An Intersectional Feminist Approach to Lyme Disease Epidemiology

Meghan Frisard
University of Maine

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AN INTERSECTIONAL FEMINIST APPROACH TO LYME DISEASE

EPIDEMILOGY

By

Meghan Frisard

A Thesis Submitted in Partial Fulfillment
of the Requirements for a Degree with Honors
(Zoology & Women’s, Gender, and Sexuality Studies)

The Honors College
University of Maine
May 2019

Advisory Committee:
Allison Gardner, Assistant Professor of Arthropod Vector Biology, Advisor
Angela Daley, Assistant Professor of Health Economics and Policy
Elizabeth Neiman, Assistant Professor in Women’s, Gender, Sexuality Studies
Edie Pratt Ellwood, Adjunct Professor in Honors (Sociology)
Laura Rickard, Assistant Professor of Risk Communication
ABSTRACT

Nationally, Maine is the state with the second highest incidence of Lyme disease. While the spread of Lyme disease is generally attributable to ecological factors that affect the life cycle of Lyme-spreading ticks, socioeconomic factors may have substantial impacts on diagnosis and reporting of human cases. Socioeconomic factors could influence one’s ability to see a healthcare provider and ultimately be diagnosed with and treated for Lyme. Additionally, access to and treatment within the healthcare system is often gendered. I hypothesize that certain socioeconomic factors will have a negative correlation with Lyme disease incidence among the general population and among women, and that other socioeconomic factors will have a positive correlation, depending on how they promote or inhibit healthcare access. Ordinary Least Squares regression analyses were performed to determine significant socioeconomic factors that correlate with patterns of Lyme disease incidence in 411 zip codes across 10 counties in southern Maine, an endemic area for Lyme disease transmission. Geographically Weighted Regression analyses were performed to understand how these relationships varied spatially. Total family income, per capita income, percent of the population with public health insurance, and percent of the population that speaks a language other than English all have significant correlations with overall Lyme incidence. Percent of the population with any health insurance has a significant correlation with the percentage of Lyme disease cases that are women. Conclusions from this work could inform public health departments, schools, insurers, and healthcare providers about which populations are most at risk for Lyme disease.
DEDICATION

To Taylor, the air to my earth, and to all of the people I’ve met along the way - Team Maine, FemC, Mabel’s Staff – we all did this. To The College of Our Hearts Always, I am who I am because of my time here.
ACKNOWLEDGMENTS

There are so many people to thank for this project. My advisor, Allie, and the rest of my committee for taking a chance on this project and helping me every step of the way. I could never have made it this far without you. To my friends and family who listened to me talk about feminism for four years, this is the result. To all of the members of the Gardner lab who took time out of their schedules to let me practice my presentations for them. My parents, aunts, uncles, and cousins who took time out of their lives to read draft after draft. Lastly, to Jenny Desmond, for always answering all of my questions about this thesis process, at any time of day, and generally being the world’s best role model.
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INTRODUCTION

Lyme Disease

There are 329,000 estimated cases of Lyme disease in the United States annually, making it the most common vector-borne disease in the United States (Nelson et al. 2015). In Maine alone, 1,769 confirmed and probable cases were reported in 2017, which produces an incidence rate of 132.4 cases per 100,000 people (Robinson and McFarren 2018). The Maine Centers for Disease Control (CDC) tracks Lyme disease infection through a combination of active surveillance, which requires clinicians to report any diagnosis of Lyme disease, and syndromic surveillance, which identifies patients who visit a participating emergency department complaining of a tick bite. While reported rates in the United States have hovered around 10 cases per 100,000 people since 2008, reported rates within Maine have been more variable, yet also significantly higher, ranging from near 70 per 100,000 in 2008 to 132.4 per 100,000 in 2017 (Robinson and McFarren 2018).

Lyme disease in North America is caused by Borrelia burgdorferi, a spirochete bacteria that is spread to humans through the bite of the blacklegged tick, Ixodes scapularis. Outside of this region, other types of ticks can cause Lyme disease through the spread of other types of Borrelia bacteria (Lou & Wu 2017). Understanding the transmission of Lyme disease requires an understanding of the life cycle of I. scapularis. Tick eggs hatch into larvae with no pathogen infection, even if the female that laid the eggs has the spirochete. The transmission of the B. burgdorferi bacteria begins when one of these larval ticks feeds on a spirochete-positive reservoir host such as a white-footed mouse before molting into a nymphal tick. The tick saliva produces a chemical that stimulates the bacteria
to migrate towards the source of the bite (Radolf et al., 2012). These nympha ticks transmit
the pathogen to a vertebrate host while feeding – in North America, this host is often a
deer. Human’s get infected with *B. burgdorferi* when one of these ticks bites them.
Confmed cases of Lyme disease are based on the presence of a characteristic Erythema
Migrans “bullseye” rash on a patient who lives in or has visited an area in which Lyme is
endemic, such as Maine, and recommended treatment is a course of antibiotics (Bretton et
al 2008, Robinson and McFarren 2018). Within the initial weeks of infection, fatigue, 
fever, headache, and joint pain are common. If the infection is not caught within these first
weeks, symptoms can include arthritis (joint swelling), Bell’s Palsy or similar cranial nerve 
paralysis, meningitis, or carditis (Robinson and McFarren 2018). Within the human body, 
the bacteria causes these symptoms through a mechanism of the mammalian host’s own
immune system. The genome of the bacteria itself does not encode for any toxins, or any
new cellular components needed to secrete a toxic substance (Radolf et al 2012).

Current literature on the topic discusses Lyme disease incidence as a function of
only ecological factors that affect the presence of deer ticks. Lyme disease transmission is
reliant on the life cycles, habitats, feeding habits, and reproductive patterns of multiple
vectors, hosts, and reservoir species, which produce a large number of conflating factors
that can increase or decrease the breadth of Lyme disease infection in a given area (Radolf
et al. 2012, Lou & Wu 2017, Arsnoe et al. 2019). Many Lyme disease models have been
created to examine these ecological factors, including seasonal growth in tick populations,
changes in biodiversity, deer abundance and mortality, white footed mouse abundance and
mortality, and changes migratory bird populations (Lu and Wu 2017). Some of these
ecological changes are thought to be driven by a changing climate, producing a wider
habitat for *I. scapularis*, and longer, warmer summer days producing a larger time frame in which infection is likely to occur (Lin et al. 2019). Using geospatial information systems, such as ArcGIS, tick abundance has been linked to certain environmental conditions, such as vegetation, humidity, landscape slope, and soil type (Glass et al. 1995). Lyme disease incidence is so often explicitly tied to tick presence that reported infection rates are often used to model presence of *I. Scapularis* (Lin et al. 2019).

