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Sociodemographic and Spatial-Temporal Cluster Analyses of Socioeconomic Status and Salmonellosis in Georgia, 2010-2012

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An abstract of
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Abstract

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The purpose of this study was to investigate the association between socioeconomic status and salmonellosis outcomes in Georgia from 2010 to 2012 using sociodemographic groups and spatial-temporal analyses.

Methods

Poisson regression models were utilized to estimate the incidence, hospitalization, and case fatality rate ratios for all non-typhoidal serotypes of *Salmonella enterica*, and *Salmonella* Enteritidis, Typhimurium, Newport, and Javiana. The highest socioeconomic status group (A of A-D) or subgroup (A.1 of A.1-D.7) served as the reference category. Spatial-temporal analyses were conducted to describe the geospatial distribution of *Salmonella* Newport and Javiana cases.

Results

7,590 cases of salmonellosis were included in the analysis. The incidence rate ratios were generally protective for *Salmonella* Enteritidis. The highest, significant incidence rate ratios occurred in sociodemographic group C and D for *Salmonella* Typhimurium (IRR 1.82-2.36), A and C for *Salmonella* Newport (1.90-2.60), and C for *Salmonella* Javiana (IRR 1.59-1.79). Significant hospitalization rate ratios above the null were noted among many of the subgroups in A, C, and D for *Salmonella* Typhimurium, Newport, and Javiana; hospitalization rates were similar to the null for *Salmonella* Enteritidis. The case fatality rate ratio was significantly greater than the null for group C (RR=2.89, p=0.01). The spatial-temporal analyses identified geospatial clusters in the lower two-thirds and northeastern corner of the state for both *Salmonella* Newport and Javiana.

Discussion

These results suggest an increased incidence, hospitalization, and case fatality rate for salmonellosis cases in the lower middle socioeconomic status group (C) relative to those in the highest socioeconomic status group (A). The spatial-temporal analyses further identified geospatial clusters in regions of the state mostly populated by cases in group C.

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I. Background/Literature Review

A. Burden of Salmonellosis

1. National burden of Salmonella enterica

The most recent United States surveillance report indicated 51,887 cases of salmonellosis were reported in 2011, with an estimated incidence of 16.8 illnesses per 100,000 population (1). The real burden of infection is estimated to be as high as 38 times higher because only a small proportion of cases seek medical attention and have a stool sample collected for lab-confirmation (2). The estimated national burden in 2011 for non-typhoidal *Salmonella* was 1,027,561 cases (90% credible interval: 644,786-1,679,667) (3). Consequently, 11% of domestically acquired foodborne illnesses are projected to be due to salmonellosis (3). *Salmonella enterica* was also the most common pathogen identified in foodborne outbreaks in 2011 (4), and the second most common cause of foodborne outbreaks from 1998 to 2008 (5).

The 2020 Healthy People goal for the nation for *Salmonella enterica* infections is 11.4 illnesses per 100,000 population (6). Since 2003, however, the annual incidence has ranged from 14.5 to 17.7 cases per 100,000 population, with an average incidence of 16.0 per 100,000 population (1). Specifically, the serotypes of *Salmonella enterica* subspecies *enterica* resulting in the highest proportion of salmonellosis in 2011 were as follows: Enteritidis (7,553 cases; 16.5%), Typhimurium (6,131 cases; (13.4%), Newport (5,211 cases; 11.4%), and Javiana (2,937 cases; 6.4%) (7).

In order to enhance the accuracy of foodborne disease surveillance, the Centers for Disease Control and Prevention coordinates with ten sentinel active surveillance sites in states across the nation. The state of Georgia participates in this network, known as Foodborne Diseases Active Surveillance Network (FoodNet) (8). Among the FoodNet

sites, 8,256 cases (17.6 cases per 100,000 population) of salmonellosis were reported for 2011, 2,290 cases (27.7%) resulted in hospitalization, and 29 cases (0.4%) resulting in fatalities (9). National estimates for 2011 (including the FoodNet sites), reported 19,336 hospitalizations (90% credible interval: 8,545-37,490) and 378 deaths (90% credible interval: 0-1,011) (3). Therefore, in addition to being responsible for a large proportion of domestically-acquired foodborne illnesses and outbreaks, non-typhoidal *Salmonella enterica* serotypes are also responsible for approximately 35% of the hospitalizations and 28% of the deaths due to domestically-acquired foodborne diseases (3).

Although the majority of salmonellosis infections do not result in hospitalization or death, the consequential costs to the healthcare system are not insignificant. Illnesses due to *Salmonella enterica* infections are estimated to have an annual cost of $365 million for direct medical expenses (9), and an overall cost of $3.3 to $4.4 billion dollars (10) . These costs further support the importance of prevention and control efforts in public health to work toward the Healthy People 2020 goal of an annual incidence rate of 11.4 illnesses per 100,000 population for salmonellosis.

2. Burden of Salmonella enterica in Georgia

According to unpublished surveillance data, the total number of salmonellosis cases in Georgia has ranged from 1,840 cases in 2003 to 2,646 cases in 2012 for the period of 2003 to 2012 (Figure 1) (11). In 2011, approximately 2,632 cases of salmonellosis were reported in Georgia to FoodNet, with a surveillance population of approximately 9,815,210, resulting in an annual incidence of approximately 26.8 illnesses per 100,000 population (12). Relative to the other fifty states, Georgia's annual case count has been among the top four highest for 2008 through 2011, behind Florida, Texas, and California

(1, 13-15). Although the case counts in Georgia may be lower, Georgia is less populous than the other three states, resulting in the highest annual incidence rate in the country.

Among the 2,632 cases reported in 2011, 1,877 resulted in outpatient medical services, 733 resulted in hospitalization (27.8% of all cases), and 22 cases had an unknown outcome (12). Five deaths were reported, with the survivability of 173 cases unknown, resulting in a case fatality rate of 0.19 per 100,000 population (12).

3. Patterns of illness by serotype

Similar to national figures, the four most common serotypes causing illness in Georgia are *Salmonella* Enteritidis, Typhimurium, Newport, and Javiana. Since 2003, the number of annual cases in Georgia has varied by serotype (Figure2). Cases due *Salmonella* Enteritidis increased from 2003 (103 cases) to 2008 (269 cases), and have since leveled off with 216 cases in 2012. The case counts for *Salmonella* Typhimurium have slowly declined from 288 cases in 2003 to 221 cases in 2011.

The patterns for *Salmonella* Newport and *Salmonella* Javiana have been similar. The case counts declined from 2003 to 2006, rose rapidly until 2010, and then declined from 2011 to 2012. For *Salmonella* Newport, the case counts ranged from 216 cases in 2006 to 542 cases in 2010 for Georgia. Nationally, the southeastern region demonstrates the highest incidence for this serotype (2011 case counts: AL=283, GA=452, LA=226, NC=612, SC=318, TX=389) (7).

For *Salmonella* Javiana, the case counts peaked in 2010 at 576 cases, and have remained stable around 526 cases for 2011 and 2012. The 2011 National Enteric Disease Surveillance report on *Salmonella enterica* noted an increase of 250% between 2001 and 2011 for cases of *Salmonella* Javiana nationwide. The most notable increase occurred after 2006, similar to the pattern described above for Georgia (16). Similar to *Salmonella*

Newport, the annual incidence of *Salmonella* Javiana is also highest in the southeastern region (2011 case counts: AL=230, GA=497, SC=374, NC=528) (7). Georgia reported the second highest case count of *Salmonella* Javiana cases for the southeast, indicating illnesses associated with this serotype are a growing public health concern.

