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Persistent Local-Area Chlamydia and Gonorrhea Clusters and Associated Community Characteristics in the Southeastern United States

Lia CB Scott

ABSTRACT

Background: The sexually transmitted infections (STIs), chlamydia and gonorrhea, disproportionately affect racial and ethnic minorities. Community attributes like poverty and prevalence of STIs, along with residential segregation and its impact on composition of sexual networks contribute to these disparate rates. The Southeast had the highest rates of chlamydial and gonorrheal infection among the four regions of the United States. Because relationships between race and place can confound national statistics, it is important to examine whether racial disparities within the region are associated with higher rates of infection.

Purpose: The study aims to evaluate local geospatial clustering of gonorrhea and chlamydia rates in the Southeast, and their persistence during 2000-2005 and any associations with residential segregation, income inequality, unemployment and uninsured rates, and race.

Methods: Using the Local Indicators of Spatial Association tests of spatial clustering, cluster maps were created for each STI outcome and year. Independent sample t-tests were then used to examine the difference in means of each community level variable across counties composing the high-rate clusters and all other counties in the region.

Results: Over 60% of counties composing high-rate clusters persisted as high rate clusters over time, and were significantly associated with higher levels of community disadvantage than all other counties ($p < 0.01$). Overall gonorrhea rates decreased from 2000 to 2005 and chlamydia rates increased, while their associations with community disadvantage remained persistently strong over time.

Conclusions: Counties with higher rates of chlamydia and gonorrhea persist over time and experience persistently higher levels of residential segregation and income inequality, as well as higher unemployment and uninsured rates, and higher proportions of blacks in the population. The social environment and segregated sexual networks may play important roles in the persistently high rates of chlamydia and gonorrhea observed for certain regions within the Southeast. Continued surveillance of reportable STIs and their probable predictors is needed in order to better understand the persistent disparities in STI rates across counties in the Southeast.

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By

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TABLE OF CONTENTS

Page

ACKNOWLEDGEMENTS ix

LIST OF TABLES...x

LIST OF FIGURES...xi

CHAPTER

I. INTRODUCTION..1

Study Objectives..4

Hypotheses..5

II. REVIEW OF THE LITERATURE 6

References..10

III. MANUSCRIPT..17

References..29

Tables...31

Figures..32

Supplementary Material..34

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LIST OF TABLES

Table 1. Results of t-tests and Descriptive Statistics of Chlamydia Rates and Community variables by Cluster group (k=6 closest neighbors weights)…………………..31

Table 2. Results of t-tests and Descriptive Statistics of Gonorrhea Rates and Community variables by Cluster group (k=6 closest neighbors weights)…………………..31

Table 3. Results of t-tests Comparing Mean STI Rates of High-High Rate County Clusters over time (k=6 closest neighbors weights)…………………………...31

LIST OF FIGURES

Figure 1. Spatial patterns of Chlamydia rates per 100,000, in 2000, k=6 closest neighbors weights …………………………………………………………………...32

Figure 2. Spatial patterns of Chlamydia rates per 100,000, in 2005, k=6 closest neighbors weights……………………………………………………………………32

Figure 3. Spatial patterns of Gonorrhea rates per 100,000, in 2000, k=6 closest neighbors weights……………………………………………………………………33

Figure 4. Spatial patterns of Gonorrhea rates per 100,000, in 2005, k=6 closest neighbors weights……………………………………………………………………33

Supplementary Materials

Figure S1. Chlamydia rates per 100,000, in 2000, quantile breaks……………………...34

Figure S2. Chlamydia rates per 100,000, in 2005, based on 2000 quantile breaks……...34

Figure S3. Gonorrhea rates per 100,000, in 2000, quantile breaks………………………35

Figure S4. Gonorrhea rates per 100,000, in 2005, based on 2000 quantile breaks……....35

Figure S5. Spatial patterns of Chlamydia rates per 100,000, in 2000, Three Neighbor Weight Definitions………………………………………………………..36

Figure S6. Spatial patterns of Chlamydia rates per 100,000 in 2005, Three Neighbor Weight Definitions……………………………………………………......36

Figure S7. Spatial patterns of Gonorrhea rates per 100,000 in 2000, Three Neighbor Weight Definitions……………………………………………………......36

Figure S8. Spatial patterns of Gonorrhea rates per 100,000 in 2005, Three Neighbor Weight Definitions………………………………………………………..37

CHAPTER I

INTRODUCTION

1.1 Background

Sexually transmitted infections (STIs) disproportionately affect racial and ethnic minorities, with non-Hispanic blacks carrying the most burden. National statistics show this burden on non-Hispanic blacks, regardless of geographic location. At a national and regional scale, race confounds place. The study of various social determinants of health, like race and poverty, and their associations with STI outcomes is not new, but none have utilized spatial cluster statistics, namely the Local Indicators of Spatial Association (LISA) statistics, to examine differences among smaller areas within the Southeast. This region is crucial to examine since there is a disproportionate concentration of non-Hispanic blacks when compared to other regions within the United States. LISA test statistics allows researchers to examine differences and disparities within the Southeast region rather than across the region.

Epidemiology of Disease and Consequences

Chlamydia trachomatis infection is the most common notifiable STI in the United States with over 1.4 million cases reported in 2011, although an estimated 2.86 million infections occur annually (Centers for Disease Control and Prevention [CDC], 2012; Stamm & Holmes, 1999). It is the most common STI among young people and can cause serious and permanent damage to a woman's reproductive organs when left untreated

(Stamm & Holmes, 1999). Chlamydial infection can facilitate the transmission of HIV and pregnant women can pass the infection to their infants during delivery (Fleming & Wasserheit, 1999; Workowski & Berman, 2010). *Neisseria gonorrhoeae* is the second most common notifiable STI with over 320,000 cases reported in 2011. Like chlamydial infection, gonorrheal infection can cause pelvic inflammatory disease in women and infertility (Fleming & Wasserheit, 1999; CDC, 2012). Additionally, *Neisseria gonorrhoeae* is progressively developing antibiotic resistance, indicative of a need for continued surveillance (CDC, 2007).

Racial Burden of STIs

Nationally, both chlamydia and gonorrhea rates remained the highest among non-Hispanic blacks in 2011. The rate of gonorrhea among non-Hispanic blacks was 17 times the rate among non-Hispanic whites, and the rate of chlamydia among non-Hispanic blacks was 7 times the rate among non-Hispanic whites (CDC, 2012). Community attributes—including poverty and prevalence of STIs—can increase the frequency of and risk associated with individual behaviors and can impede the ability of individuals to adopt preventive behaviors (Stamm & Holmes, 1999). Social and economic conditions hamper individuals' efforts in protecting their sexual health (Gonzalez, Hendriksen, Collins, Durán, & Safren, 2009). Adverse social determinants of health create an environment that leads indirectly to infectious disease and the epidemiological context interacts with individual behaviors to influence risk of transmission and acquisition of STIs (Hogben & Leichliter, 2008).