There are minimal studies addressing incidence beyond these ecological factors. Previous research on gender Lyme disease in Maine indicates that there is no significant gender difference in surveillance data or Lyme disease related in patient visits (Robinson 2014). Many studies have indicated that Lyme is most prevalent among children and older adults (Lin et al 2019, Seukep et al 2015). One study addressed Lyme disease incidence from both an ecological and demographic perspective, associating Lyme disease with increased forest covers and lower proportions of developed land, as well as higher income in northern Virginia. This study attributed the income correlation to the expensive nature of homes in rural areas versus urban areas in northern Virginia, just outside of Washington D.C, and the expensive nature of many outdoor hobbies that would put people in heavily forested areas, such as backpacking (Seukep et al 2015). While valid for Virginia, the general applicability of these results should be questioned. In Maine, our rural areas are often the cheapest places to live, and these rural areas can be heavily forested. There is a gap in knowledge of how Lyme disease incidence associates with sociodemographic factors in Maine, and there is a gap in knowledge of how Lyme disease associates with socioeconomic factors beyond income, age, and gender.
Intersectional Feminist Social Epidemiology

The World Health Organization (WHO) has grounded its organization and practices within the model of social determinants of health. The WHO describes this model as socioeconomic positions, created by social, economic, and political mechanisms, shaping specific determinants of health status (Solar & Irwin 2010). Gradients in quality of health and disease are not contained to those only at the very top or very bottom of social and economic hierarchy; there is evidence of a strong social gradient that correlates with level of health across all social classes among low-, middle-, and high-income countries (Marmot & Allen 2014). Human bodies are created by the environments in which they live, and that includes, in the words of Smith and Lynch (2004), “socially patterned nutritional, health, and environmental experiences of parents and self” (p. 107). The American Community Survey has been used to approximate ways in which socioeconomic factors correlate to health outcomes; one study found that low-income children and adults are three to six times more likely to be both disabled and uninsured, and, further, that socioeconomic factors account for a majority in variation in adult health insurance coverage and disability among racial and ethnic groups. This indicates that while correlations between race/ethnicity and access to healthcare can be found, these correlations are primarily due to socioeconomic factors, not racial or ethnic diversity (Singh & Lin 2013).

These types of social-health analyses are not new. Studies conducted as far back as 1845 have linked social factors to measurable public health outcomes such as mortality, cancer, and cardiovascular disease (Smith & Lynch 2004). A widely applied theory of social epidemiology is the fundamental cause theory, which, in essence, posits that socioeconomic status is a fundamental cause of health inequality. The model is predicated
on the fact that high-SES people have resources that are not available to those in lower socioeconomic classes, and that these resources are not simply measurable goods like money and expensive health insurance, but also knowledge, prestige, and social connections that allow them to protect their health (Berkman and Kawachi 2014). While this model is useful to an extent in explaining why the upper class always has better health than the lower class, it does not provide mechanisms through which this observation occurs. Thus, there has become a need for a theoretical model of public health that takes into account all of the compounding factors that contribute to health inequality, including personal social positions and relations to institutions (Gkouleka et al. 2018).

The theory of intersectionality thus lends itself as a useful framework in analyzing the ways in which multiple forms of societal oppression inhibit a person’s ability to access adequate health care and treatment. The term was first phrased in the context of legal discrimination against black women; Kimberlé Crenshaw (1989) writes “[Black women] often experience double-discrimination – the combined effects of practices which discriminate on the basis of race, and on the basis of sex” (Crenshaw 1989). In the years since Crenshaw wrote this influential theory, her concept of intersectionality has been applied to many other social categories and human institutions beyond race and the law. Intersectionality emphasizes that multiple forms of oppression are not simply additive, but also interlocking and interconnected. The experience of a poor woman is not simply that of an upper-class woman overlaid with that of a poor man; her experience is that of a poor woman.

One institution within which intersecting forms oppression can be seen is healthcare. Applying intersectionality to the institution of medicine as a whole, finds that
marginalized people often lack access to care, or receive insufficient care within the system. Wilkerson (1998) highlights variable health needs, insufficient access to healthcare, and poor treatment within the healthcare system itself as three major ways that oppression manifests itself within healthcare. Similarly, Loretta Ross and SisterSong Women of Color Reproductive Justice Collective (2001) found that many health programs are discriminatory, inaccessible, or inappropriate for women of color, and that healthcare providers are generally not culturally competent enough to provide proper healthcare in communities of color (Ross et al. 2001). Ross also acknowledged that women of different racial and ethnic backgrounds have unique and specific needs that are not met by the healthcare system, and this work furthers the idea that socioeconomic status, race, and ethnicity are all implicitly linked – a notable example being that health insurance coverage is often dependent on immigration status (Ross et al. 2001). While the study described in this paper does not explicitly analyze racial bias within Lyme disease incidence, Ross and SisterSong use race and ethnicity to provide examples of how oppression intersects with our healthcare system. Their work highlights how people who exist within multiple axes of oppression – such as women who are socioeconomically disadvantaged - could be underrepresented in infectious disease reporting rates. Thus, understanding intersectionality is vital to understanding feminist and social epidemiology, which allows for a complete picture of how ones social situation affects their physical health.

This project works with a framework of intersectional feminist epidemiology to determine how a wide range of socioeconomic factors affect reported Lyme disease incidence within the state of Maine. The research question at the foundation of this study asks to what degree socioeconomic factors impact Lyme disease incidence rates, and the
rates with which women are formally diagnosed with Lyme disease. Due to limited funding and staffing, many states with endemic Lyme disease no longer count all of the individual cases the way that Maine does, but Maine is considering a switch to an estimation system that is used in these other areas (Robinson and McFarren 2018). The CDC acknowledges that Lyme is highly underreported; since the 1990s, studies have attempted to gauge the extent of this underreporting (Nelson et al. 2015). Underreporting to the national surveillance system does not inherently indicate a lack of treatment (Nelson et al. 2015), but if the state of Maine is going to estimate the incidence of Lyme Disease, and use that estimation to inform public health funding and policy, such estimations must fully consider all of the factors that inform Lyme disease reporting rates.
METHODS

Study Area
Maine is one of 14 states in which over 96% of Lyme disease cases occur (Centers for Disease Control and Prevention 2018), and Lyme disease is spreading throughout the state (Robinson and McFarren 2018). Newspapers with large followings and name recognition such as The Portland Press Herald (Rathke 2016) and Bangor Daily News have been reporting on Lyme disease incidence in the state for years, and Bangor Daily News publishes a regular blog about a local woman’s life with Lyme disease (Barry 2015). Within the state, the study area was chosen based on where Lyme disease is already considered endemic, in an effort to view the impact of the socioeconomic variables regarding income, education, health insurance coverage, immigration status, and language spoken at home, as opposed to ecological factors that vary by geography. A disease or condition is considered endemic if there is constant occurrence within a geographic area of population group (Porta 2014). Using this criteria and available Lyme disease data, the study area was chosen as Androscoggin, Cumberland, Hancock, Kennebec, Knox, Oxford, Sagadhoc, Waldo, Washington, and York counties (figure 1).
Figure 1: Area of study includes Maine zip codes where Lyme disease is already established. Zip codes considered in this study are shaded red.
Data Sources

Lyme disease case data was obtained from the Maine Centers for Disease Control. Lyme disease is a Category II Notifiable Disease, meaning all cases must be reported to the state within 24 hours (Maine Department of Health and Human Services 2015). The patient’s residence address and date of report are part of the required information to be reported, allowing for the data to be consolidated by zip code and year. Published data (https://www.maine.gov/dhhs/mecdc/infectious-disease/epi/vector-borne/lyme/#data) for Lyme disease does not include communities with populations under 1000 people, due to the possibility that age/gender information would reveal identities in small communities, but special access to the entire Lyme dataset was achieved for this project (IRB approval #2017-09-06).

To test the hypothesis that lower socioeconomic status leads to higher Lyme disease incidence, economic, housing, population, and social data was collected from the American Community Survey (ACS). The ACS is a survey from the U.S Census Bureau that uses monthly samples to create estimates for the same types of statistics that are created from the 10-year long-form census (Torrieri 2014). The ACS publishes data based on 5-year estimates for all communities down to the 5-digit zip code, and the most current 5-year estimate available is for 2012-2016. These limitations within the ACS data is what drove the data usage for this project; Lyme disease cases were aggregated for the years 2012-2016 to coincide with the years of the ACS data, and this total calculation was based on the report date to ensure that no case was counted twice. Lyme disease case data was then analyzed by zip code, the smallest spatial unit available for both data sets. Lyme disease incidence was calculated using the total case data for 2012-2016 divided by the 5-year
estimate population for each zip code, and then multiplied to obtain a value for incidence, defined as the number of cases per 100,000 people.