4. Surveillance and diagnostics

In the United States, the National Notifiable Diseases Surveillance System (NNDSS) is the electronic database established to capture cases of salmonellosis and other diseases considered nationally notifiable (17). The process of identifying a case generally involves an ill patient seeking medical treatment due to symptoms (gastrointestinal and fever), having a stool sample taken (most common; although urine and blood samples may also be taken), and then having a clinical laboratory isolate the bacteria through a variety of diagnostic methods.

In the state of Georgia, those specimens that test positive for salmonellosis at a hospital or clinical lab are forwarded to the state public health laboratory for culture confirmation and serotyping. The results are then reported in the State Electronic Notifiable Disease Surveillance System (SENDSS) and forwarded to the Centers for Disease Control and Prevention for reporting in NNDSS (18).

B. Epidemiology of *Salmonella enterica*

1. Organism and nomenclature

The genus *Salmonella* is characterized by Gram-negative, rod-shaped, enteric bacteria. The species *Salmonella enterica* is responsible for human infection, and includes six subspecies, within which there are over 2,500 serotypes (19). Serotypes in the first subspecies, *Salmonella enterica* subspecies *enterica,* are generally represented by common names that reference their discovery (such as Enteritidis, Typhimurium, Newport, and

Javiana described above). Serotypes in the remaining subspecies are referenced by Roman numerals and a combination of numbers and letters to represent the antigenic formulae (20, 21).

Broadly, salmonellosis is referred to as typhoidal or non-typhoidal salmonellosis, which differentiates serotypes into two categories and aides surveillance, diagnosis, and treatment. *Salmonella enterica* (subspecies *enterica)* serotype T*yphi* (more commonly referred to as *Salmonella* Typhi or Typhoid fever) is differentiated from the other infectious serotypes because humans are the only known reservoir, and the associated course of illness is generally more severe and may be life-threatening (20, 22).

2. Reservoirs and environmental viability

Non-typhoidal serotypes may be found in the intestinal tracts of humans and other animals, water and other environmental habitats, or may be unknown (20). Transmission of the bacteria to humans is via the fecal-oral route, and therefore contact with contaminated, water, soil, food, or animals are common sources of exposure.

The virulence varies among serotypes and strains within serotypes, while the virulence is unknown for some. Estimates of the infective dose depend on the serotype and host susceptibility factors such as age, immune status, and gastric acidity (21, 23). Evidence for the infective dose estimates come from both human challenges studies and outbreak investigations (24, 25). For *Salmonella* Typhi, the infective dose may be fewer than 103, or as high as 100,000, bacteria depending on the host and exposure circumstances (21, 26). For the non-typhoidal serotypes, estimates range from a single bacterium to 1,000 bacteria (21, 23).

The bacteria are facultative, meaning *Salmonella enterica* are able to survive in both aerobic and anaerobic environments, which contributes to the hardiness in the

environment. Outside of the host, survivability of the bacteria depends on the serotype and medium, but may be days to months to years (23). The preferred temperature range for most serotypes to grow is 7-48°C (44.6-118.4°F) (27). Growth rates are slowed below 10°C (50°F), however, the bacteria is known to have survived in chilled and frozen foods (27). The optimal pH level is 6.5-7.5, although some serotypes can grow in conditions ranging from a pH of 3.7 to 9.5 (27). A water activity level of 0.94 is necessary for *Salmonella enterica* to grow in foods, although the bacteria may take significant time (in years) to die in dry environments (27).

C. Salmonellosis and Socioeconomic Status

1. Association between socioeconomic variables and salmonellosis

Research evaluating the association between socioeconomic variables and the incidence of salmonellosis has produced variable results, depending on the measures of socioeconomic status and serotypes included. Table 1 summarizes the results of relevant studies. The focus of research largely has been on either all non-typhoidal serotypes of *Salmonella enterica* or on the serotype *Salmonella* Enteritidis.

For all non-typhoidal serotypes (including *Salmonella* Enteritidis and *Salmonella* Typhimurium), an unpublished abstract (poster presented at the Council for State and Territorial Epidemiologists annual conference in 2013) found differing results for 2000 and 2010 (28). The researchers categorized cases by the percentage of poverty in their residential census tracts and found a higher incidence was associated with higher income in 2000, but for 2010 a higher incidence was associated with a lower income. A second unpublished abstract found a higher incidence for higher income cases (29).

Two studies have shown an increased association of higher income with *Salmonella* Enteritidis cases, although one of those same studies found an association of

illness with the low income group as well (30, 31). A third study found no association with income, but rather an increased association of illness with increased education (32). When *Salmonella* Enteritidis and *Salmonella* Typhimurium were excluded from the overall category of non-typhoidal serotypes, a fourth study found a higher incidence for higher income level and no association with education level (31). For *Salmonella* Typhimurium, the same researchers found having an income in one of the two highest income levels was protective, and concurrently, the higher level of education was also protective (31) .

2. Hypotheses for the association between higher socioeconomic status and higher incidence

Researchers in the studies described above asserted several potential factors that could lead to an association between higher socioeconomic status and a higher incidence of salmonellosis. Younus et al. (2006) suggested cases of a higher socioeconomic status likely have greater access to healthcare and increased health-seeking behaviors. In addition, they may dine outside of the home more frequently, which is a known risk factor for infection. The researchers also projected these cases may have increased animal contact through pet ownership, which could increase their risk for infection.

Varga et al. (2013) found an increased risk for both the higher and lower income groups. The researchers suggested the higher income group was at greater risk due to increased international travel. This hypothesis was supported in the Simonsen et al. (2008) study in Denmark. When the researchers removed the (international) travel-associated cases from the analysis, the incidence rate ratios for income were reduced for the high-income groups. The researchers hypothesized the increased rates of infection in the high-income group may have reflected increased travel, a more exotic and

contaminated diet, more frequent dining outside of the home, or increased consumption of imported fresh produce.

II. Manuscript

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A. Abstract

Background

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Methods

Poisson regression models were utilized to estimate the incidence, hospitalization, and case fatality rate ratios for all non-typhoidal serotypes of *Salmonella enterica*, and *Salmonella* Enteritidis, Typhimurium, Newport, and Javiana. The highest socioeconomic status group (A of A-D) or subgroup (A.1 of A.1-D.7) served as the reference category. Spatial-temporal analyses were conducted to describe the geospatial distribution of *Salmonella* Newport and Javiana cases.

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hospitalization rates were similar to the null for *Salmonella* Enteritidis. The case fatality rate ratio was significantly greater than the null for group C (RR=2.89, p=0.01). The spatial-temporal analyses identified geospatial clusters in the lower two-thirds and northeastern corner of the state for both *Salmonella* Newport and Javiana.

Discussion

These results suggest an increased incidence, hospitalization, and case fatality rate for salmonellosis cases in the lower middle socioeconomic status group (C) relative to those in the highest socioeconomic status group (A). The spatial-temporal analyses further identified geospatial clusters in regions of the state mostly populated by cases in group C.

B. Introduction

The state of Georgia has the highest incidence rate of salmonellosis in the United States (26.8 cases per 100,000 population in 2011), with approximately 2,500 cases annually. The four most common serotypes causing illness are *Salmonella* Enteritidis, Typhimurium, Newport, and Javiana. Research on salmonellosis largely has been focused on case-control studies establishing the exposures contributing to increased risk of infection and illness. Some of these studies have looked at the exposures for all serotypes of non-typhoidal salmonellosis, while others have focused on the specific serotypes listed above. Fewer studies have evaluated the association between socioeconomic variables and the risk for illness from *Salmonella enterica.* The limited research available has shown varied associations between incidence and level of income or education, with more studies reporting an association between higher levels of income and a higher incidence of infection.