Economic Burden of STIs

The overall annual economic burden of all major STIs is estimated to be $16.9 billion (Chesson et al., 2011). As previously stated, *Chlamydia trachomatis* is the most commonly reported bacterial STI in the United States. According to Washington, Johnson and Sanders (1987), the economic cost of *C. trachomatis* in the United States is over $1.4 billion annually both in direct and indirect costs. The American Social Health Association (ASHA) estimated that annual medical costs total $374.6 million (ASHA, 1998). Chlamydial infections in women greatly exceed those in men, with women carrying about 79% of the cost (Chesson et al., 2011; Washington et al., 1987). Chesson, Blandford, Gift, Tao, and Irwin (2004) estimate the average cost per case of chlamydia is $20 for men and $244 for women. Additionally, ASHA estimated the annual medical costs for gonorrhea to be $56.0 million dollars (1998). The average cost per case is $53 for men and $266 for women. Costs for both chlamydia and gonorrhea increase significantly when left untreated due to latter complications (Chesson et al., 2004).

Geographic Approach

The Southeast had the highest rates of chlamydial and gonorrheal infection per 100,000 among the four regions in the United States (CDC, 2012). It is important to consider the geographic differences regardless of race (Farley, 2006; O'Reilly & Piot, 1996). If STI prevalence is higher in certain communities, individuals are more susceptible to infection because there is a greater chance of encountering an infected partner (Ellen, Aral, & Madger, 1998; Hogben & Leichliter, 2008). This issue is of geographic importance as blacks represent a far larger proportion of the population in the south that in any other region (Farley, 2006). Geographic approaches to STI research has garnered attention in recent years (Bernstein et al., 2004; Jennings, Curriero, Celentano,

& Ellen, 2005; Martinez et al., 2014; Rothenberg, 1983; Rothenberg & Potterat, 1988; Shahmanesh et al., 2000; Zenilman et al., 2002) and the literature demonstrates that STIs are not equally distributed across geographic areas or among population subgroups (Jennings et al., 2005). Racial disparities are important, and are often confounded by place in national statistics. This study plans to examine those disparities within places rather than across regions, requiring a more local focus with spatial analysis.

1.2 Study Objectives

This study will evaluate geospatial clustering of gonorrhea and chlamydia rates, patterns in the spatial prevalence of the disease from 2000-2005, and associations with community-level characteristics: residential segregation, income inequality, unemployment rates, uninsured rates, and proportion of population that are non-Hispanic blacks. The study examines the Southeast region of the United States (HHS Region IV): Alabama, Florida, Georgia, Kentucky, Mississippi, North Carolina, South Carolina, and Tennessee.

1.3 Research Questions

My research questions are as follows:

1. Is there geospatial clustering of the STIs, chlamydia and gonorrhea, at the county-level in the Southeastern United States (HHS Region IV)?
2. Focusing on high-rate clusters, are those clusters persistent in their locations over time?
3. Are counties in the high-rate clusters significantly different from all other counties in terms of mean STI rates and mean community-level characteristics?

Hypotheses

1. There are statistically significant local clusters of STIs at the county-level in HHS Region IV.
2. The high-rate clusters remain persistent over the time interval, 2000-2005.
3. Counties composing the high-rate clusters will have mean values for key variables (STI rates, community level characteristics) that are significantly different from all other counties
    a. Counties composing the high-rate clusters will exhibit higher levels of residential segregation, income inequality, unemployment rates, uninsured rates, and a larger proportion of non-Hispanic blacks than the rest of the counties.

CHAPTER II

REVIEW OF THE LITERATURE

This study will evaluate geospatial local-area clustering of gonorrhea and chlamydia rates, revealing patterns in the spatial prevalence of the disease from 2000-2005. Clustered counties with high rates will be contrasted with other counties to ascertain differences in their mean values of several community-level characteristics thought to be causally related to the clustering: residential segregation, income inequality, unemployment rates, uninsured rates, and non-Hispanic black population proportion. The following is an overview of the literature regarding how multiple social factors have contributed to the transmission of STIs, and exacerbated disparities.

2.1 Residential Segregation and Race

Residential segregation adversely impacts the health of blacks (Collins 1999, Collins and Williams 1999). Segregation promulgates negative social environments as highly segregated cities often experience higher levels of violent and property crimes (Peterson and Krivo 1993, Velez, Krivo et al. 2003, Kramer and Hogue 2009). Isolation that results from residential segregation can amplify the spread of STIs. Thomas and Gaffield (2003) found that black isolation was independently and strongly associated with endemically high rates of gonorrhea. Residential segregation impacts access to health-relevant sources. Even after controlling for risk factors, segregation may have a statistically significant effect on health outcomes because of the way it shapes contact patterns and social networks (Acevedo-Garcia 2000).

Research has shown that STI prevalence rates are associated with demographic factors such as percentage African-American in the area (Becker, Glass, Brathwaite, & Zenilman, 1999; Hamers et al., 1995; Jennings, Curriero, Celentano, & Ellen, 2005). Geographic variation in STI prevalence has also been associated with racial and ethnic composition (Rice, Roberts, Handsfield, & Holmes, 1991). Rice et al (1991) found that two clusters of high-incidence census tracts (>1000 cases per 100,000 population per year) in south and central Seattle after mapping gonorrhea incidence. These clusters corresponded to those tracts with the highest proportion of non-White residents.

2.2 Income Inequality and Unemployment Rates

Research demonstrates that the United States is the most unequal in terms of wealth distribution among all developed countries. The top 1 percent of households own 38 to 47 percent of all wealth (Wolff 1996, Wolff 1998, Keister and Moller 2000). The Gini coefficient is the most commonly used indicator of income inequality, and its use here allows for comparisons with other income inequality studies (Nowatzki 2012; Jones-Smith, Gordon-Larsen, Siddiqi, & Popkin, 2011). Holtgrave and Crosby (2003) found income inequality to be significantly correlated with gonorrhea and chlamydia rates at the state level using 1999 state-level case rates per 100,000. The association between income inequality and mortality has also been established at cross-country and national levels (Kaplan, Pamuk et al. 1996; McIsaac and Wilkinson 1997).

Kessler, House, and Turner (1987) found that area unemployment has significant health - damaging effects. The health of subjects in the study who were stably employed was influenced by high unemployment rates in the area (Brenner and Mooney, 1983).

2.4 Uninsured Rates

In 2000, an estimated 14.0 percent of the population, 38.7 million individuals, lived without health insurance in the United States (Mills, 2001). This number increased to 15.9% or 46.6 million individuals in 2005 (DeNavas-Walt, 2010). Uninsured adults are more likely to report poor health status (Franks, Clancy, Gold & Nutting, 1993; Hahn and Flood, 1995). Additionally, they are more likely to delay seeking medical care or to forgo necessary treatment options for serious symptoms (Weissman, Stern, Fielding & Epstein, 1991; Baker, Shapiro & Schur, 2000). This is important since chlamydia and gonorrhea are often asymptomatic, and ongoing presence of infection in undiagnosed cases can lead to serious complications.