In order to create graphic maps that could show trends and patterns among the selected zip codes, the data had to be made compatible with ArcGIS; this was done by combining all Lyme incidence data and ACS data with a publically available shapefile from Esri Data and Maps (https://www.arcgis.com/home/item.html?id=8d2012a2016e484da faac0451f9aea24) that includes all 5 digit zip codes for the United States. There are a handful of zip codes that have reported Lyme disease cases and ACS data, but were excluded from Esri’s shapefile due to their small size. All of these zip codes were villages or neighborhoods located within larger towns (e.g. East Winthrop combined with Winthrop), and all of the data for these towns was combined with the data of their surrounding town to accommodate analysis (Appendix A).

Data Analysis

All data analysis was completed using ArcGIS software (Esri 2011). Statistical tools used included ordinary least squares (OLS) regression, Moran’s I test for spatial autocorrelation, and a geographically weighted regression (GWR) analysis to determine how the relationships between variables changed geographically. Separate OLS analyses were performed with all ACS data points (Appendix B) as the independent variables and Lyme disease incidence and the percentage of Lyme disease cases for women as the dependent variables. These initial OLS regression results were used to create stronger OLS models that included only ACS variables that produced significant results, and had higher r-squared values and lower VIF values than the initial OLS regression. The best-fit model was chosen based individual variable significance and overall model adjusted R-squared value, with the majority of variables being significant and the adjusted R-squared value
being high to ensure that the model was representing as much variation within the Lyme
disease data as possible. GWR analyses were then run using the same variables that were
used in the chosen OLS models, to determine the extent to which the relationships depicted
in the OLS model were geographically dependent. Finally, a Morans I test was ran on the
residuals of the GWR model, to determine whether the zip codes that strayed farthest from
the model were randomly spaced or not.
RESULTS

Overall Lyme Disease Incidence

Within the study area of Androscoggin, Cumberland, Hancock, Kennebec, Knox, Oxford, Sagadahoc, Waldo, Washington, and York counties, Lyme disease incidence ranged from 0.0 CDC confirmed cases per 100,000 people to 9813.1 cases per 100,000 people from 2012-2016 (figure 1). An ordinary least squares regression analysis model (table 1) indicated a significant relationship between Lyme disease incidence and total family income, per capita income, percent of the population with public health insurance, and percent of the population that primarily speak a language other than English in the home. This model also indicated a marginally significant relationship between Lyme disease incidence and the percentage of the foreign-born population that are United States Citizens. The overall model has an adjusted R-squared value of 0.2682, a Koenker (BP) statistic of 19.1483 (p=0.0018), and a Joint Wald Statistic of 24.3048 (p=0.0002) (table 2). A geographically weighted regression model of the same variables using a fixed kernel method had an AICc value of 3987.5, and an adjusted r-Squared value of 0.478. The higher R-squared value for GWR compared to OLS indicates that the data has a strong spatial component, and that 47.8% of the variation in Lyme disease incidence is due to the variables included in the model. Results of the geographically weighted regression show the change in coefficient for the measured variables across Maine zip codes (figures 3-7). A Morans I test for spatial autocorrelation gave the model a z-score of 4.617 (p=0.000), indicating that there are other factors not deciphered by this model that inform the variation in Lyme disease incidence. Due to the significant z-value for the Morans I test, a figure showing the distribution of the standard error residuals was created.
(figure 8), indicating which zip codes were closest to the regression coefficient and thus fit the model the best.

Figure 2: Lyme disease incidence (number of CDC confirmed cases per 100,000 people) from 2012-2016 among selected Maine counties. Inset maps show Casco Bay and the area surrounding Mount Desert Island, and it can be seen that many of the zip codes with highest incidence are included in these ocean-surrounded parts of the state.
Table 1: Ordinary least squares regression for Lyme disease, total family income, per capita income, percent of the population with public health insurance, percent of the population over the age of 5 that speaks a language other than English as the primary language, and the percent of foreign born citizens who are United States citizens. The variable of citizenship among immigrants did not contribute significantly to this model, but removing it would have resulted in a model in which no variables were significant and the overall model significance was lower. Robust statistics should be used to measure significance because they account for spatial variability as indicated by significant Koenker test. Variance Inflation Factors less than 7 indicate no redundancy among variables.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Coefficient</th>
<th>StdError</th>
<th>t-Statistic</th>
<th>Probability</th>
<th>Robust SE</th>
<th>Robust t</th>
<th>Robust P</th>
<th>VIF</th>
</tr>
</thead>
</table>
| Intercept                         | 758.702     | 323.962  | 2.342       | 0.019*      | 334.945   | 2.265    | 0.024*   | -----
| Household Income                  | -0.027      | 0.005    | -5.520      | 0.000*      | 0.0085    | -3.152   | 0.002*   | 1.913 |
| Per Capita Income                 | 0.070       | 0.008    | 9.189       | 0.000*      | 0.017     | 4.073    | 0.000*   | 1.621 |
| public health insurance           | -0.027      | 5.764    | -2.025      | 0.044*      | 5.550     | -2.104   | 0.036*   | 1.167 |
| English is not the Primary Language | -0.027    | 19.695   | -3.254      | 0.001*      | 16.827    | -3.808   | 0.000*   | 1.012 |
| Foreign-born pop. that are U.S citizens | 0.070   | 2.102    | 1.800       | 0.073       | 1.959     | 1.932    | 0.055    | 1.173 |

Table 2: Diagnostic results for table 1. Adjusted R-squared value indicates how much of the variance in the model can be explained by the variables included in the model. Significant Koenker (BP) statistic indicates that results are not equally statistic across space and that a geographically weighted regression may produce a more specified model. Significance of Koenker statistic indicates that Wald Statistic must be used to determine overall model significance as opposed to F-Statistic, though both are significant.