The sociodemographic profiles vary widely across the state, from the metropolitan statistical area of Atlanta to the outlying rural farmlands, coastal marshlands, and other smaller urban centers. In an effort to understand the association between sociodemographic variables and public health issues, the Office of Health Indicators for Planning at the Georgia Department of Public Health has established four sociodemographic groups and eighteen subgroups. The sociodemographic groups and subgroups represent a different way of analyzing the cumulative effects of individual socioeconomic variables, thus accounting for possible multivariate interactions. This study seeks to describe the association between these groups and subgroups and the incidence, hospitalization, and death rates for salmonellosis. Socioeconomic characteristics may impact exposures resulting in *Salmonella enterica* infection and illness.

Research has shown significant variability in the exposures associated with various serotypes, and therefore a subset analysis for the four most common serotypes in Georgia is also necessary to understand those differences.

In addition, Georgia has one of the highest case counts of *Salmonella* Newport and Javiana in the nation, coinciding with the high prevalence of both serotypes in the southeastern region. This study also seeks to describe the distribution of these serotypes by using spatial-temporal analyses to look at the geographic distribution, timing, and sociodemographic groups of cases.

C. Methods

1. Study population

Surveillance data from the State Electronic Notifiable Disease Surveillance System (SENDSS) at the Georgia Department of Public Health were used to identify relevant cases of salmonellosis. Laboratory-confirmed cases of non-typhoidal salmonellosis in Georgia residents, with onset dates between January 1, 2010 and December 31, 2012, were selected. Cases with domestic or international travel during the incubation were not excluded.

The case level variables included in the analysis dataset included the unique, numeric case identifier populated by SENDSS for each case, sex, age (in place of date of birth), address (including county), date of onset (month and year), serotype, hospitalization status, and outcome (fatalities). The case addresses were geocoded using Centrus (Boulder, CO) geospatial information systems software. Cases with addresses that did not match at an accuracy level more specific than the county level (including those with unknown addresses) did not meet the standards of the Office of Health Indicators for Planning at the Georgia Department of Public Health and were excluded.

The addresses for these cases were uploaded into ArcGIS 10.2 geospatial information systems software (Environmental System Research Institute, Redlands, CA, USA) and geocoded a second time (33). For the sociodemographic group assignment, the coordinates provided by the address locator in the ArcGIS software were used for those cases with an address match score of 80 or higher (34, 35). The coordinates provided by the Centrus software were used for cases with a match score of less than 80. The ArcGIS software was then used to assign each case a sociodemographic group by

completing a spatial join between the Microsoft Excel spreadsheet of addresses and a shapefile of the sociodemographic groups in Georgia.

2. Sociodemographic groups

The Office of Health Indicators for Planning at the Georgia Department of Public Health has created four general, and eighteen more specific, sociodemographic groups based on data from EASI Demographics (2011) (36-38). The groups are drawn from data at the block group level in the 2010 census, and incorporate twenty-five measures of socioeconomic status, including education, income, employment, housing, family structure, and age . Groups may be noncontiguous, meaning there may be multiple areas of persons who share characteristics of the same group throughout different parts of the state (37).

Descriptive features of each sociodemographic subgroup are shown in Table 2 and described in Appendix A; the subgroups are ordered from highest (A.1) to lowest socioeconomic status (D.7) (37). The four main groups are identified by letters, A, B, C, and D. The eighteen subgroups are identified by the group letter and a number (A.1-A.3, B.1-B.4, C.1-C.4, and D.1-D.7). Subgroup codes beginning with A indicate groups with a higher socioeconomic status, B indicate middle socioeconomic status, C indicate lower middle socioeconomic status, and D indicate lower socioeconomic status.

3. Serotypes

The serotypes included in this study are all non-typhoidal serotypes (all serotypes except for *Salmonella enterica* subspecies *enterica* serotype Typhi) and the four most common non-typhoidal serotypes, *Salmonella* Enteritidis, Typhimurium, Newport, and Javiana. The serotype associated with each case was identified in the data query completed in the state electronic reportable disease system (SENDSS) to identify cases.

All cases with a non-typhoidal serotype diagnosed by laboratory testing were included in the all non-typhoidal serotypes category, including those with an undetermined serotype. The category of *Salmonella* Typhimurium included variants of one of the antigens for the serotype.

4. Analysis

The attribute table in the ArcGIS software containing the spatially joined case and group data was exported into Microsoft Excel. A separate analysis dataset was developed to include the total number of all cases, hospitalizations, and deaths due to all non-typhoidal serotypes. The total population estimates for each group were taken from the EASI Demographics (2011) projections for Georgia (38). Estimates were not available for 2010 and 2012, and therefore the 2011 estimates were applied to those years of onset. The total population estimates were added to the analysis dataset.

Further analyses were completed using SAS 9.3 statistical software (Cary, NC) (39). Chi-square tests were completed to compare the differences between cases included in and excluded from the final dataset (based on geocoding accuracy), by group, and for demographic characteristics, year of onset, outcome, and serotype. Poisson regression models were developed to calculate the incidence, hospitalization, and fatality rate ratios for all cases of non-typhoidal *Salmonella enterica* and the four most common serotypes by subgroup or group. All of the models included either the eighteen sociodemographic subgroups (incidence and hospitalization) or the four groups (case fatality), the total number of cases by subgroup/group for each of the three years in the study (2010-2012), and the total number of persons at risk for each subgroup/group in each year (38). The natural log of the annual population estimates

for each subgroup/group was used as the offset for the GENMOD procedure in the SAS software.

Due to overdispersion for some of the incidence models using Poisson regression, negative binomial regression models were also conducted (Appendix B, Table B.1). The overdispersion estimates were not significant, and therefore the Poisson models were maintained for interpretation. A scaling factor was added to the models for *Salmonella* Enteritidis and *Salmonella* Newport to adjust the estimates due to overdispersion. For calculating the rate ratios, the subgroup with the highest socioeconomic status (A.1), was selected as the reference category.

Poisson regression models were also used for the hospitalization rate ratios (Appendix B, Table B.2). Overdispersion was addressed with a scaling factor only for *Salmonella* Enteritidis. The reference category continued to be the A.1 subgroup. Poisson regression models were unstable for the all non-typhoidal and individual serotypes using the eighteen subgroups to calculate the case fatality rate ratios. When the counts were separated into the four groups (A, B, C, and D) by the individual serotypes, the models continued to be unstable. Consequently, case fatality rate ratios could only be calculated for all of the non-typhoidal serotypes combined as a single category and for the four main groups (Appendix B, Table B.3). Group A was used as the reference category.

Due to the high proportion of *Salmonella* Newport and Javiana cases in Georgia, the SaTScan 9.3 (Boston, MA) software was used to conduct a spatial-temporal analysis to describe the geographic distribution of cases due to these serotypes (40). Three files were developed for import into the software system, including a file for cases containing the dates of onset of illness, a population file containing the annual population estimates

for each of the cases' counties in Georgia (41), and a coordinates file containing the coordinates of each case's home address. Spatial-temporal analyses were conducted using a Poisson discrete probability model, the Kulldorff scan statistic, and Monte Carlo simulations (42). The scanning size of the cylindrical scanning window utilized for the scan statistic was for up to 50% of the statewide population spatially and 50% of the time interval temporally. The analyses were completed based on a time interval of one year and one month. The SaTScan software outputted a summary of the significant geospatial clusters identified by the scan statistic and a shapefile that was imported into the ArcGIS software to map the clusters. The ArcGIS software was used to map each of the clusters as a buffer, or circular boundary, with the cases included in the boundary highlighted. For those counties with a single case during the cluster time period, cases were mapped to the county centroids.