2.5 Sexual Networks

With such disparate rates between racial groups, it is important to note that social networks are critical in the spread of sexually transmitted infections. Social context is an important influence on behavior as well (Adimora & Schoenbach, 2005). Disparities are persistent between blacks and whites even when socioeconomic factors are accounted for. Both poverty and residential segregation contribute to higher rates and racial or ethnic disparities in STIs as well as the unequal patterns of migration in mostly black communities (Aral, Padian, & Holmes, 2005; Hogben & Leichliter, 2008). Additionally, sexual networks tend to be segregated, contributing to the persistence of STIs in the black population as the prevalence of STIs are higher within that racial group (Farley, 2006;

Laumann & Youm, 1999). Physical proximity is a commonality between carriers of gonorrhea as research suggests that one infected person lives closer to another infected person than would be expected by chance (Hogben & Leichliter, 2008; Zenilman et al., 1999).

Core groups play a key role in maintaining disease transmission by providing multiple pathways to spread infection (Brunham, R. C., 1991; Jennings, Curriero, Celentano, & Ellen, 2005). It is critical to reduce infection among core transmitters to effectively reduce population levels of STIs (Jennings et al, 2005; Over & Piot, 1996).

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Chapter III

Manuscript

Title: Persistent Local-Area Chlamydia and Gonorrhea Clusters and Associated Community Characteristics in the Southeastern United States

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Abstract:

Background: The sexually transmitted infections (STIs), chlamydia and gonorrhea, disproportionately affect racial and ethnic minorities. Community attributes like poverty and prevalence of STIs, along with residential segregation and its impact on composition of sexual networks contribute to these disparate rates. The Southeast had the highest rates of chlamydial and gonorrheal infection among the four regions of the United States. Because relationships between race and place can confound national statistics, it is important to examine whether racial disparities within the region are associated with higher rates of infection.

Purpose: The study evaluates local geospatial clustering of gonorrhea and chlamydia rates in the Southeast, their persistence during 2000-2005, and associations with residential segregation, income inequality, unemployment and uninsured rates, and race.

Methods: Using the Local Indicators of Spatial Association tests of spatial clustering, cluster maps were created for each STI outcome and year. Independent sample t-tests were then used to examine the difference in means of each community level variable across counties composing the high-rate clusters and all other counties in the region.

Results: Approximately 60% of counties composing high-rate clusters persisted over time, and were significantly associated with higher levels of community disadvantage than all other counties ($p < 0.001$).

Conclusions: Counties with higher rates of chlamydia and gonorrhea persist over time and experience persistently higher levels of community disadvantage. Continued surveillance of reportable STIs and their probable predictors is needed in order to better understand the persistent disparities in STI rates across counties in the Southeast.

Introduction

Sexually Transmitted Infections (STI) disproportionately affect racial and ethnic minorities, specifically non-Hispanic blacks. *Chlamydia trachomatis* infection is the most common notifiable STI in the United States with over 1.4 million cases reported in 2011, although an estimated 2.86 million infections occur annually.[1-2] *Neisseria gonorrhoeae* is the second most common notifiable STI with over 320,000 cases reported in 2011. Both chlamydia and gonorrhea rates remained the highest among non-Hispanic blacks in 2011. The rate of gonorrhea among non-Hispanic blacks was 17 times the rate among non-Hispanic whites, and the rate of chlamydia among non-Hispanic blacks was 7 times the rate among non-Hispanic whites.[1]

With such disparate rates between racial groups, it is important to note that social networks are critical in the spread of sexually transmitted infections. Social context is an important influence on behavior as well.[3] Community attributes—including poverty and prevalence of STIs—can increase the frequency of and risk associated with individual behaviors and can impede the ability of individuals to adopt preventive behaviors.[2] Social and economic conditions hamper individuals' efforts in protecting their sexual health.[4]

The Southeast had the highest rates of chlamydial and gonorrheal infection per 100,000 among the four regions in the United States.[1] Geographic approaches to STI research have garnered attention in recent years[5-11] and the literature demonstrates that STIs are not equally distributed across geographic areas or among population subgroups.[9]

This study will evaluate local geospatial clustering of gonorrhea and chlamydia rates, revealing patterns in the spatial prevalence of the disease from 2000-2005, and examine associations with community-level characteristics: residential segregation, income inequality, unemployment rates, uninsured rates, and non-Hispanic black population proportion.

Methods

Data

Gonorrhea and chlamydia are notifiable diseases and cases are reported by local health authorities to state health departments. Data on the incidence of chlamydia and gonorrhea in 2000 and 2005 were obtained from the Nationally Notifiable Diseases Surveillance System (NNDSS), collected through National Electronic Telecommunications System for Surveillance (NETSS) from the Centers of Disease Control and Prevention (CDC) and from state health departments. The study focused on states located in HHS Region IV which includes counties in Alabama, Florida, Georgia, Kentucky, Mississippi, North Carolina, South Carolina, and Tennessee (n = 734 counties).

The data included population-based rates of chlamydia and gonorrhea per 100,000 at the county-level. Miami-Dade County was excluded due to missing data in both years. Demographic data on the STI population was unavailable due to potential confidentiality issues at the county level of analysis. Contextual county-level data on demographics and other factors was obtained from the RTI Spatial Impact Factor Database created from multisourced data (supported by a National Cancer Institute grant (1R01CA126858-01A1)).[12] (https://rtispatialdata.rti.org)

The study focused on high-rate clusters and their associations with four dimensions of community characteristics: residential segregation, income inequality, the uninsured population, and race. Residential segregation for African Americans is represented using the Interaction Index as defined by Massey and Denton[13], which measures the probability that Blacks will meet Whites. The higher the value, the more integrated the county and the more likely the races will mix. Income inequality is represented by two variables: the GINI Index and unemployment rates. The GINI Index of family income inequality reflects the degree to which income is equally shared. A coefficient of 0 represents a perfectly equal society while a coefficient of 1 represents a perfectly unequal society. Unemployment rates were derived from the U.S. Bureau of Labor Statistics and represent the number of unemployed people as a percentage of the labor force. Uninsured rates were represented as the percent uninsured in the total population under age 65. The only racial dimension studied was the contextual variable defined as proportion of non-Hispanic blacks in the county, which was the only group exhibiting disparate rates relative to whites.

Methods

The dataset was combined and summary statistics were computed using SAS Software (SAS 9.4, SAS Institute Inc., Cary, NC). The dataset was imported into ArcMap 10.1 (ArcGIS 10.1, ESRI, Redlands, CA) and joined to the county shapefile by FIPS code. Counties with missing data were individually excluded for each disease and year. Shapefiles were created for each year and disease outcome to account for the actual counties with available data. Less than 10% of data from each disease-year were missing. Spatial analyses were performed in GeoDa software[14, 15] and results were mapped in QGIS (free, open source GIS software).

Following the approach in Mobley et al[16] and Schieb et al[17], the Global (Moran's I) and Local Indicators of Spatial Association (LISA) spatial clustering tests were performed using GeoDa software. For each STI variable and year, both the global and local univariate tests of spatial autocorrelation were performed to determine the presence of spatial clustering. The global Moran's I test determines if there is global clustering in the pattern of chlamydia and gonorrhea rates; a rejection of the hypothesis of spatial randomness with the Moran's test predicates use of the LISA test for identification of local clusters.[14, 15] There are four types of spatial clusters identified using the LISA statistic: high-high (higher than average rates adjacent to higher than average rates), low-low, high-low, low-high. Positive spatial autocorrelation in STI rates among counties is represented by both high-high and low-low clusters, while negative spatial autocorrelation is represented by high-low and low-high clusters.[14, 15] Significant positive clustering was found at $p < 0.001$, which suggests that the chlamydia and gonorrhea rates are too similar across neighboring counties in some local areas to have occurred by chance. Thus, statistically significant local spatial clusters exist in these data.