<table>
<thead>
<tr>
<th>Diagnostic</th>
<th>Value</th>
<th>Significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of Observations:</td>
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<td></td>
</tr>
<tr>
<td>Akaike's Information Criterion (AICc)</td>
<td>4060.513</td>
<td></td>
</tr>
<tr>
<td>Multiple R-Squared</td>
<td>0.283</td>
<td></td>
</tr>
<tr>
<td>Adjusted R-Squared</td>
<td>0.268</td>
<td></td>
</tr>
<tr>
<td>Joint F-Statistic</td>
<td>18.810</td>
<td>Prob(&gt;F), (5,238) degrees of freedom: 0.000*</td>
</tr>
<tr>
<td>Joint Wald Statistic</td>
<td>24.305</td>
<td>Prob(&gt;chi-squared), (5) degrees of freedom: 0.000*</td>
</tr>
<tr>
<td>Koenker (BP) Statistic</td>
<td>19.148</td>
<td>Prob(&gt;chi-squared), (5) degrees of freedom: 0.002*</td>
</tr>
<tr>
<td>Jarque-Bera Statistic</td>
<td>4131.554</td>
<td>Prob(&gt;chi-squared), (2) degrees of freedom: 0.000*</td>
</tr>
</tbody>
</table>
Figure 3. Results of geographically weighted regression analysis, showing geographically weighted relationships between Lyme Disease Incidence and median total family income. Appendix C shows the geographic distribution of median family income by zip code. Zip codes shaded blue represent the part of the state that has the strongest negative correlation between variables, meaning that zip codes with high median incomes are likely to have lower Lyme incidence rates in this part of the state. Zip codes shaded red represent the part of the state that has the strongest positive correlation between variables, meaning that zip codes with high median incomes are likely to have higher Lyme disease incidence in this part of the state. The regression coefficient for the red-shaded zip codes is close to 0 which indicates that while there is a significant correlation, it is not particularly strongly positive or negative.
Figure 4. Results of geographically weighted regression analysis, showing geographically weighted relationships between Lyme Disease Incidence and percent of the population with public health insurance. Appendix D shows the geographic distribution of public health insurance by zip code. Zip codes shaded blue represent the part of the state with the strongest negative correlation between variables, meaning that zip codes with high rates of public insurance are likely to have lower Lyme incidence rates in this part of the state. Zip codes shaded red represent the part of the state with the strongest positive correlation between variables, meaning that zip codes with high rates of public insurance are likely to have higher Lyme disease incidence in this part of the state.
Figure 5. Results of geographically weighted regression analysis, showing geographically weighted relationships between Lyme Disease Incidence and median per capita income. Appendix E shows the geographic distribution of median per capita income by zip code. Indicated in the legend, the relationship is positive across the entire state. Zip codes shaded blue represent the part of the state the has the weakest correlation between variables, meaning that zip codes with high median incomes likely to have higher Lyme incidence rates in this part of the state, but the relationship is not as strong. Zip codes shaded red represent the part of the state the has the strongest correlation between variables, meaning that zip codes with high median incomes are likely to have higher Lyme disease incidence in this part of the state.
Figure 6. Results of geographically weighted regression analysis, showing geographically weighted relationships between Lyme Disease Incidence and percent of the immigrant population that are U.S citizens. Appendix F shows the geographic distribution of citizenship among immigrants by zip code. Zip codes shaded blue represent the part of the state that has the weakest correlation between variables. Here, this corresponds to partially negative and partially positive, meaning that the relationship is essentially a horizontal line, likely because there is not a lot of variation in one or both variables here. Zip codes shaded red represent the part of the state that has the strongest positive correlation between variables, meaning that zip codes with high rates of citizenship among immigrants are likely to have higher Lyme disease incidence in this part of the state.
Figure 7. Results of geographically weighted regression analysis, showing geographically weighted relationships between Lyme Disease Incidence and percent of the population over the age of 5 that speaks a language other than English as the primary language. Appendix G shows the geographic distribution of the population that speaks a language other than English by zip code. Zip codes shaded blue represent the part of the state that has the strongest negative correlation between variables, meaning that zip codes with high percentages of the population that speak a language other than English at home are likely to have lower Lyme incidence rates in this part of the state. Zip codes shaded red represent the part of the state that has the strongest positive correlation between variables, meaning that zip codes with high percentages of the population that speak a language other than English at home are likely to have higher Lyme disease incidence in this part of the state.
Figure 8. Results of geographically weighted regression analysis, showing residuals of the geographically weighted relationships between Lyme Disease Incidence, total family income, per capita income, percent of the population with public health insurance, percent of the population over the age of 5 that speaks a language other than English as the primary language in terms of the number of standard deviations from the regression model. Negative standard deviations (red) indicates that the zip code has a higher Lyme incidence than the model would predict, and positive standard deviations (blue) indicates that the zip code has a lower Lyme incidence than the model would predict.
Female Lyme Disease Cases

The percentage of CDC confirmed Lyme disease cases affecting women in the selected zip codes ranged from 0-100% in 2012-2016 (figure 9). An ordinary least squares regression analysis model (table 3) indicated a significant relationship between the percentage of female Lyme disease cases and the percentage of the population with health insurance (p=0.002), and a non-significant relationship with the percentage of the population born outside of the United States (p=0.101), and the percentage of the population with a Bachelor’s degree (p=0.699). The overall model has an adjusted R-squared value of 0.049, and a Koenker (BP) statistic of 6.294 (p=0.098) (table 4). A geographically weighted regression model of the same variables using a fixed kernel method had an AICc value of 2220.074, and an adjusted r-Squared value of 0.0698, indicating that 6.98% of the variation in the percentage of female Lyme disease cases can be explained by this model. Results of the geographically weighted regression show the change in coefficient for the measured variables across Maine zip codes (figure 10-13). A Morans I test for spatial autocorrelation gave the model a z-score of -1.022 (p=0.306), indicating that the pattern displayed does not appear to be significantly different from random.
Figure 9. Figure shows the percentage of CDC confirmed Lyme disease cases affecting women in the selected zip codes from 2012-2016. Inset maps show Casco Bay and the area surrounding Mount Desert Island.
Table 3. Ordinary Least Squares Regression Data for percentage of Lyme disease cases affecting women, percentage of the population with health insurance, percentage of the population born outside of the United States, and percentage of the population with a Bachelor’s degree. Not significant Koenker statistic indicates that robust statistics are not needed to measure significance, though the only significant variable, health insurance coverage, is significant whether the robust value is used or not. Variance Inflation Factors less than 7 indicate no redundancy among variables.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Coefficient</th>
<th>Std Error</th>
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<td>0.168</td>
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Table 4. Diagnostic results for table 1. Non-significant Koenker (BP) statistic indicates that $F$-statistic can be used to determine overall model significance. Adjusted $R$-squared value indicates that 4.9% of the variation in the model can be explained by the variables included in the model.

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Figure 10. Results of geographically weighted regression analysis, showing geographically weighted relationships between the percentage of Lyme disease cases affecting women and the percent of the population with health insurance coverage. As indicated in the legend, the relationship is positive across the entire state. Zip codes shaded blue represent the part of the state the has the weakest correlation between variables, meaning that zip codes with high rates of health insurance coverage are likely to have higher Lyme incidence rates in this part of the state, but the relationship is not as strong. Zip codes shaded red represent the part of the state the has the strongest correlation between variables, meaning that zip codes with high rates of health insurance coverage are likely to have higher Lyme disease incidence in this part of the state. There is not a wide range in the coefficient values, indicating that the geographical component of the regression is not particularly strong.
Figure 11. Results of geographically weighted regression analysis, showing geographically weighted relationships between the percentage of Lyme disease cases affecting women and the percent of the population with a bachelor’s degree. As indicated in the legend, the relationship is positive across the entire state. Zip codes shaded blue represent the part of the state the has the weakest correlation between variables, meaning that zip codes with high rates of Bachelor’s degrees are likely to have higher Lyme incidence rates among women in this part of the state, but the relationship is not as strong. Zip codes shaded red represent the part of the state the has the strongest correlation between variables, meaning that zip codes with high rates of Bachelor’s degrees are likely to have higher Lyme disease incidence among women in this part of the state. There is not a wide range in the coefficient values, indicating that the geographical component of the regression is not particularly strong.
Figure 12. Results of geographically weighted regression analysis, showing geographically weighted relationships between the percentage of Lyme disease cases affecting women and the percent of the population born outside of the United States. Zip codes shaded blue represent the part of the state the has the strongest negative correlation between variables, meaning that zip codes with high proportions of immigrant populations are likely to have lower Lyme incidence rates in this part of the state. Zip codes shaded red represent the part of the state the has the strongest positive correlation between variables, meaning that zip codes with high proportions of immigrant populations likely to have higher Lyme disease incidence in this part of the state.
DISCUSSION