D. Results

1. Characteristics of the study population

Between 2010 and 2012, 8,901 confirmed cases of salmonellosis were reported in Georgia. Five-hundred-and-one cases (6.2%) were excluded; 498 for addresses that did not meet OHIP standards and 3 for unknown addresses. The remaining cases included in the analysis dataset totaled 7,590 (93.8%) (Table 3).

The sex of the included cases was evenly distributed, with 49.7% male and 20 cases with an unknown sex. Pediatric cases were categorized by the following age groups: <1, 1-4, 5-9, 10-14, and 15-19 years. Adults ages 20-79-years-old were categorized into 10-year age groups and cases aged 80-years-old or older were grouped into the final category. Age was missing for one case. The greatest number of cases were in the 1-4-year-old range (22.2%), followed by the <1-year-old range (16.5%).

For race, 64.7% of cases were White, 19.4% Black/African American, 1.6% Asian, 1.1% Multiracial, and less than 1% American Indian/Alaska Native and Hawaiian/Pacific Islander. Race was unknown for 9.5%, listed as other for 3.0%, and not available for 0.5% of cases. According to the 2010 Census, the racial distribution for the state of Georgia was similar: 59.7% White, 30.5% Black/African American, 4.0% other, 3.2% Asian, and less than 1% American Indian/Alaska Native and Hawaiian/Pacific Islander (41). The breakdown for ethnicity was as follows: 64.8% non-Hispanic, 6.2% Hispanic, 27.0% unknown, and 2.0% not available. The 2010 Census estimated 91.2% of Georgians were non-Hispanic and 8.8% were Hispanic (41).

Chi-square tests were conducted to compare the demographic distribution of cases included and excluded in the analysis, with no significant differences noted for sex, age, race, or ethnicity (at a significance level of 0.05).

The number of cases included in the analysis was fairly evenly distributed across the three years of onset, ranging from 2,463 cases (32.5%) in 2012 to 2,627 cases (34.6%) in 2010 (Appendix C, Table C.1). The outcomes of concern included hospitalization status and mortality. Overall, 28.9% of cases were reported hospitalized. An additional 14.7% of included cases visited a hospital emergency department for services, but were not admitted. Of the remaining cases, 55.3% were not hospitalized and did not visit an ER, 1.1% of cases had no known hospitalization status, and 0.04% of cases did not have the information available in their records. The number of deaths due to salmonellosis was 37 (0.5%). The status was not known for 5.6% of cases, and the remaining 93.9% of cases were reported to survive the illness.

The distribution of cases by serotype for those cases included and excluded was similar. For all of the non-typhoidal serotypes (excluding *Salmonella* Enteritidis, Typhimurium, Newport, and Javiana), the proportion of cases ranged from 44.6% (included) to 44.8% (excluded) (Appendix C, Table C.2). For the four main serotypes, the proportions were as follows: Enteritidis (8.3-8.4%), Typhimurium (8.6-8.7%), Newport (18.0-18.2%), and Javiana (20.1-20.3%).

No significant differences were noted in the distribution of cases included and excluded across the year of onset, outcome, or serotype variables using the chi-square tests.

2. Rate ratios for incidence by serotype and group

For all non-typhoidal serotypes, there was variability in the incidence rate ratios across the reference value, although only four of the rate ratios were less than the reference value and only three of those were significant. The rate ratios were significantly greater than the reference category (A.1) for subgroups A.2, C.2-C.4, and

D.2-D.3 (Table 4 Figure 3A). The largest difference was for subgroup D.2 (small military cluster), with a rate ratio of 2.31 (CI 1.61-3.33). The rate ratios were significantly lower for subgroups B.1, B.4, and D.4. The lowest rate ratio was 0.64 for subgroup B.1 (CI 0.52-0.78).

The rate ratios for *Salmonella* Enteritidis and all of the subgroups were less than the reference category. Significant differences were noted for subgroups A.3, C.1, C.4, and D.3. The lowest rate ratio was for subgroup D.3, with a rate ratio of 0.33 (CI 0.15-0.76) (Table 5; Figure 3B).

For *Salmonella* Typhimurium, most of the rate ratios were greater than the reference value (Table 6; Figure 3C). An increase in the rate ratios was noted across subgroups in group C, with an increase from 1.02 (not significant) for C.1, to 1.82 for C.2 (CI 1.22-2.72), to 2.15 for C.3 (CI 1.29-3.58), and 1.93 for C.4 (CI 1.27-2.94). The highest, significant rate ratio was for subgroup D.6 with a rate ratio of 2.36 (CI 1.47-3.81).

Similar patterns were noted for *Salmonella* Newport (Table 7; Figure 3D) and *Salmonella* Javiana (Table 8; Figure 3E) as for all non-typhoidal serotypes with regard to the fluctuation of the rate ratios across subgroups. Most rate ratios continued to be greater than the reference value. The rate ratios increased for A.2, declined to B.1, and increased for C.1-C.3. For *Salmonella* Newport, significantly different rate ratios were noted for A.2, A.3, B.1, C.2, C.3, and C.4. The greatest increase was for C.2 with a rate ratio of 2.60 (CI 1.85-3.65) and the greatest decrease was for B.1 with a rate ratio of 0.45 (CI 0.21-0.98). The significant differences for *Salmonella* Javiana were for subgroups A.2, B.1, C.2, C.3, C.4, D.4, D.6, and D.7. The greatest increase was for C.2 with a rate ratio of 1.79 (CI 1.42-2.25) and the greatest decrease was for B.1 with a rate ratio of 0.18 (CI 0.08-0.39).

3. Rate ratios for hospitalization by serotype and group

The proportion of cases resulting in hospitalization from each serotype was similar: Enteritidis (33.0%), Typhimurium (29.5%), Newport (31.3%), and Javiana 26.3% (Table 9). *Salmonella* Newport and Javiana resulted in the greatest proportion of the cases and hospitalizations, with 19.7% and 18.5% of the hospitalizations respectively. *Salmonella* Enteritidis and Typhimurium resulted in 9.6% and 8.8% of the hospitalizations, respectively.

In general, the hospitalization rate ratios for the all non-typhoidal serotypes category were greater than the reference value (with most rate ratios statistically significant), suggesting a higher rate of hospitalizations among cases in the lower socioeconomic subgroups relative to the highest socioeconomic subgroup (Table 4; Figure 4A). The greatest increase was across the subgroups in group C, with a peak for C.4 and a rate ratio of 4.31 (CI 3.33-5.57). The lowest rate ratio was 0.54 for B.2 (small military cluster) (CI0.08-3.89).

For *Salmonella* Enteritidis, most of the rate ratios were close to 1.0 or 2.0, with none of the differences statistically significant (Table 5; Figure 4B). The greatest difference was for subgroup C.3, with a rate ratio of 2.85 (CI 0.98-8.32).

Most of the rate ratios for hospitalization due to *Salmonella* Typhimurium were greater than the reference value (Table 6; Figure 4C). Several of the differences were statistically significant, although the confidence intervals were wide and therefore precision was low. The greatest difference was for subgroup D.6 with a rate ratio of 8.91 (CI 3.02-26.33), and the lowest difference was for subgroup B.4 with a rate ratio of 1.10 (CI 0.12-9.84).

