). However, the actual number of illnesses is likely greater than what is reported to health officials. Lyme disease is transmitted through the bite of certain species of infected ticks (commonly referred to as deer ticks) that carry the bacteria *Borrelia burgdorferi* that cause Lyme disease. These ticks live not only on deer, but also on rodents, birds, and other host animals. Deer do not harbor the bacteria that cause Lyme disease, but certain other hosts such as white-footed mice do, and ticks pick up the bacteria by feeding on these infected hosts (CDC 2016, EPA 2016).

Typical symptoms include: fever, headache, fatigue, and a characteristic skin rash called erythema migrans. If left untreated, infection can spread to joints, heart, and the nervous system. In 2014, it was reported that 96% of Lyme Disease cases occurred within 14 states of the US, heavily concentrated within the New England and Midwestern States (CDC 2016). It is pertinent for the general public, management personal, and legislators to understand how this disease is moving spatially and temporally in order to spread awareness and make educated decisions for prevention.

Methods
Lyme disease case data were acquired from the CDC website, in the form of an excel spread sheet. Shapefiles for the Contiguous United States, the corresponding counties for each state, and worldwide counties were collected from the data department (5). Drive. These collected data were placed into a Feature Class within a newly created Geodatabase for the project. The Projection was set to Lambert Conformal Conic because this projection of the contiguous United States is relative to the projection used in the CDC data. This projection was then imported into ArcMap, Comments, unknown data, and unnecessary data were deleted and removed. In order to join the data with the US Counties shapefile, a common column must be shared between the two data sets. The FIPS county code is a five-digit Federal Information Processing Standard (FIPS) code which uniquely identifies counties equivalents in the United States. However, the data given by the CDC did not include the FIPS codes for each of the counties. FIPS codes were generated for each county by combining the state and county codes.

All of the collected data (shapefile and excel table) were added to the map. A spatial join for the Lyme disease cases table and the US Counties Shapefile was performed. This resulting join was then exported as its own shapefile so that the information was permanently placed within the file. Each of the relevant states for the study were then inspected and exported as well so that only relevant information would be processed. This was done for the irrelevant states as well for background purposes. Canada was also selected and exported to be used as a background feature.

Symbology for the US Counties of the relevant states to the study were changed to show quantities using breaks (60, 130, 300, 600, 1400) in the data were chosen and used to represent the case data for 2000, 2007, and 2014. Mean centers were then calculated for each of the chosen three years to show the relative movement of the disease.

In order to further visually show the differences in case data for each state, the US Counties Lyme Disease data were summarized by State Name, showing the sum of the cases for 2000, 2007, and 2014. Three fields were then chosen for adding symbol size to the data to calculate the differences in number of cases between 2000 and 2007, between 2007 and 2014, and between 2000 and 2014. These data were then joined to a US State shapefile for the relevant states. Symbology was changed here to show quantities and labels were added.

Results and Interpretations
The fourteen-year span of data was broken up into three different year points for the first part of the analysis. These three years happened at natural breaks in the data, as well as, co-incidentally, happening at the beginning, midpoint, and end for the time period worked with.

Through the use of displaying case data for Lyme disease and displaying a mean center, it can be seen that (in Figure 1a) Lyme disease data for the beginning of the millennium was mainly concentrated in the Eastern and New England states, specifically in the South Eastern corner of New York, and its surrounding areas such as Connecticut, New Jersey, Rhode Island, and South Eastern Pennsylvania. These areas all seem to correspond with warmer coastal areas, as well as areas with larger forests and urban populations. This make sense as Lyme disease is often transmitted within the nymphal stage of ticks, which become active when temperatures are above 40 degrees Fahrenheit. Coastal and urban populations likely exhibit days that warmer, and thus allow tick population to not only thrive, but thrive earlier due to being warmer than surrounding areas. This also allows for higher potential for Lyme disease cases.

The mid-point in the data (Figure 1b) shows the 2007 case data. A general expansion of the disease can both be seen branching out from the original points described above, along the coast in both a northern and southern direction, as well as several populations and cities showing up in the Midwest. It is likely this spread is also due to ideal climatic factors, as well as habitat. Some of the counties in south eastern New York (and surrounding areas) are seen to have decreased number of cases. This could be due to the vector population moving, and the beginning of preventative measures taken by both the public and government agencies.

In 2014 (Figure 1c), the continued spread of Lyme disease through the Eastern and New England states can be seen. Massachusetts is largely affected by Lyme Disease cases, as well as much of Maine now experiencing cases. Areas all throughout Pennsylvania are largely affected as well, especially the area around Pittsburgh. The cases within the Midwest, while still more so that in 2000, have become less concentrated, but have also spread northward. Through the Mean Centers seen throughout Figure 1, cases of Lyme disease start off concentrated within the Eastern States, before more cases show up within the Midwest around 2007 which pulls the center in a north western fashion, before in 2014, cases become more severe and both Pennsylvania and Minnesota states saw a mean center eastern again. Figure 2. Highlights these changes more readily when viewed. It can be seen that the Midwestern States like Wisconsin and Minnesota have more cases between 2000-2007 (Figure 2a), however, in Figure 2b, cases decrease, while eastern states like Pennsylvania and Massachusetts consistently increase in Cases. Other states such as Maine, Virginia and New Jersey have seen a relatively high number of cases over this period of time. Connecticut and New York, on the other spectrum, can be seen to have overall decreasing numbers in cases throughout the entire time period. Again this can be due to population dispersal, but also preventative measures taken but local government, as well as public awareness of the disease.

Summary and Conclusions
Through the gathering of both online and already available data, a spatiotemporal analysis was able to be conducted on the states within the US that have most heavily been affected by Lyme disease outbreaks. These data were then joined and displayed in three year points to see general trends in the data. Mean centers were calculated to aid in the movement of the disease. State level data was summarized and shown to give a broader, overall view of how the states have been affected in recent years by the case outbreaks. It was seen that starting in 2000, Lyme disease cases more commonly concentrated in south eastern New York and its surrounding areas (upwards of 1600 cases in some counties) with relatively small amount of cases occurring in the Midwest (mainly below 20 cases per county). By 2007, cases were seen to have decreased in some of these initial areas, however, more cases were readily seen spreading in both a northern and southern direction along the coast. Areas around Philadelphia were especially concentrated around this time, and the northern extent of cases even extended into Maine. The Midwest saw a few counties with more concentrated numbers of cases. Finally, in 2014 cases in the Midwest became less concentrated and started moving northward in intensity, while the East coast continued to see the spreading of higher numbers of cases. Much of Pennsylvania was seen to have more cases, as well as Maine. Massachusetts saw the highest number of cases per county in this time period with 1023 cases. This figure displayed that, overall, most states were seeing increasing number of cases, especially Pennsylvania, Massachusetts, New Jersey, Wisconsin and Minnesota. New York and Connecticut have seen overall decreases in cases. This can be both due to the spread of the vectors out of the region, as well as preventative measures taken by both the government and general public awareness.

References


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