The results of the data analysis from this study indicate correlative relationships between specific socioeconomic factors and Lyme disease incidence. Median total family income has a relatively strong negative correlation with Lyme disease incidence in the northeast part of the study area, indicating that a high family income is correlated with a high Lyme incidence in this area, and a small but significant positive correlation in the northwest part of the study area, indicating that a high family income is correlated with a low Lyme incidence in this area. Per capita income has a significant positive correlation across the whole state, though it is stronger in some parts of the study area. The correlation is strongest in the northeast part of the study area, indicating that a high median per capita income is strongly correlated with a high Lyme incidence. Public health insurance coverage has a strong negative correlation in the northwest part of the study area, indicating that a high rate of public insurance coverage is correlated with a low Lyme incidence in this area, and a strong positive correlation in the southwest area of the study area, indicating that a high percentage of public health insurance is correlated with a high Lyme incidence in this area. Percentage of the population over 5 years old that speaks a language other than English has a strong positive correlation in the northwest and northeast parts of the study area, indicating that a high percentage of non-English speakers is correlated with a high Lyme incidence in this area, and a strong negative correlation in the center of the study area, indicating that a high percentage of non-English speakers is correlated with a low Lyme incidence in this area. The percentage of Lyme disease cases affecting women is positively correlated with health insurance across the entire state, though the relationship
is strongest in the southern part of the map, indicating that more women get diagnosed with Lyme disease in areas with high rates of health insurance coverage.

When social factors are considered, the once simply ecological cause of rising Lyme disease incidence changes. Many of the ecological factors known to affect Lyme disease incidence are socially mediated in and of themselves. Biodiversity changes caused by anthropogenic deforestation and increased suburban development have led to decreased predator species that would normally prey on host species such as the white-footed mouse, leading to increased tick populations (McMichael 2004). Climate factors including temperature and humidity have also been changing due to anthropogenic greenhouse gas emissions, which have been shown to alter *I. scapularis* prevalence (McMichael 2004, Glass et al. 1995). This concept of socially mediated ecological factors can be linked back to the origins of Lyme disease as a new infectious disease in Connecticut in the 1980s. The characteristic Erythema Migrans rash had been seen in parts of the U.S. and the condition associated with it was called Erythema Chronicum Migrans, and *B. burgdorferi* infection had been noted clinically in Europe, but not until there was a cluster of childhood arthritis cases in the wealthy, predominantly white town of Lyme, Connecticut did doctors come to identify Lyme disease as a unique syndrome (Barbour & Fish 1993). Part of the emergence of the disease is due to rampant deforestation in the eighteenth and nineteenth centuries. Forests were cleared to make way for farm lands, and this deforestation, combined with an increased social interest in deer hunting, nearly eliminated deer populations, but there are parts of the country that remained forested and retained a sizeable population of deer, and thus also *I. scapularis* (Aronwitz 1991, Barbour & Fish 1993, Kilpatrick et al. 2016). One of these areas was Long Island, New York; it is theorized that as the popularity of suburbs
increased and the necessity of sprawling farms decreased, the returning forests brought
deer, ticks, and *B. burgdorferi* infection to Lyme, Connecticut (Barbour & Fish 1993). In
a sense, Lyme disease is socially constructed; a number of isolated symptoms and
conditions—primarily erythema chronicum migrans, Lyme arthritis, and *B. burgdorferi*
infection—were combined to become what is known as Lyme disease, a new epidemic
with a relatively easily identifiable ecological vector (Aronwitz 1991, Harvey & Salto
2003).

These geographical relationships of Lyme disease in Maine produce an image
where two parts of the state are consistently notable – the northwest part of the study area,
the area containing Bar Harbor and Mount Desert Island (MDI), and the south west part of
the study area, the area containing Portland and its suburbs. The zip codes that are farthest
from conforming to the regression model are also contained within these geographic areas.
Part of this variation in incidence could be due to the ecological factors mentioned earlier;
the Maine islands such as MDI, Deer Isle, Isleboro, and those in Portland’s Casco Bay are
going to be more densely forested and less developed than other parts of the state, and
forestation is linked to an increased deer population and an increased population of infected
ticks, as discussed (Seukep et al 2015, Kilpatrick et al. 2016). Part of the pattern could also
be due to the amount of time that residents of these areas spend outside, in environments
that infected ticks are known to live in, a behavior that is also linked with increased Lyme
disease risk (Quine et al. 2011). Mount Desert Island includes Acadia National Park, a
nationally renowned outdoor recreation area known for its hiking trails, as well as Bar
Harbor, a popular coastal town that experiences a boom in population during the summer
months, both of which are environments that lead to people being outside. While the ACS
does collect occupation information the occupation information does not include any measure of how much of the work is outdoors, which would theoretically lead to an increased Lyme disease risk. This correlation, though often theorized, has never been observed (Piacentino & Schwartz 2002).

These correlations could also be due to different social environments of these parts of the state. Maine’s Cumberland, Androscoggin, and Penobscot counties are considered to be the state’s only urban counties; only two are considered Lyme-endemic, and there are numerous rural communities within these urban counties (Kahn-Troster et al. 2016). Many, if not all, social experiences and demographics are intertwined; Maine is a notoriously rural state, and the level of urban development often influences all of the socioeconomic factors researched in this project. Nationally, half of all Americans who work in rural communities do not have access to employer-sponsored health insurance, and a reliance on public health insurance systems places a burden on hospitals and providers struggling to provide adequate care for a growing population with limited insurance (Kahn-Troster et al. 2016). Rural living situations are also linked with poorer health outcomes in general, due to compounding social factors including aging populations, low incomes, low educational attainments, and geographic and financial barriers to health services (Southit et al. 2015, Kahn-Troster et al. 2016). All of these components of rural life can be applied to Lyme disease incidence; in addition to the data presented in this project regarding income, insurance, and education, the population ages 65+ is the group that is second most likely to get diagnoses with Lyme Disease in Maine (Appendix I). Per capita income has the strongest positive coefficient in the counties farthest from the urban counties; this could be a reflection of geographical barriers to care where having more disposable income renders
someone better able to travel a long distance to see a provider. Public health insurance coverage has a strong negative coefficient far from urban counties, and a strong positive coefficient in the urban counties; this could be a result of the noted lack of providers in rural communities, particularly of those that willing to accept the public insurance that many members of these communities rely on.

Social situations that are less measurable also produce inequalities in rural health and contribute to the observed relationships. Nationwide, living in a rural community was linked to higher mortality rates, even when other socioeconomic factors were controlled for. Rural communities have higher poverty rates, but due to the compounding factors associated with accessing healthcare in these areas, poverty has stronger negative health effects than in urban areas (Singh & Siahpush 2013). Additionally, healthcare providers often live in the same communities in which they work, and this means that many patients have personal relationships with their doctors. These relationships can change the degree to which a patient is willing to disclose sensitive health information to their provider, depending on the nature of their personal relationship (Southit et al. 2015). In the context of Lyme disease, this sort of personal relationship could provide some insight as to why speaking a language other than English at home is significantly correlated with Lyme disease incidence, as the strong negative correlation roughly corresponds to a part of the state in which a relatively large percentage of the population speaks a language other than English (Appendix F). Understanding that in rural communities, physicians are often community members with strong relationships with their patients, it follows that someone who does not primarily speak English would have a stronger relationship with a physician who also speaks the same language. Whether low socioeconomic status leads to rural
living, or if rural living leads to low socioeconomic status, or if both factors engage with each other in a feedback loop is not as clear as the fact that healthcare access in rural communities is not equal to that of urban communities.