A similar pattern of hospitalization rate ratios was observed for *Salmonella* Newport (Table 7; Figure 4D) and *Salmonella* Javiana (Table 8; Figure 4E). Peaks in the hospitalization rate ratios were noted for A.2, B.3, group C, D.3, and D.6. For *Salmonella* Newport, the greatest differences were for C.4, with a rate ratio of 5.92 (CI 3.06-11.44), and B.1, with a rate ratio of 0.48 (CI 0.11-2.20). For *Salmonella* Javiana, the greatest rate ratio was 4.2 (CI 2.13-8.31) for C.3, and the lowest rate ratio was 0.68 (CI 0.15-3.00) for B.4.

4. Rate ratios for case fatality by serotype and group

Salmonella Newport was responsible for the largest proportion of deaths, resulting in 18.9% of all deaths due to non-typhoidal salmonellosis (Table 9). Both *Salmonella* Typhimurium and Javiana were responsible for 13.5% of the fatal cases. *Salmonella* Enteritidis was responsible for the lowest proportion of deaths, at 2.7%. Case fatality rate ratios were calculated for the four groups for all non-typhoidal serotypes as a single category. The only significant case fatality rate ratio was for group C, with a rate ratio of 2.89 (CI 1.26-6.65) (Table 10; Figure 5).

5. Spatial-temporal analyses of Salmonella Newport and Javiana cases

The spatial-temporal analyses were completed using one-year and one-month time intervals for the *Salmonella* Newport and Javiana cases. For *Salmonella* Newport, the one-year and one-month time intervals both identified two significant clusters. Using the one-year interval, a significant cluster was identified in the lower two-thirds of the state from January 1, 2010 to December 31, 2010 (Figure 6). For that time span and population, 73.62 cases were expected, and 231 cases were observed, with a relative risk of 3.57 ($p<0.0001$). Between January 1, 2011 and December 31, 2011, a smaller cluster of 29 cases (expected 9.82 cases) was observed in the northeastern corner of the

state (relative risk of 2.99 and p=0.008) (Figure 7). The one-month interval analysis identified the same lower two-thirds of the state as a larger cluster from June 1, 2010 through November 30, 2011, and including 501 cases (155.30 cases expected) (relative risk of 4.50 and p<0.0001) (Figure 8). Similarly, the one-month interval analysis identified a small cluster in the northeastern area of the state between May 1, 2010 and October 31, 2011 (Figure 9). The cluster included 60 cases, with 17.24 cases expected for the area and time (relative risk of 3.59 and p< 0.0001).

For *Salmonella* Javiana, a similar pattern of clusters was observed as for *Salmonella* Newport. The one-year time interval analysis identified one larger cluster spanning much of the lower two-thirds of Georgia and occurring from January 1, 2012 through December 31, 2012 (Figure 10). Based on the maximum likelihood estimates, 74.22 cases were expected in the geographic area during the year and a total of 246 cases were observed, resulting in a relative risk of 3.75 (p < 0.0001). Using the one-month time interval, two significant clusters were identified. The first group included cases from June 1, 2010 through November 30, 2011, and spanned much of the same area of the state as the cluster identified using the one-year interval (Figure 11). The cluster included 574 cases, with an expected case count of 171.94, and a relative risk of 4.73 (p <0.0001). The second cluster included cases from August 1, 2011 through September 30, 2011, and occurred in the northeastern portion of the state (Figure 12). The cluster was much smaller than the other two, included only eleven cases, and had an expected case count of 1.07 and a relative risk of 10.39 (p=0.011).

E. Discussion

1. Incidence, serotype, and sociodemographic group

The incidence rate ratios varied significantly across the subgroups for the different serotypes. The analysis for the subgroups comprised of military personnel and their families (B.2 and D.2) resulted in unstable rate ratios because of the small population in each subgroup, often including no cases and resulting in no rate ratio estimates, or resulting in very high rate ratios for few cases.

The most notable difference among the serotypes was for *Salmonella* Enteritidis, for which all of the incidence rate ratios were less than the reference value (although significance varied). The rate ratios indicate persons in sociodemographic subgroups below the highest socioeconomic status subgroup may have a lower risk of illness. These results are consistent with two previously discussed studies, which found an increased association of higher income with *Salmonella* Enteritidis cases (30, 31).

The results for the remaining serotypes varied across the reference value, with most of the rate ratios being greater than the reference value (although significance varied). Cases in groups C and D demonstrated the greatest rate ratios for *Salmonella* Typhimurium. These groups comprised the lowest two socioeconomic groups. Similarly, Simonsen et al. (2008) found a protective effect for cases in the highest two income levels of a study conducted in Denmark for *Salmonella* Typhimurium.

For *Salmonella* Newport, groups A and C demonstrated rate ratios significantly greater than the reference category. Group A included cases with the highest socioeconomic status, whereas cases in group C were in the lower middle socioeconomic group. The greatest rate ratios for *Salmonella* Javiana were also in group C, as well as in the lowest two subgroups of group D (D.6 and D.7).

2. Hospitalization, case fatality, serotype, and group

Significant hospitalization rate ratios above the reference value were noted among many of the subgroups in A, C, and D for *Salmonella* Typhimurium, Newport, and Javiana; hospitalization rates were similar to the reference value for *Salmonella* Enteritidis. In general, cases in the subgroups of group C had the highest rate ratios for hospitalization.

The case fatality rate ratios were modeled only for the four main groups. The rate ratio was the highest for cases in group C. Relative to group A, cases in group C represented a higher proportion of hospitalizations and deaths, which coincides with the greater incidence due to *Salmonella* Newport and *Salmonella* Javiana.

3. Spatial-temporal analyses

The spatial-temporal analysis identified two areas of the state with greater than expected incident cases of *Salmonella* Newport and Javiana during the study period. For both serotypes, a large cluster spanning the lower two-thirds of the state and a smaller cluster in the northeastern corner were identified. The wide timeframe for the clusters may indicate a higher background prevalence for those geographic areas relative to other areas of the state.

The areas in which these spatial-temporal groups were identified align with the rural areas of Georgia mostly characterized by cases in group C. Both *Salmonella* Newport and Javiana have been associated with produce, meat, poultry, and environmental exposures when implicated in outbreaks and routine testing of non-human isolates (43, 44). Cases in group C are characterized by outdoor occupations, such as farming and construction, which may increase opportunities for exposure to infected animals or contaminated habitats. Amphibian or reptile hosts are

hypothesized as another natural reservoir for *Salmonella* Javiana, which have increased areas for natural habitats in the northern and southern coastal regions of the state (45).

4. Limitations

The data for this study were taken from the statewide reportable diseases database, which are populated primarily through passive surveillance. One limitation of using surveillance data is the possibility that the counts for cases, hospitalizations, and deaths are underestimates of the true burden in Georgia. The system only captures those cases who seek out medical care and also have clinical samples submitted to a laboratory for testing. As noted earlier, the true burden of salmonellosis is estimated to be as many as 38 times greater than the case counts captured by surveillance (2).