This finding of significant local clusters was robust to the use of several different neighbor weights definitions, which define the neighboring counties compared to one another in the LISA test. Maps were similar, regardless of which weights were used. The k-nearest neighbor weights matrix with the 4, 6, and 8 nearest neighbors was used, rather than a Queen or Rook neighbor definition which is sensitive to islands (holes) characterizing counties with missing data. The cluster maps presented here (Figures 1-4) are based on the 6 closest neighbor definition. The maps show the center of the cluster in color (ie., red for high-high), while the actual extent of the cluster includes the center and its surrounding neighbors as defined by the weights matrix.[14, 15] The neighbors are properly included in the cluster, shown here as a dark grey buffer zone around the center.

Descriptive statistics were calculated for the outcome variables and the five contextual variables of interest. Using the means and variances of these variables by group (whether in a high-rate cluster, or not), independent samples t-tests were conducted to determine whether there was a statistically significant difference in the STI rates or the contextual variables across the two groups, at each point in time (Tables 1, 2).The independent samples t-test was also used to examine whether there was a significant change over time in the STI rates in the two temporal groups of high-rate cluster counties (Table 3).

Results

Descriptive Statistics

The STI data had less than 10% missing. Chlamydia rates from 2005 were the only set to include all 734 counties in the Southeast. None of the contextual variables had missing data. The mean chlamydia rate of all counties included in analysis increased from 250.9 ± 209.7 to 331.9 ± 263.2 (per 100,000) from 2000 to 2005, while the mean gonorrhea rate decreased slightly from 164.5 ± 151.6 to 132.6 ± 115.6 (per 100,000).

Tests of Spatial Association

The Global Moran's I statistic was statistically significant at $p < 0.001$ for both gonorrhea and chlamydia in both time periods. The Global Moran's I increased from 0.42 to 0.61 for chlamydia rates, and from 0.39 to 0.42 for gonorrhea rates. This increase suggests that there was increased spatial clustering within the Southeast region from 2000 to 2005.

The LISA maps (Figures 1-4) show the statistically significant positive clusters of high- rate and low-rate clusters. The counties identified in low-rate clusters are of interest in that they persist over time and spread. For chlamydia, low-rate clusters were located in eastern Kentucky, across Tennessee, the Tennessee-North Carolina border, and parts of north Alabama and Georgia in 2000. The clusters in Kentucky grew to cover the entire eastern portion of the state, were persistent on the Tennessee- North Carolina border and north Georgia. Similar results were found for gonorrhea. Low-rate clusters remained persistent in eastern Kentucky and along the Tennessee-North Carolina border. The counties identified as components in the high-high cluster were of most interest. High-rate counties and their neighbors had higher than average STI rates, generating strong spatial correlation in the values across neighboring counties. For chlamydia, the high rate clusters were located in primarily in Mississippi and southern Alabama, with two counties near the Atlanta Metropolitan Statistical Area (MSA) in 2000. The clusters grew to cover the majority of Mississippi and diminished from Alabama and Georgia in 2005. High-rate clusters also appeared in counties along the coast of South Carolina. Over time, the areas of high-high clustering for chlamydia spread from 7.2% (*n* = 725) of counties to 13.8% (n = 734) of counties.

In 2000, high-rate clusters of gonorrhea covered the western portion of Mississippi, parts of central Alabama, the Atlanta MSA in Georgia, and eastern North Carolina. The cluster in eastern North Carolina spread to capture both the North and South Carolina coast in 2005. While the Atlanta MSA cluster shrank to include fewer counties, smaller high rate clusters appeared over time in both south Alabama and Georgia. The cluster in western Mississippi grew slightly to include more of central Mississippi. Counties in the high-high cluster for gonorrhea spread from 14.9% (*n* = 672) of counties to 17.9% (*n* = 694) of counties.

Comparison of LISA estimates for core counties (cluster centers) in high-high clusters show that 60% of core counties from 2000 were core counties in 2005 for chlamydia ($n = 15$). These persistent core counties were all located in Mississippi. For gonorrhea, approximately 58% of core counties in high-high clusters from 2000 were core counties in 2005 ($n = 31$). Eleven of those counties were located in Mississippi. Counties that transitioned into a high-rate cluster were primarily located along the eastern seaboard and in Mississippi for both outcomes.

Independent Samples t- test

Following the approach used in Mobley et al[16] and Schieb et al,[17] comparisons of the contextual variables in high-rate county clusters (core and neighbors) versus all other counties (Tables 1 and 2) demonstrate that high-rate counties had significantly different contexts present across the diseases studied and time periods. Table 1 shows that high-rate county clusters for chlamydial infection in 2000 were more segregated/had lower racial mixing or interaction (0.417 vs. 0.684 in other counties), had higher levels of income inequality (0.481 vs. 0.453), higher rates of unemployment (5.88% vs. 4.68%), higher uninsured rates (19.09% vs.15.79%), and had a larger proportion of non-Hispanic black population (0.478 vs. 0.189) than other counties. These results were highly significant ($p < 0.001$). Similar results were found for chlamydia in 2005 (Table 1) and gonorrhea in 2000 and 2005 (Table 2).

T-tests were also used to compare the mean rates of STI in high-high cluster counties over time, to determine whether the apparent change was statistically significant (Table 3). The increase in chlamydial infection rate was not statistically significant at p<0.01 (592.73 vs. 738.72), while the mean rates of gonorrheal infection were significantly lower in high-rate counties in 2005 than in 2000 (355.69 vs. 266.81, $p < 0.001$).

Discussion

In this study, spatial clusters of high-rate STIs remained mostly intact in the same locations over 2000 to 2005. Clusters of high-rates were most persistent in Mississippi. Counties along the North and South Carolina coast line transitioned into high-rate clusters. There were also changes in cluster status as the clusters spread out over time; 48 and 19 counties transitioned over time into high-rate clusters for chlamydia and gonorrhea, respectively. Despite the decrease in mean gonorrhea rate, the total number of high-rate core counties increased from 2000 to 2005. The number of high-rate core counties also increased for chlamydia outcomes.

In general, community deprivation characteristics were more prevalent in these high-rate cluster counties than in other counties, and this disparity in community context also persisted over time. High-rate county clusters had significantly higher levels of residential segregation, income inequality, unemployment, and uninsured people. High-rate county clusters had a larger proportion of population who were black. Together these findings may suggest that residential segregation serves as an isolating factor, further perpetuating the high rates of disease within this race. The social environment and sexual networks may play a role in perpetuating the persistently high rates of chlamydia and gonorrhea.

While not the focus of this paper, the counties in low-rate clusters, and their persistence over time, is also of policy interest. For both outcomes, low-rate clusters were present in 2000 and spread to cover more counties by 2005. Future studies should examine community contextual factors in these low-rate clusters to determine whether any community-level protective factors may exist.