All of these results, while individually significant, paint a picture where one’s socioeconomic status is directly tied to one’s ability to access healthcare. These results are not surprising, considering how socioeconomic status has long been linked to poorer health outcomes throughout human history. This link corresponds to a health gradient in which the upper class consistently has the best health outcomes, the middle class has better health outcomes than the lower class, and the lower class consistently has the poorest health outcomes (Power & Kuh 2006, Glymour et al. 2014). The health effects of socioeconomic status are long term and pervasive through all stages of life. Low socioeconomic status often causes one negative health outcome early in life, and leads to numerous adverse health outcomes later in life. One example is how socioeconomic status has been linked to increased exposure to tobacco in utero as well as adult tobacco use, and childhood obesity, both of which produce a host of adverse health effects in adulthood including increased risk for coronary heart disease, one of the most common adult problems (Power & Kuh 2006). Socioeconomic status is also linked to biological health outcomes through psychobiological processes, where psychological factors simulate the central nervous system to behave in certain ways that produce negative health outcomes. Many of these psychobiological processes are mediated by the hypothalamic-pituitary-adrenocortical (HPA) axis, which is involved in the release of hormones, namely the hormones involved in the stress response, and studies have shown that low socioeconomic status is correlated with a higher stress response and lower post-stress recovery, indicating disturbances in
psychobiological processes and dysfunction of the HPA axis (Steptoe 2006). These results indicate that social factors not only influence one’s access to healthcare systems, but also that stress caused by socioeconomic situations can cause biological problems. In the context of Lyme disease, what would be a complex ecological problem is further complicated by these types of social factors.

Health insurance coverage and income disparity are important in the discussion of public health because they reveal the financial burden of illness. Diagnosing and treating Lyme disease is expensive, and often cost-prohibitive. In 2006 the estimated direct patient cost of early-stage Lyme disease was $1,609 across six Maryland counties, and $4,240 for late-stage Lyme disease (Zhang et al 2006). When adjusted for inflation, those figures become $2,399 and $6,322 (Bureau of Labor and Statistics CPI inflation calculator). In 2015 it was found that a diagnosis of Lyme disease is associated with $2,968 higher healthcare costs and 87% more outpatient visits than the general population (Adriron et al. 2015). Johnson et al. found in 2011 that nearly half of respondents to their study, all of whom were considered Lyme positive by CDC regulated lab testing, had the disease for over 10 years and had to travel over 50 miles to obtain treatment (Johnson et al. 2012). Also, almost all of the studies listed here required a positive laboratory test to be considered a Lyme patient and be included in the study, so it is not possible to know how many people suffering from Lyme disease were unable to access this testing that must be ordered by a healthcare provider. For much of the population, coming up with just the co-pay for an office visit is impossible, and, as a result, they are systemically excluded from Lyme disease incidence rates. This is particularly concerning in regard to studies examining the cost of Lyme-related healthcare; the financial burden of Lyme disease would logically be
highest for the people who are unable to even see a provider; thus the conversations regarding these studies are missing a central perspective.

All of the socioeconomic factors that were found to be significant in this study have been long linked to poor health outcomes, and are all intertwined in a complex web. Many Americans get health insurance from their employer, from the state in the form of public health insurance, or by paying out of pocket to buy it directly. Thus, health insurance coverage is dependent on income and/or employment status, which is roughly linked to level of education. Health insurance coverage, income inequality, and low levels of educational attainment have all been linked to negative health outcomes, providing support for the model created in this study. Health insurance varies in terms of total coverage, cost to the patient, and reimbursement to the provider, so it is difficult to compare insured and uninsured as two wholly different groups, as there is so much variety within health insurance plans. Niedzwiecki et al. found that Medicaid-insured patients and uninsured patients had higher likelihoods of death and readmission after hospitalization for a heart attack, and that Medicaid patients were actually more affected than uninsured patients (2018), indicating that being insured is not inherently indicative of better health outcomes by itself. The geographic changes in the correlation of public health and insurance could be explained by a similar pattern, because the American Community Survey does not collect any data regarding patient copays or deductibles for office visits or prescriptions, nor does it collect data regarding the availability of Medicaid-accepting providers.

Higher educational attainment has been linked to reduction in general mortality, as well as mortality rates for heart diseases, cancer, COPD, stroke, and unintended physical injuries (Glymour et al. 2014). However, despite the breadth of research linking
educational attainment and health outcomes, causality cannot be claimed because these studies typically operate on the assumption that all education is created equal—that is untrue, particularly in rural communities such as those that dominate the Lyme-endemic areas of Maine. According to the Center for Public Education, rural public-school systems offer fewer options for higher-level courses, and students in these systems are less likely to pursue a higher education than their urban counterparts (Lavalley 2018). One of the mechanisms by which educational attainment correlates to better health outcomes is by producing higher incomes, which leads to more access to health care (Glymour et al. 2014). Higher incomes have long been linked to better health outcomes—although, similarly, studies that attempt to claim causality are flawed in experimental design, and a comprehensive literature review indicates that income, generally, has a beneficial impact on health —this relationship is dependent on the population studied, the impact of income shocks, and when in the lifetime such income shocks happen (Glymour et al. 2014). The many confounding variables that impact the relationships between health, income, and educational attainment could explain the geographical differences in correlation with Lyme disease incidence. The data available for this project does not include the nuances regarding education or income, and other more specific measures of these variables, such as literacy, access to early childhood education, and financial literacy, are not measured.

Historically, epidemiology as a field has been profoundly antifeminist, and the introduction of intersectionality into epidemiology has allowed for a better understanding of public health epidemiology mechanisms. One aspect of this that has changed in recent years is the inclusion of women in biological and epidemiological studies, as evidenced by the CDC data used in this project that records the sex of the confirmed cases. However, the
CDC provides no definition of what it means by “male” or “female”. While this may seem like a question with an obvious answer, it isn’t. In social sciences, sex is generally understood as a biological binary, based on the ability to reproduce (Inhorn & Whittle 2001), while gender is a personal identity defined by socially constructed ideals of masculinity and femininity (Butler 1990). Although this definition excludes intersex people, it is useful for understanding the framework of gender and infectious disease. The biological nature of sex makes it vital to infectious disease, as biological realities such as hormones and reproductive organs lead to people with female bodies having different physical reactions to infectious disease agents and treatments, whereas social realities regarding discrimination and access to healthcare affect the ability of women-identified people to obtain adequate health treatment (Inhorn and Whittle 2001).

While this study is rooted in intersectional feminist epidemiology, applying the results to the framework is difficult. Intersectionality is, by definition, nearly impossible to measure without an understanding of how multiple forms of oppression influence the experience of an individual person. This paper attempts to theorize how the social conditions experienced by Mainers intersect with the physical disability caused by Lyme disease, but it cannot be said that a low-income woman living with Lyme disease in rural Maine can be fully understood by the type of additive regression analysis undertaken in this paper (Bauer 2014). Such an understanding would only be able to come from a deep understanding of her experiences with all of the forms of social oppression that she experiences due to her social position. It is also possible that the model used is unable to measure intersectionality, something that is a fundamental aspect of human experience for anyone who exists within any level of social oppression, and the immeasurable components
of intersecting identities are why the models used here did not fit the data perfectly. Different capacities of social or cultural norms regarding health care, income, gender, sex, education, or other social categories in different parts of the state could explain why geographic differences in the data would not be seen through the statistics used.