The spatial-temporal scan statistical software provided an overview of the spatial and temporal trends for *Salmonella* Newport and Javiana during the study period. Further analysis was limited by the information included in the dataset and by the surveillance data collected for each case included. There are many different variants of the *Salmonella* Newport and Javiana serotypes, identified by pulse-field gel electrophoresis patterns. These patterns are not included in the case file in the surveillance database, and therefore the spatial-temporal groups may have included groups of cases with unrelated variants of the serotypes. Therefore, the groups identified by the spatial-temporal analysis may be more of an indication that there is a high environmental prevalence of those serotypes rather than connected groups as part of an outbreak. Laboratory and epidemiological information would be needed to confirm the cases in the groups were caused by the same variant of *Salmonella* Newport Javiana or linked to the same exposure.

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G. Tables

Table 1. Summary of research describing the association between salmonellosis and socioeconomic status variables.

Study	Serotype	Income	Education	Location
Baer et al. 2013 (unpublished)	All	Higher incidence in higher income (less poverty) for 2000; Higher incidence in lower income (more poverty) for 2010	N/A	King County, Washington, US
Varga et al. 2013	Enteritidis	Higher incidence for high and low income vs. medium income groups	N/A	Toronto, Ontario, Canada
Martinez (n.d.; unpublished)	All	Higher incidence for high income	N/A	Harris County, Texas, US
Simonsen et al. 2008	Enteritidis	Higher incidence for high income	None	Denmark
	Typhimurium	Two highest income levels were protective	Lower incidence for increased education	
	All other	Higher incidence for high income	None	
Younus et al. 2006	Enteritidis	None	Higher incidence with increased education	Michigan, US

Table 2. Summary characteristics of the 18 sociodemographic subgroups in Georgia, 2011.*

Group Number (Code)	Income (Relative to state mean)	Education	Employment	Age	Race/ethnicity	Family status	Urban/Rural
1 (A.1)	Above	College	Executives, professionals	45-64	White, Asian	Family	Exurban-Suburban
2 (A.2)	Above	College	Professionals, managers	55+	White	Family	Suburban
3 (A.3)	Above	Some college-College	Sales, white-collar	25-45	White, African-American	Family	Suburban
4 (B.1)	Above	College	Managers, professionals	25-45	White, Asian	Non-family	Urban
5 (B.2)	Average	Some college	Military	18-34	White		
6 (B.3)	Below	Some college-College			Asian, Multiracial		Suburban-Urban
7 (B.4)	Below	High school-Some college	College students	18-24	Mixed-ethnicity	Non-family	
8 (C.1)		High school	Farming, construction	55+	White	Family	Rural
9 (C.2)	Average		Construction, production	45-64	White, African-American	Family	Rural
10 (C.3)	Below	Mixed	Service, sales, managerial	55+	African-American		Rural
11 (C.4)	Average	Some high school-High school	Farming, construction		White	Family	Rural
12 (D.1)	Below	Some high school-High school	Service		Mixed-race	Single-parent	Urban
13 (D.2)		Some college-College	Military	18-34	White	Family	
14 (D.3)	Below		Service, sales	55+	African-American, White	Non-family, Family	Suburban-Urban
15 (D.4)	Below	Some high school-High school	Service	18-34	African-American	Non-family, Family	Urban
16 (D.5)	Below	Some high school-High school	Production, construction		Hispanic, Multiracial		
17 (D.6)	Below	Some high school-High school	Service	60+	African-American		
18 (D.7)	Below	Some high school-High school		18-34	African-American		

*If no information is provided for a cell, no pattern was reported for the group (37).

Table 3. Demographic characteristics of cases of salmonellosis included and excluded in the final analysis, Georgia, 2010-2012. (n=8,091)

Demographic Characteristic	**Included** (n=7,590)		**Excluded** (n=501)		**Chi-square**
	No.	%	No.	%	p-value*
Sex					0.10
Male	3,796	49.7	230	45.9	
Unknown	20	0.3	0	0.0	
Age (years)					0.77
<1	1,250	16.5	78	15.6	
1-4	1,684	22.2	106	21.2	
5-9	710	9.4	38	7.6	
10-14	374	4.9	25	5.0	
15-19	216	2.8	16	3.2	
20-29	494	6.5	25	5.0	
30-39	459	6.0	31	6.2	
40-49	573	7.5	39	7.8	
50-59	638	8.4	50	10.0	
60-69	594	7.8	49	9.8	
70-79	397	5.2	30	6.0	
80+	200	2.6	14	2.8	
Missing	1	0.0	0	0.0	
Race					0.17
White	4,908	64.7	313	62.5	
Black/ African American	1,474	19.4	98	19.6	
Asian	119	1.6	7	1.4	
Multiracial	85	1.1	10	2.0	
American Indian/ Alaska Native	13	0.2	0	0.0	
Hawaiian/ Pacific Islander	4	0.1	0	0.0	
Unknown	718	9.5	53	10.6	
Other	229	3.0	13	2.6	
Not available	40	0.5	7	1.4	
Ethnicity					0.13
Non-Hispanic	4,921	64.8	302	60.3	
Hispanic	468	6.2	30	6.0	
Unknown	2,050	27.0	155	30.9	
Not available	151	2.0	14	2.8	

* Significance level of α=0.05.

Table 4. Incidence and hospitalization rate ratios for all non-typhoidal serotypes of *Salmonella enterica* by sociodemographic group, Georgia, 2010-2012.

Subgroup	Incidence Rate Ratio (n=7,590)			Hospitalization Rate Ratio (n=2,192)		
	RR	95% CI	p-value*	RR	95% CI	p-value*
1 (A.1)	1.00			1.00		
2 (A.2)	1.32	1.17-1.48	<0.0001	2.61	1.98-3.44	<0.0001
3 (A.3)	1.09	0.98-1.21	0.0950	1.71	1.32-2.22	<0.0001
4 (B.1)	0.64	0.52-0.78	<0.0001	0.49	0.27-0.87	0.0145
5 (B.2)	1.19	0.71-1.99	0.5122	0.54	0.08-3.89	0.5412
6 (B.3)	0.93	0.80-1.09	0.3984	1.49	1.04-2.13	0.0279
7 (B.4)	0.78	0.61-0.98	0.0325	1.21	0.73-2.01	0.4589
8 (C.1)	1.02	0.85-1.23	0.8241	2.35	1.64-3.38	<0.0001
9 (C.2)	1.64	1.48-1.82	<0.0001	3.59	2.79-4.63	<0.0001
10 (C.3)	1.45	1.26-1.68	<0.0001	3.86	2.86-5.21	<0.0001
11 (C.4)	1.68	1.51-1.87	<0.0001	4.31	3.33-5.57	<0.0001
12 (D.1)	1.02	0.90-1.16	0.7362	1.60	1.18-2.17	0.0025
13 (D.2)	2.31	1.61-3.33	<0.0001	2.04	0.75-5.58	0.1664
14 (D.3)	1.19	1.02-1.38	0.0298	2.91	2.12-3.98	<0.0001
15 (D.4)	0.78	0.67-0.93	0.0051	1.25	0.87-1.82	0.2392
16 (D.5)	1.11	0.96-1.28	0.1678	2.44	1.79-3.33	<0.0001
17 (D.6)	1.16	1.00-1.35	0.0500	3.33	2.47-4.48	<0.0001
18 (D.7)	1.17	0.97-1.41	0.0991	2.59	1.18-3.75	<0.0001

* Significance level of α=0.05.

Table 5. Incidence and hospitalization rate ratios for *Salmonella* Enteritidis by sociodemographic group, Georgia, 2010-2012.