These current findings suggest there is a need for consistent surveillance of reportable STIs and their contextual predictors at actionable geographic scales, such as counties, in order to better develop public health interventions.

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Table 1. Independent-sample t-tests of Differences in Chlamydia Rates and Community Context in High-rate Cluster Counties (k=6 closest neighbors weights) and Other Counties

Outcome	2000			2005		
	High Rate Cluster Counties	Other Counties		High Rate Cluster Counties	Other Counties	
	n = 52	n = 673		n = 101	n = 633	
	Mean	Mean	t	Mean	Mean	t
Chlamydia Rate (per 100,000)	592.73	224.58	6.21†	738.72	267.05	14.32†
Interaction Index	0.417	0.684	-10.14†	0.465	0.699	-12.54†
GINI Index	0.481	0.453	4.15†	0.482	0.451	9.164†
Unemployment Rate (%)	5.88	4.68	3.84†	8.15	5.79	10.37†
Uninsured Rate (%)	19.09	15.79	5.24†	18.90	15.57	8.25†
Proportion of Non-Hispanic Black	0.478	0.189	10.89†	0.445	0.171	14.55†

†statistically significant at $p < .001$

Table 2. Independent-sample t-tests of Differences in Gonorrhea Rates and Community Context in High-rate Cluster Counties (k=6 closest neighbors weights) and Other Counties

Outcome	2000			2005		
	High Rate Cluster Counties	Other Counties		High Rate Cluster Counties	Other Counties	
	n = 100	n = 572		n = 124	n = 570	
	Mean	Mean	t	Mean	Mean	t
Gonorrhea Rate (per 100,000)	335.69	131.04	11.42†	266.81	103.45	13.70†
Interaction Index	0.427	0.687	-14.07†	0.459	0.698	-14.51†
GINI Index	0.478	0.450	6.310†	0.475	0.449	7.716†
Unemployment Rate (%)	5.95	4.50	6.55†	7.33	5.77	6.81†
Uninsured Rate (%)	18.88	15.51	7.92†	18.96	15.41	10.25†
Proportion of Non-Hispanic Black	0.461	0.181	13.94†	0.435	0.173	15.57†

†statistically significant at $p < .001$

Table 3. Independent-sample t-tests of Differences in Mean STI Rates of High-High Rate County Clusters over time (k=6 closest neighbors weights)

Outcome	Year		
	2000	2005	
	Mean	Mean	t
Chlamydia Rate (per 100,000)	592.73 (n=52)	738.72 (n=101)	-2.17
Gonorrhea Rate (per 100,000)	355.69 (n=100)	266.81 (n=124)	4.01†

†statistically significant at $p < .001$

Figures

Figure 1. Spatial patterns of Chlamydia rates per 100,000, in 2000, k=6 closest neighbors weights

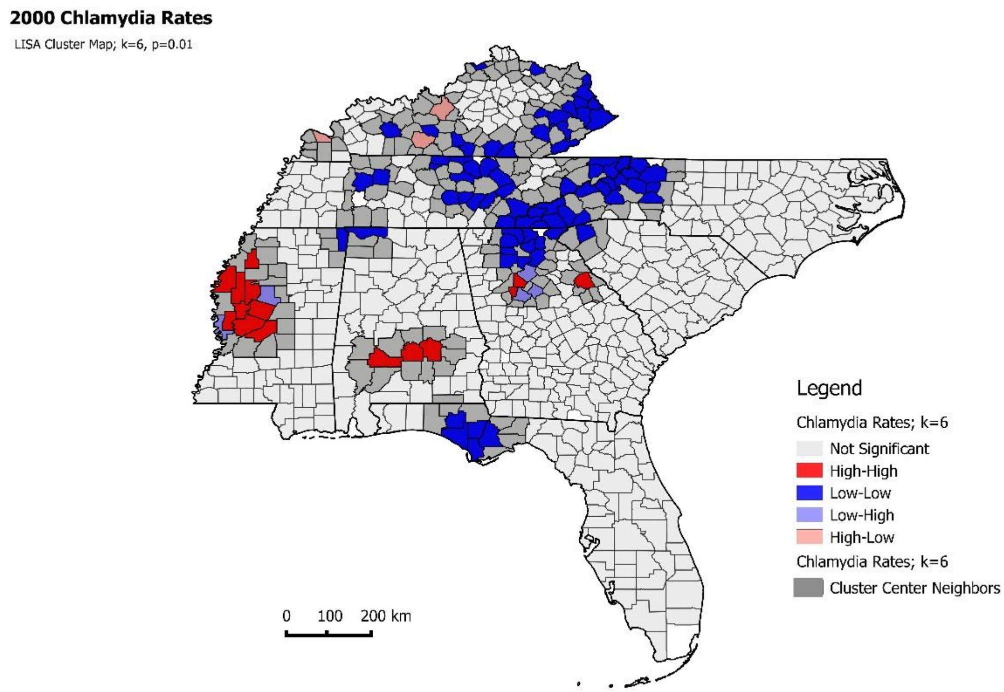


Figure 2. Spatial patterns of Chlamydia rates per 100,000, in 2005, *k=6 closest neighbors weights*.

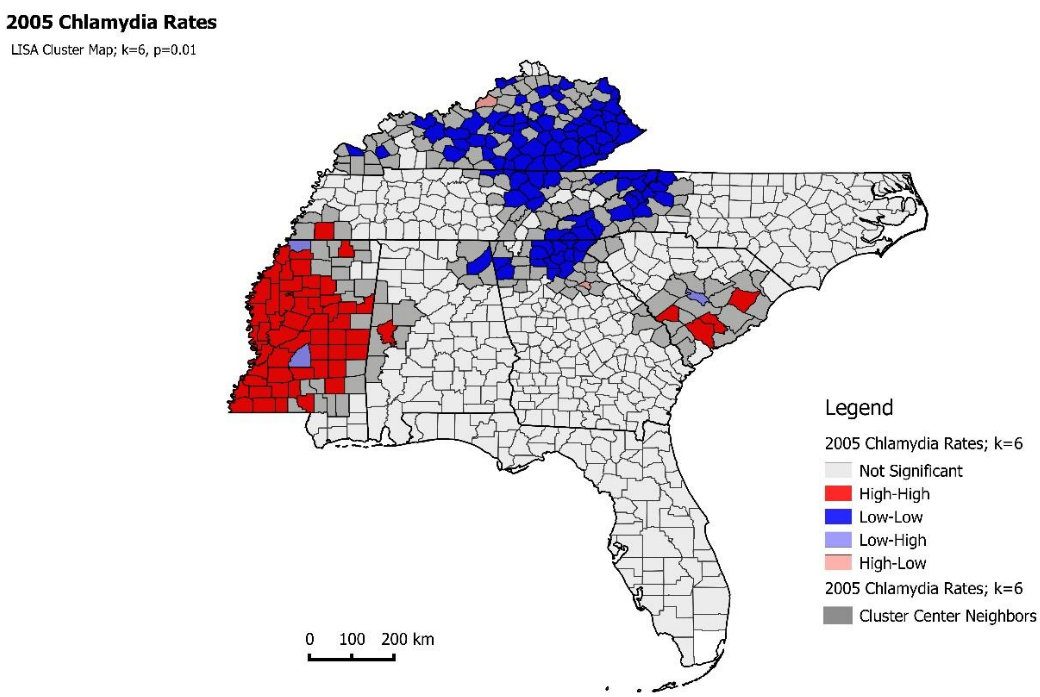


Figure 3. Spatial patterns of Gonorrhea rates per 100,000, in 2000, *k=6 closest neighbors weights*