This study is limited by a number of factors. First, there is detection bias inherent in the CDC reporting mechanisms that this study is predicated on. While the correlations found in this study are strong and significant, causation cannot be determined due to this bias. In the words of Glymour, Avendano, and Kawachi (2016): “[W]e may repeatedly find that people who are in the hospital have a higher risk of dying than those who are not in the hospital, but we would be mistaken to conclude from this consistency that hospitals kill people” (18). CDC requirements for Lyme diagnosis are either positive laboratory testing or “physician diagnosed” Erythema Migrans rash (Appendix G). Any patient who is unable to see a physician will not be included in the reported numbers of Lyme disease, thus skewing the data in favor of people who are able to access health care. Second, regression analyses were carried out using 15 different socioeconomic variables from the American Community Survey, and the most significant model was the model described here; this indicates that the so-called missing variable is likely something that is not reportable among statistical census data. For general incidence, ecology likely is responsible for the majority of the pattern of incidence, but ecology should not be gendered. This indicates that the low r-squared value for the data regarding the percentage of cases affecting women is missing some other large social factor that is not present through the ACS. This could be due to the nature of statistics; while numerous attempts have been made to describe intersectionality on a population-based level using statistics, none have been able to describe the true nature
of intersectional research questions (Bauer 2014). Third, there were also substantial changes to the health-insurance and health-policy landscape that took place over the course of this study, namely the implementation of the Affordable Care Act (ACA) in 2012. It would be outside of the scope of this study to analyze the effects of the ACA on Lyme disease reporting, but the effects of nearly 77,000 Mainers getting health coverage from this legislation (Anderson 2018a), definitely has the ability to skew the results of this project.

There is also a lot of controversy within the Lyme disease community that could not be represented within any of the recognized methodologies, but have the power to alter the results of this study completely, namely controversies surrounding diagnosis of Lyme disease and the existence of chronic Lyme disease. Clinically, Lyme disease most commonly presents as a characteristic ‘bullseye’ Erythema Migrans (EM) rash at the site of the tick bite (Robinson and McFarren 2018). For many years, this EM rash was all that was required for a clinical diagnosis of Lyme (Robinson 2014); patients would be diagnosed simply by presenting to their healthcare provider with an EM rash or other symptoms and by living in an area in which I. Scapularis is known to inhabit (Bratton et al. 2008). However, recent research is suggesting that the EM rash is caused by a component of tick saliva, as studies have found that bites from arthropods that transfer bacteria other than B. burgdorferi also cause the same rash, and new clinical diagnostic criteria are moving away from the EM rash as enough to warrant a Lyme diagnosis (Kannangara & Patel 2018). This characteristic rash is caused when the immune system recruits T-cells to the source of infection (Radolf et al. 2012), which supports the hypothesis that it is not unique to Lyme infection. Since at least 2003, Lyme researchers
have noted that EM might occur anywhere from a few days to months or years after the tick bite, if it even appears at all (Harvey & Salvato 2003). Notably, this rash is still enough to warrant a reportable Lyme disease case in the state of Maine (Appendix G). Among the 1,769 cases in Maine in 2017, only 49% showed the Erythema Migrans rash, while 29% showed arthritis, and 11% showed some Neurological symptom (Robinson and McFarren 2018).

The other method of diagnosis for Lyme disease is laboratory testing, which is also wrought with controversy. The CDC prescribes a two-tiered testing model (Appendix H) that uses an enzyme immunoassay or immunofluorescence assay first, testing for lipoproteins that exist on the bacterium itself, and then a Western Blot that tests for antibodies if the first result is positive. The use of these lab tests as definitive diagnostic tools leads to the controversy surrounding Chronic Lyme Disease (CLD), understood as a pattern of persistent symptoms in patients with or without *B. burgdorferi* infection (Borgermans et al. 2014). There is some biological and ecological support for the possibility of a chronic Lyme infection (Craft et al 1986, Radold et al. 2012), and the International Lyme and Associated Diseases Society endorses its existence (Robinson and McFarren 2018). A 2009 special review panel was convened by the Infectious Disease Society of America to consider changing the clinical diagnostic criteria for Lyme disease based on the medical and scientific literature surrounding chronic Lyme infection, testimonials, and public comment. The panel found that there is “no convincing evidence for the existence of chronic Lyme infection” and declared the use of antibiotics to treat a chronic Lyme disease infection does more harm than good (Robinson and McFarren 2018). Many believers in CLD believe that the accepted Lyme tests promoted by the CDC are
unreliable, and there is evidence that Polymerase Chain Reaction detection of synovial fluid can detect *B. burgdorferi* in cases of long term arthritis (Nocton et al. 1994), and that liquid-chromatography coupled to mass spectrometry can be used to detect differences in cerebrospinal fluid among CLD patients (Schutzer et al. 2011).

Chronic Lyme Disease falls well within the realm of the chronic disease construct, but is much poorly understood compared to other chronic illnesses. Its detection, treatment, and follow up are not well understood by healthcare providers (Borgermans et al 2014), possibly because of the question to whether or not it even exists. CLD results from misdiagnosed and thus untreated Lyme, or from a diagnosed and treated infection that did not respond to prescribed antibiotics, which is why the same set of symptoms is sometimes called Post Lyme Disease Treatment Syndrome (PLDTS). Among the many misdiagnoses of Chronic Lyme are fibromyalgia and chronic fatigue syndrome (Borgermans et al 2014), both of which are considered women-dominant, as are most illnesses in which chronic pain is the primary symptom (Samulowitz et al 2018). Women often face discrimination in healthcare settings, and socially stigmatized illnesses – such as CLD, which many do not even acknowledge as real – have been linked to more discrimination and marginalization (Dehkordy et al 2016). Increased healthcare visits have also been linked to more experiences of healthcare discrimination (Dehkordy et al 2016), and outpatient visits in Maine related to Lyme are a higher percentage female than male (Robinson 2014). Patients with CLD often describe barriers to initial diagnosis and access to healthcare in general (Borgermans et al 2014) and high out-of-pocket health costs (Ali et al 2014) as part of their experience with Chronic Lyme. Among a group of Lyme-positive patients, having one or more diagnoses of a symptom related to PTLDS was associated with $3,798 higher
healthcare costs, 66% more outpatient visits, and 89% more emergency department visits (Adriiron et al 2014), supporting the experiences of CLD patients experiencing higher healthcare costs. Many CLD patients rely on complementary or alternative medicine (CAM) (Adriiron et al 2014), which is rarely covered by health insurance. If women were getting misdiagnosed by their doctors when presenting with chronic joint pain and then not getting diagnosed with Lyme disease, this could account for some of the variation in female Lyme cases. If women were initially getting misdiagnosed, returning to their healthcare provider multiple times, and ultimately getting diagnosed with CLD, this social mechanism would fit with the literature regarding women’s experiences with healthcare as well as the literature regarding chronic Lyme. The additional expense of CLD could account for why general health insurance coverage was significant for women, whereas public health insurance was significant for the general population; public health insurance would be less likely to cover the extra doctor visits, or the alternative therapies that many CLD patients depend on. While the literature is not substantial enough to make a claim that the disparity in distribution of female Lyme cases is due to an increased probability of undiagnosed chronic Lyme, it is something that would be worth examining further.

The results of this study could be used by public health officials, educators, healthcare providers, or the general public. Maine CDC has embarked on a number of efforts to reduce the public health impacts of Lyme disease and educate the public about the illness. In 2017, a clinical management guide was distributed to 101 hospitals, urgent care providers, and geriatric practices. There were also 36 presentations throughout the state of Maine for students in the 3rd-8th grade, and web resources for educators of this age group were visited 1481 times (Robinson and McFarren 2018). An instructional video
detailing how to perform a tick check was also viewed 753 times in 2017, and the Maine CDC’s FAQ section of the organizations Lyme Disease website was visited 35,416 times in 2017 (Robinson and McFarren 2018). It should be noted that nearly all of these resources are internet-dependent, and that roughly 200,000 Mainers lack broadband internet access, with 20,000 of them having no internet access at all (Anderson 2018b). Lack of internet access is cited as a contributing factor to poor health in rural communities (Douthit et al.), such as the majority of the state of Maine and its Lyme endemic counties. Understanding the needs of Maine’s Lyme susceptible populations, interventions should not be internet based, unless these interventions involve expanding internet access.