Subgroup	Incidence Rate Ratio (n=636)			Hospitalization Rate Ratio (n=210)		
	RR	95% CI	p-value*	RR	95% CI	p-value*
1 (A.1)	1.00			1.00		
2 (A.2)	0.68	0.43-1.07	0.0944	1.30	0.46-3.66	0.6187
3 (A.3)	0.61	0.42-0.88	0.0086	1.56	0.65-3.73	0.3199
4 (B.1)	0.78	0.43-1.42	0.4166	0.24	0.02-3.31	0.2868
5 (B.2)	0.00	0.00-0.00	0.9996	0.00	0.00-0.00	0.9998
6 (B.3)	0.70	0.39-1.23	0.2130	1.91	0.62-5.83	0.2583
7 (B.4)	0.65	0.29-1.49	0.3116	1.32	0.25-6.84	0.7409
8 (C.1)	0.34	0.13-0.89	0.0274	1.27	0.29-5.59	0.7483
9 (C.2)	0.71	0.48-1.05	0.0899	1.78	0.72-4.37	0.2125
10 (C.3)	0.68	0.36-1.27	0.2209	2.85	0.98-8.32	0.0547
11 (C.4)	0.45	0.26-0.77	0.0040	1.81	0.70-4.67	0.2175
12 (D.1)	0.58	0.37-0.91	0.0175	0.97	031-3.04	0.9519
13 (D.2)	0.95	0.15-5.89	0.9560	0.00	0.00-0.00	0.9998
14 (D.3)	0.33	0.15-0.76	0.0091	1.80	0.55-5.90	0.3303
15 (D.4)	0.62	0.34-1.13	0.1210	2.31	0.79-6.72	0.1260
16 (D.5)	0.72	0.41-1.25	0.2417	1.60	0.51-5.04	0.4239
17 (D.6)	0.72	0.41-1.28	0.2654	2.18	0.73-6.49	0.1624
18 (D.7)	0.51	0.22-1.21	0.1275	2.28	0.63-8.28	0.2108

* Significance level of α=0.05.

Table 6. Incidence and hospitalization rate ratios for *Salmonella* Typhimurium by sociodemographic group, Georgia, 2010-2012.

Subgroup	Incidence Rate Ratio (n=650)			Hospitalization Rate Ratio (n=192)		
	RR	95% CI	p-value*	RR	95% CI	p-value*
1 (A.1)	1.00			1.00		
2 (A.2)	1.32	0.83-2.09	0.2384	3.25	1.07- 9.88	0.0376
3 (A.3)	1.51	1.02-2.23	0.0393	3.46	1.24- 9.68	0.0179
4 (B.1)	0.78	0.38-1.59	0.4863	0.00	0.00- 0.00	0.9999
5 (B.2)	1.20	0.16-8.81	0.8557	0.00	0.00- 0.00	0.9999
6 (B.3)	1.41	0.82-2.42	0.2805	2.86	0.81-10.13	0.1038
7 (B.4)	0.99	0.44-2.26	0.9876	1.10	0.12- 9.84	0.9321
8 (C.1)	1.02	0.50-2.10	0.9409	3.18	0.80-12.74	0.1014
9 (C.2)	1.82	1.22-2.72	0.0033	3.77	1.32-10.73	0.0131
10 (C.3)	2.15	1.29-3.58	0.0034	4.16	1.22-14.22	0.0229
11 (C.4)	1.93	1.27-2.94	0.0020	5.72	2.01-16.27	0.0011
12 (D.1)	1.49	0.94-2.36	0.0918	2.15	0.65- 7.12	0.2127
13 (D.2)	0.00	0.00-0.00	0.9994	0.00	0.00- 0.00	0.9999
14 (D.3)	1.74	1.02-2.97	0.0409	5.63	1.77-17.95	0.0035
15 (D.4)	1.98	1.21-3.25	0.0066	1.92	0.48- 7.68	0.3558
16 (D.5)	1.78	1.08-2.92	0.0239	5.77	1.88-17.69	0.0022
17 (D.6)	2.36	1.47-3.81	0.0004	8.91	3.02-26.33	<0.0001
18 (D.7)	1.59	0.83-3.04	0.1587	5.70	1.61-20.19	0.0070

* Significance level of α=0.05.

Table 7. Incidence and hospitalization rate ratios for *Salmonella* Newport by sociodemographic group, Georgia, 2010-2012.

Subgroup	Incidence Rate Ratio (n=1,379)			Hospitalization Rate Ratio (n=431)		
	RR	95% CI	p-value*	RR	95% CI	p-value*
1 (A.1)	1.00			1.00		
2 (A.2)	2.38	1.65-3.43	<0.0001	4.46	2.26- 8.81	<0.0001
3 (A.3)	1.90	1.36-2.66	0.0002	2.91	1.51- 5.60	0.0014
4 (B.1)	0.45	0.21-0.98	0.0443	0.48	0.11- 2.20	0.3452
5 (B.2)	0.00	0.00-0.00	0.9989	0.00	0.00- 0.00	0.9997
6 (B.3)	0.97	0.57-1.65	0.9072	2.10	0.89- 4.93	0.0904
7 (B.4)	0.97	0.47-2.00	0.9335	1.76	0.55- 5.61	0.3393
8 (C.1)	1.51	0.88-2.61	0.1380	1.59	0.54- 4.66	0.3957
9 (C.2)	2.60	1.85-3.65	<0.001	5.38	2.81-10.30	<0.0001
10 (C.3)	1.94	1.22-3.07	0.0051	4.52	2.10- 9.72	0.0001
11 (C.4)	2.47	1.73-3.53	<0.0001	5.92	3.06-11.44	<0.0001
12 (D.1)	1.31	0.86-1.99	0.2065	2.57	1.23- 5.38	0.0120
13 (D.2)	2.38	0.70-8.14	0.1660	0.00	0.00- 0.00	0.9997
14 (D.3)	1.37	0.83-2.27	0.2155	2.25	0.94- 5.41	0.0695
15 (D.4)	0.78	0.44-1.39	0.4014	0.77	0.24- 2.45	0.6562
16 (D.5)	1.56	1.00-2.46	0.0525	2.31	1.01- 5.26	0.0468
17 (D.6)	1.28	0.78-2.09	0.3355	3.37	1.54- 7.35	0.0023
18 (D.7)	1.22	0.65-2.29	0.5287	1.90	0.65- 5.56	0.2414

* Significance level of α=0.05.

Table 8. Incidence and hospitalization rate ratios for *Salmonella* Javiana by sociodemographic group, Georgia, 2010-2012.

Subgroup	Incidence Rate Ratio (n=1,541)			Hospitalization Rate Ratio (n=405)		
	RR	95% CI	p-value*	RR	95% CI	p-value*
1 (A.1)	1.00			1.00		
2 (A.2)	1.56	1.21-2.01	0.0007	3.36	1.82-6.21	0.0001
3 (A.3)	1.11	0.88-1.40	0.3669	1.52	0.83-2.77	0.1745
4 (B.1)	0.18	0.08-0.39	<0.0001	0.00	0.00-0.00	0.9996
5 (B.2)	1.60	0.59-4.36	0.3549	0.00	0.00-0.00	0.9997
6 (B.3)	0.86	0.60-1.24	0.4188	1.03	0.41-2.57	0.9565
7 (B.4)	0.95	0.58-1.53	0.8224	0.68	0.15-3.00	0.6074
8 (C.1)	1.06	0.71-1.59	0.7733	2.94	1.34-6.44	0.0071
9 (C.2)	1.79	1.42-2.25	<0.0001	3.43	1.91-6.16	<0.0001
10 (C.3)	1.59	1.15-2.19	0.0049	4.21	2.13-8.31	<0.0001
11 (C.4)	1.59	1.24-2.04	0.0002	3.94	2.17-7.15	<0.0001
12 (D.1)	0.96	0.71-1.29	0.7722	1.73	0.87-3.46	0.1194
13 (D.2)	0.38	0.05-2.71	0.3331	0.00	0.00-0.00	0.9997
14 (D.3)	1.26	0.90-1.77	0.1831	2.77	1.33-5.76	0.0063
15 (D.4)	0.58	0.38-0.88	0.0111	0.74	0.26-2.07	0.5653
16 (D.5)	1.03	0.74-1.44	0.8599	2.73	1.36-5.49	0.0048
17 (D.6)	1.60	1.18-2.16	0.0026	4.11	2.12-7.97	<0.0001
18 (D.7)	1.51	1.03-2.21	0.0336	2.05	0.82-5.13	0.1269

* Significance level of α=0.05.