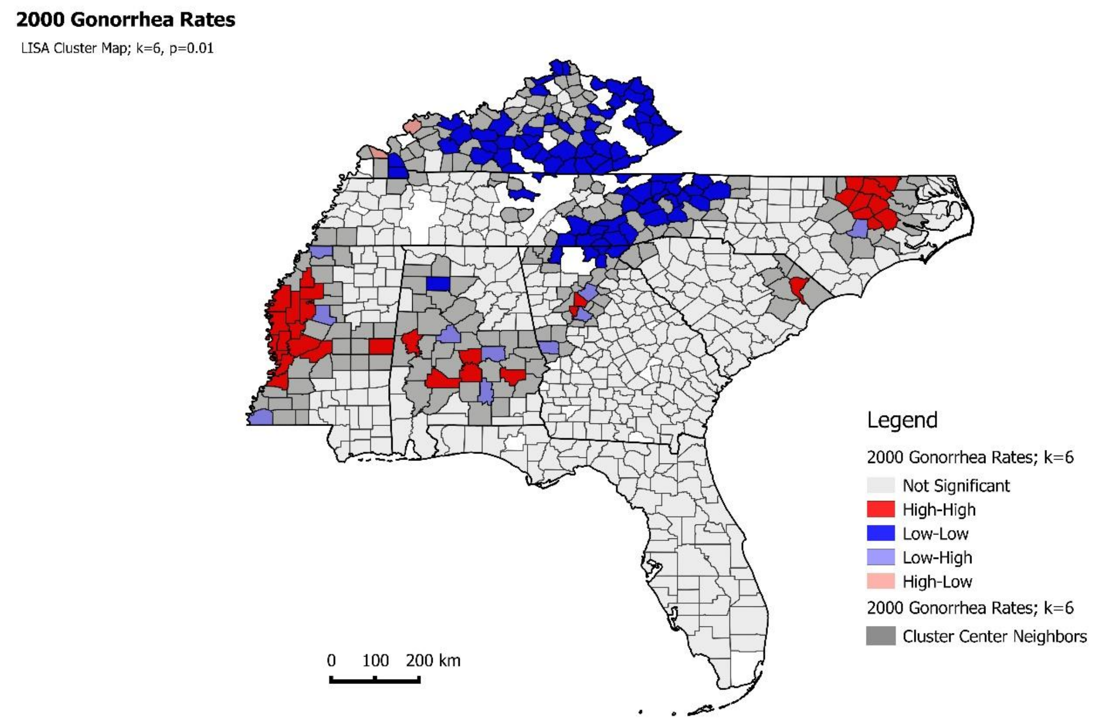
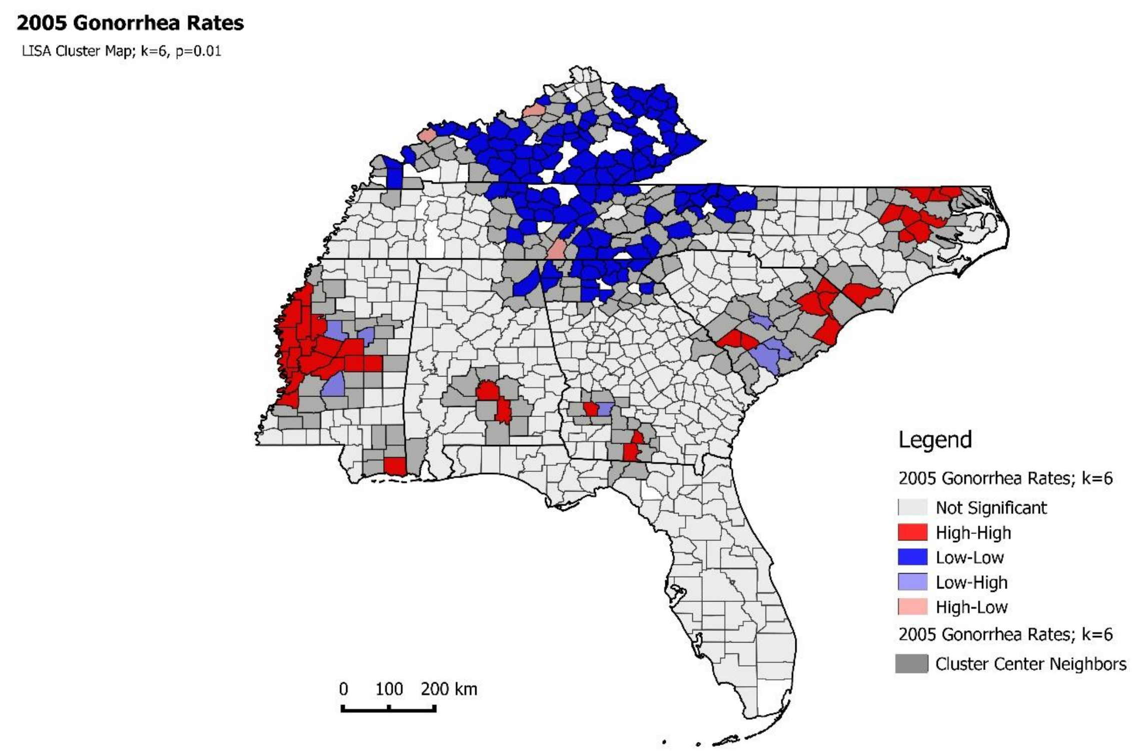


Figure 4. Spatial patterns of Gonorrhea rates per 100,000, in 2005, *k=6 closest neighbors weights*



Supplementary Materials
Figures

Figure S1. Chlamydia rates per 100,000, in 2000, quantile breaks.