This study also proposes many avenues for future research. On a population-based level, this research could lead to future research regarding the gendered nature of healthcare access. It is well understood that rural communities and low socioeconomic status communities have poorer health outcomes, but there is not substantial research on if or how this relationship is gendered. In the context of Lyme disease, research that analyzed these socioeconomic factors on an individual-case level would indicate a much stronger correlative relationship, and possible indicate causation, though data collection for a project of such a scale would be logistically difficult. An analysis of Lyme-positive women’s experiences with healthcare systems in relation to their diagnosis could provide stronger information about the gendered nature of Lyme disease. Are women having to see more doctors or have more tests before getting a diagnosis? Is this phenomenon related to the Chronic Lyme controversy? Ultimately, this study might propose more questions than it answers, but it provides a clear path for future research.
CONCLUSIONS

This study shows geographically weighted correlations between Lyme disease incidence and public health insurance coverage, median per capita and total household income, and native language spoken, as well as correlations between health insurance coverage and the percentage of Lyme disease cases affecting women. These results are in line with understandings of how socioeconomic factors affect public health outcomes, though no study has explicitly examined the effects of these socioeconomic factors on Lyme disease incidence. The dominant understanding of Lyme disease does not account for: the inaccessibility of required laboratory tests, the repercussions of controversy surrounding Lyme disease diagnosis, and the ways in which socioeconomic status and gender explicitly affect the ways in which Mainers interact with the healthcare system, meaning that the experiences of many potentially Lyme-positive people are ignored. Lyme disease interventions should be sensitive to the needs of at-risk communities and should be administered with the intention of mitigating the social effects of living in rural areas, being on public insurance, or having a low income.
Appendix A. Combined Zip Codes used to create ARCGIS maps and statistical analysis.

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<th>No. Lyme Cases</th>
<th>Adjusted Zip Code</th>
<th>Adjusted Town Name</th>
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Appendix B. List of all ACS data points used in initial OLS regression.

<table>
<thead>
<tr>
<th>Variable</th>
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<tbody>
<tr>
<td>Intercept</td>
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<tr>
<td>Population</td>
</tr>
<tr>
<td>Unemployment rate</td>
</tr>
<tr>
<td>Percent of pop. working in Management business science and arts occupations</td>
</tr>
<tr>
<td>Percent of pop. Working in service occupations</td>
</tr>
<tr>
<td>Percent of pop. Working in Sales and office occupations</td>
</tr>
<tr>
<td>Percent of pop. Working in Natural resources construction and maintenance occupations</td>
</tr>
<tr>
<td>Percent of pop. Production transportation and material moving occupations</td>
</tr>
<tr>
<td>Total Family Income</td>
</tr>
<tr>
<td>Per Capita Income</td>
</tr>
<tr>
<td>Percent of pop. With health insurance</td>
</tr>
<tr>
<td>Percent of pop. With public health insurance</td>
</tr>
<tr>
<td>Percent of pop. With no health insurance</td>
</tr>
<tr>
<td>Percent of families below 100% of the poverty line</td>
</tr>
<tr>
<td>Percent of Population 5 years and over where English is not the primary language</td>
</tr>
<tr>
<td>Percent of Population 5 years and over where English is the primary language</td>
</tr>
<tr>
<td>Percent of Foreign-born population that are not U.S citizens</td>
</tr>
<tr>
<td>Percent of Foreign-born population that are U.S citizens</td>
</tr>
<tr>
<td>Percent of population born outside of the U.S</td>
</tr>
<tr>
<td>Percent of population born in the U.S</td>
</tr>
<tr>
<td>Percent of Population that has not moved residences in the last year</td>
</tr>
<tr>
<td>Percent of Population with a High School Diploma</td>
</tr>
<tr>
<td>Percent of Population with a Bachelors Degree</td>
</tr>
</tbody>
</table>
Appendix C. Map of study area and median household income.
Appendix D. Map of study area and the percentage of the population with public health insurance.
Appendix E. Map of study area and median per capita income.
Appendix E. Map of study area and the percentage of the population born outside of the United States that are United States citizens.
Appendix F. Map of study area and language other than English as a primary language.
Appendix G. Map of study area and the percentage of the population that was born outside of the United States.
Appendix H. Map of study area and the percentage of the population with health insurance.
Appendix I. Map of study area and the percentage of the population with a Bachelor’s degree.

**Percentage of Population with a Bachelor's Degree**
## Appendix J: Maine CDC Lyme disease reporting form.

### Maine Center for Disease Control and Prevention

#### Lyme Disease Case Report Form

### Patient Information
- **Last Name:**
- **First Name:**
- **Street Address:**
- **City:**
- **State:**
- **Zip:**
- **Date of Birth:**
- **Gender:**
- **Race:**
  - White
  - Black
  - Amer. Indian/Eskimo
  - Asian/Pacific Islander
  - Unknown
- **Ethnicity:**
  - Hispanic
  - Non-Hispanic
- **Occupation:**

### Symptoms and Signs of Current Episode: Please Answer Each Question
- **Dermatologic:** Erythema migrans (physician diagnosed EM at least 5cm in diameter).
- **Rheumatologic:** Arthritis characterized by brief attacks of joint swelling.
- **Neurologic:** Bell’s palsy or other cranial neuritis.
- **Cardiologic:** 2nd or 3rd degree atrioventricular block.
- **Yes**
- **No**
- **Unk**

### Date of Onset of First Symptoms:

### Date of Diagnosis:

### Patient diagnosed with Lyme disease in the past?
- **Yes**
- **No**
- **Unk**

### Patient tested for other tickborne diseases?
- **Yes**
- **No**
- **Unk**

### Was the patient hospitalized?
- **Yes**
- **No**
- **Unk**

### Laboratory Findings
- Please send a copy of all Lyme disease testing.
- Without laboratory report, form will be incomplete and not counted, except when Erythema migrans is present.

### Diagnosis
- **Yes,** this patient has been diagnosed with Lyme disease.
- **No,** this patient is still undergoing evaluation. Please contact me again in [ ] 15 [ ] 30 [ ] 60 days.
- **I do not believe this patient has Lyme disease.**
- Please contact the following health care provider to obtain information about this patient:

### Provider/Reporter Information
- **Provider’s Name:**
- **Telephone Number:**
- **Address:**
- **City:**
- **State:**

### Date Sent by Maine CDC:

### Date Returned:

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Reviewed 5/2014

Maine CDC Fax: 1-207-287-6865

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Appendix K: Two tiered testing standards for Lyme Disease from Maine CDC.

Appendix L. Maine Lyme disease incidence by age, 2012-2016 Maine CDC.


Originally from Groton, Massachusetts and a graduate of Groton-Dunstable Regional High School, Meghan is a double major in Zoology (pre-medical concentration) and Women’s, Gender, and Sexuality studies. At the University of Maine she is works for the Office of Admissions and Recruitment as a part of Team Maine, she previously served as co-chair of the Feminist Collective and Recording Secretary of the Delta Nu chapter of Gamma Sigma Sigma National Service Sorority, and she has been an active member of the Student Alliance for Sexual Health. Through all of this, she developed a passion for reproductive justice, serving as an 1 in 3 Campus Organizer with Advocates for Youth, and completing an internship that led to a position as an Office Assistant with Mabel Wadsworth Center in Bangor, Maine.