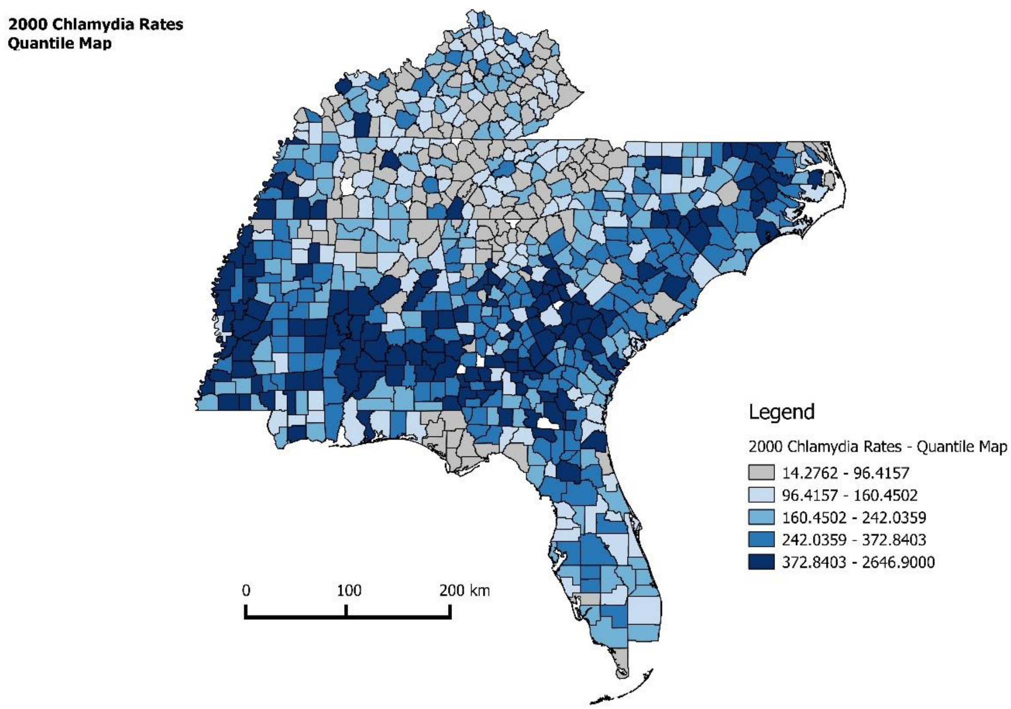


Figure S2. Chlamydia rates per 100,000, in 2005, based on 2000 quantile breaks.

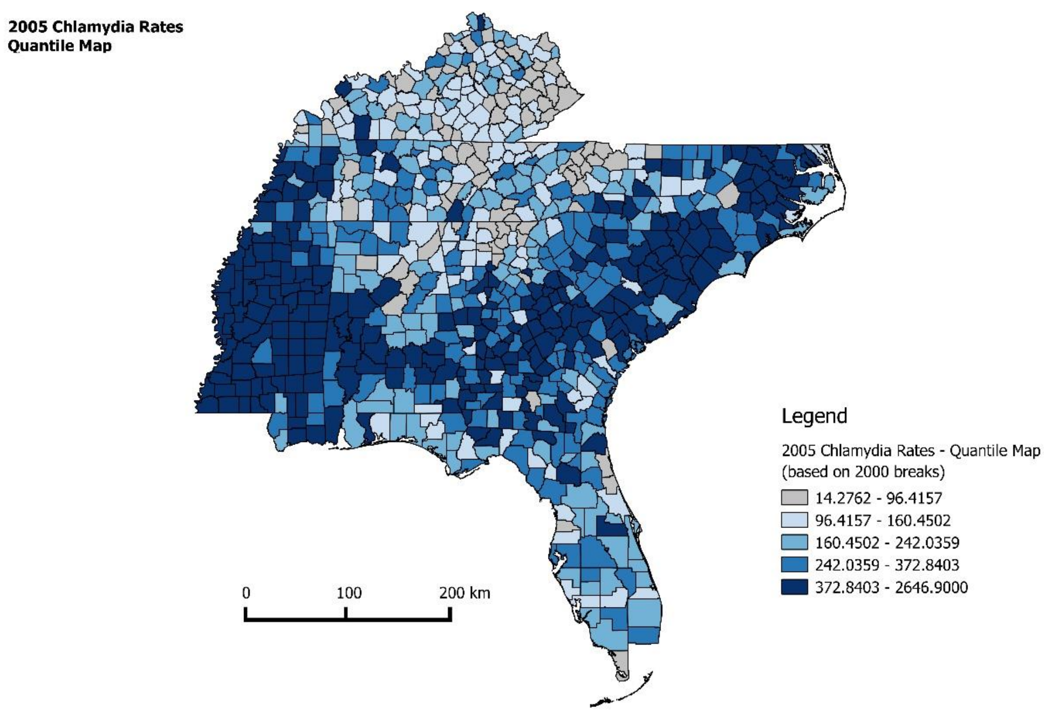


Figure S3. Gonorrhea rates per 100,000, in 2000, using quantile breaks.

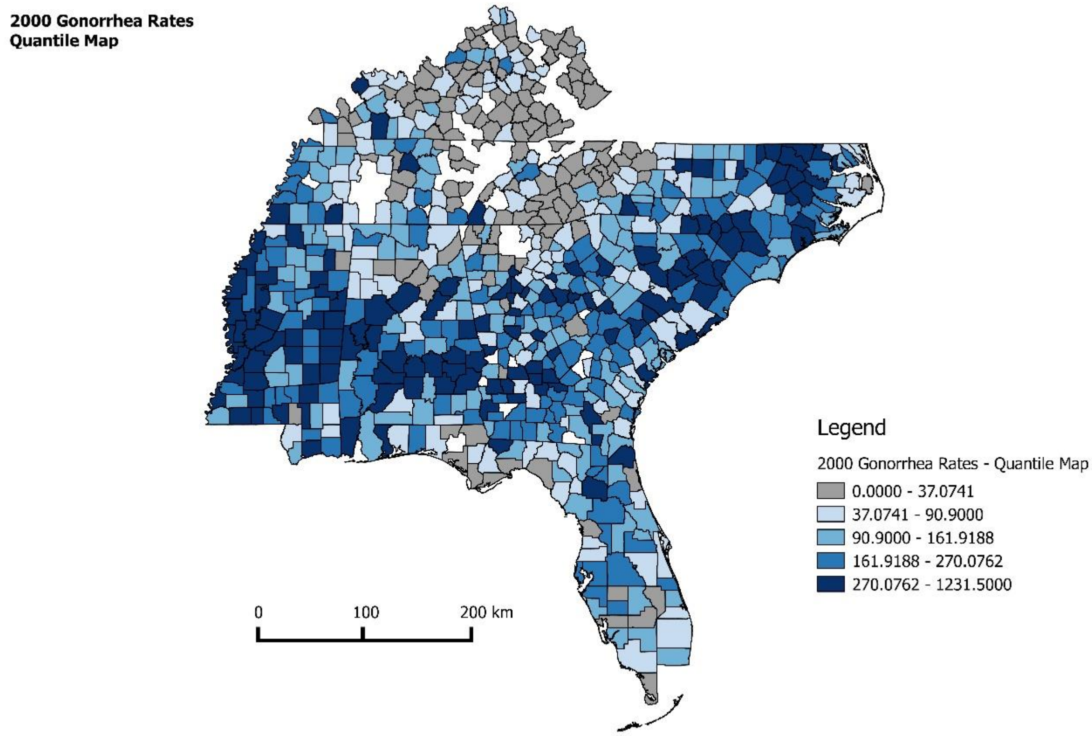


Figure S4. Gonorrhea rates per 100,000, in 2005, based on 2000 quantile breaks.

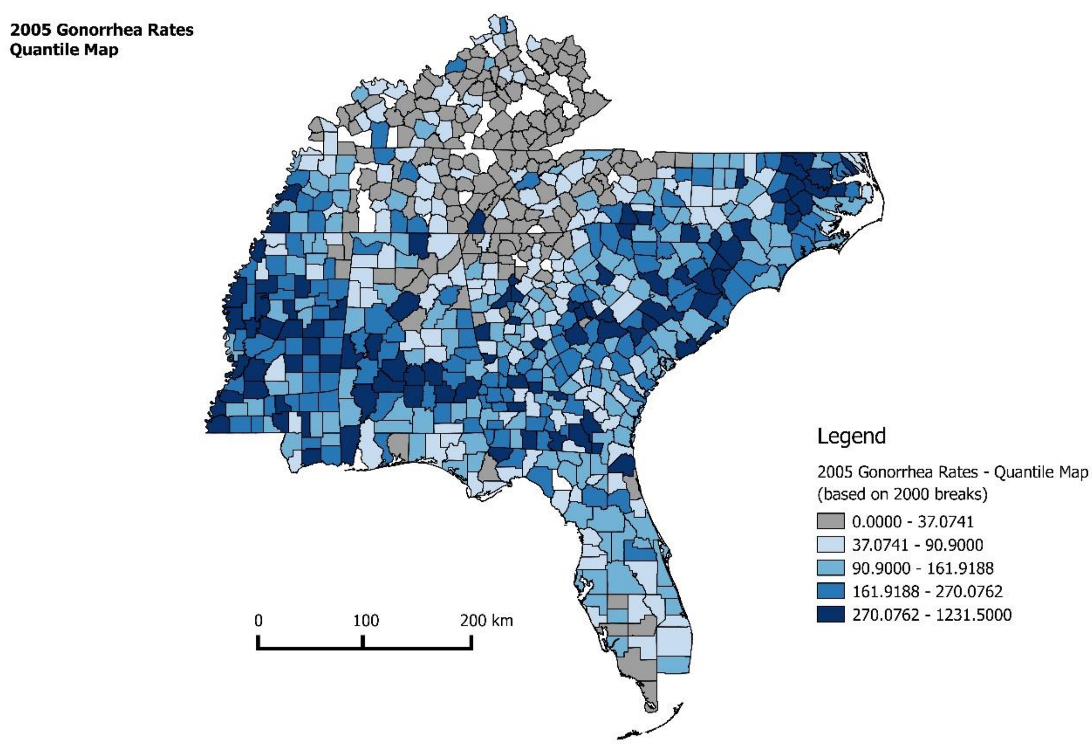


Figure S5. Spatial patterns of Chlamydia rates per 100,000, in 2000, Three Neighbor Weight Definitions.

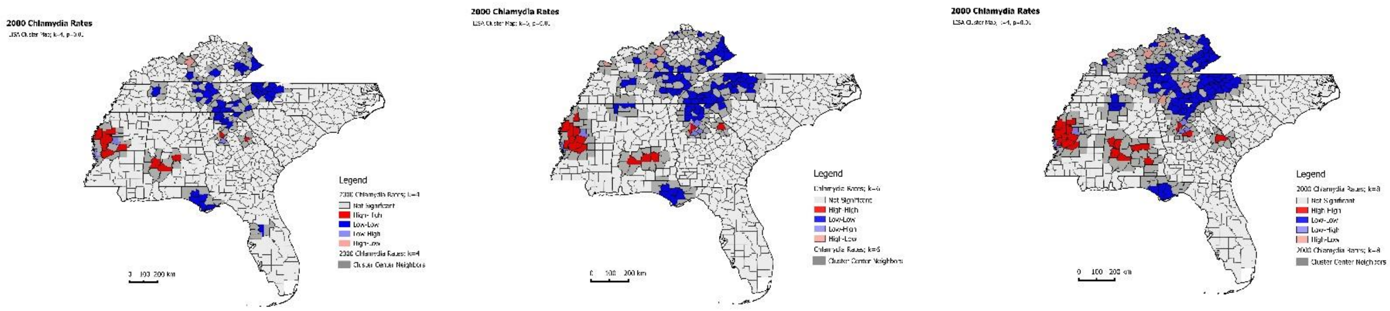


Figure S6. Spatial patterns of Chlamydia rates per 100,000 in 2005, Three Neighbor Weight Definitions.

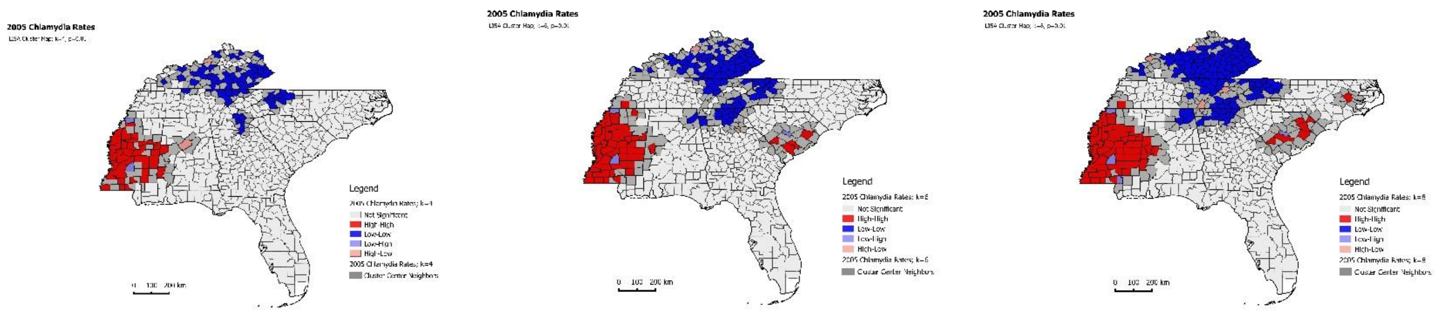


Figure S7. Spatial patterns of Gonorrhea rates per 100,000 in 2000, Three Neighbor Weight Definitions.

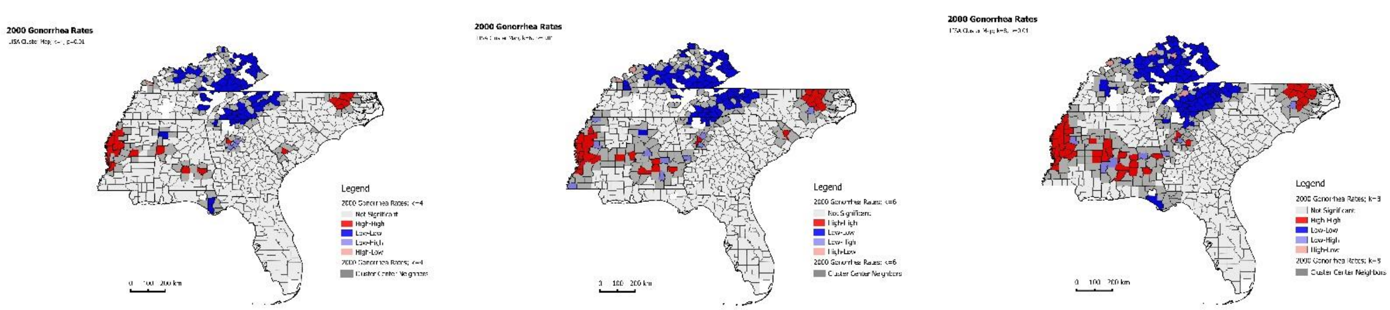


Figure S8. Spatial patterns of Gonorrhea rates per 100,000 in 2005, Three Neighbor Weight Definitions.