Table 9. Case counts, hospitalization, and deaths by serotype and year of onset, Georgia, 2010-2012. (n=7,590)

Serotype	Cases (n=7,590)		Cases Hospitalized (n=2,192)		Deaths (n=37)	
	No.	%	No.	%	No.	%
All Non-typhoidal		100.0		100.0		100.0
2010	2,627		776		13	
2011	2,500		683		10	
2012	2,463		733		14	
Total	7,590		2,192		37	
Enteritidis		8.4		9.6		2.7
2010	226		76		1	
2011	208		70		0	
2012	202		64		0	
Total	636		210	(33.0)**	1	
Typhimurium		8.6		8.8		13.5
2010	246		72		3	
2011	198		54		1	
2012	206		66		1	
Total	650		192	(29.5)**	5	
Newport		18.2		19.7		18.9
2010	513		164		3	
2011	436		127		1	
2012	430		140		3	
Total	1,379		431	(31.3)**	7	
Javiana		20.3		18.5		13.5
2010	548		149		1	
2011	503		122		2	
2012	490		134		2	
Total	1,541		405	(26.3)**	5	

*Note the category of non-typhoidal serotypes includes *Salmonella* Enteritidis, Typhimurium, Newport, and Javiana, as well as many other serotypes. As a result, the percentage totals for cases, cases hospitalized, and deaths will not add to 100.

**The percentages in parentheses are calculated across the row. For example, the percentage of *Salmonella* Enteritidis cases hospitalized is 33.0% or 210/636.

Table 10. Case fatality rate ratios for all non-typhoidal serotypes of *Salmonella enterica* by sociodemographic group, Georgia, 2010-2012. (n=37)

Group	**Case Fatality Rate Ratio**		
	RR	95% CI	p-value*
A	1.00		
B	0.52	0.07-4.15	0.5370
C	2.89	1.26-6.65	0.0124
D	1.91	0.75-4.83	0.1741

* Significance level of α=0.05.

H. Figures

Figure 1. Total number of confirmed salmonellosis cases for all serotypes, by year of onset, Georgia, 2003-2012.

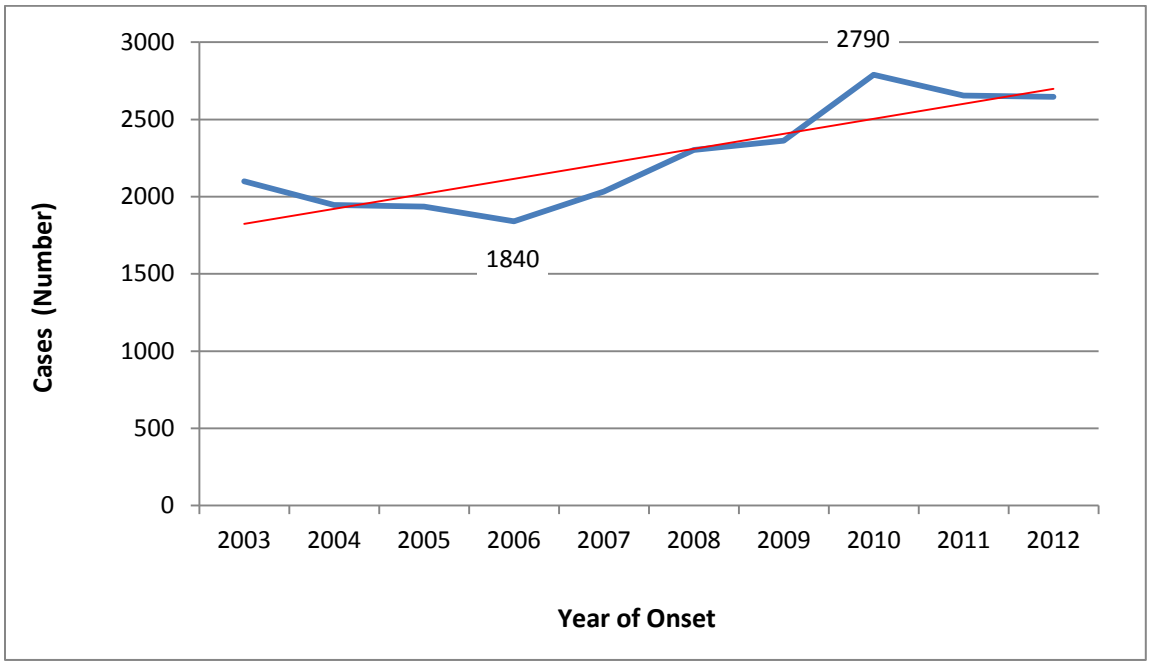
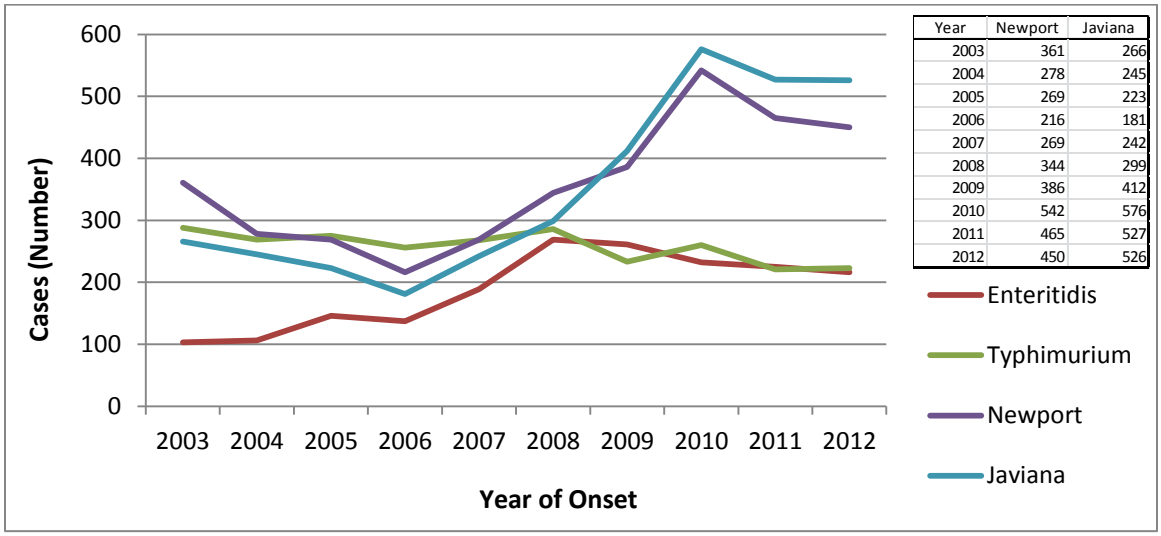


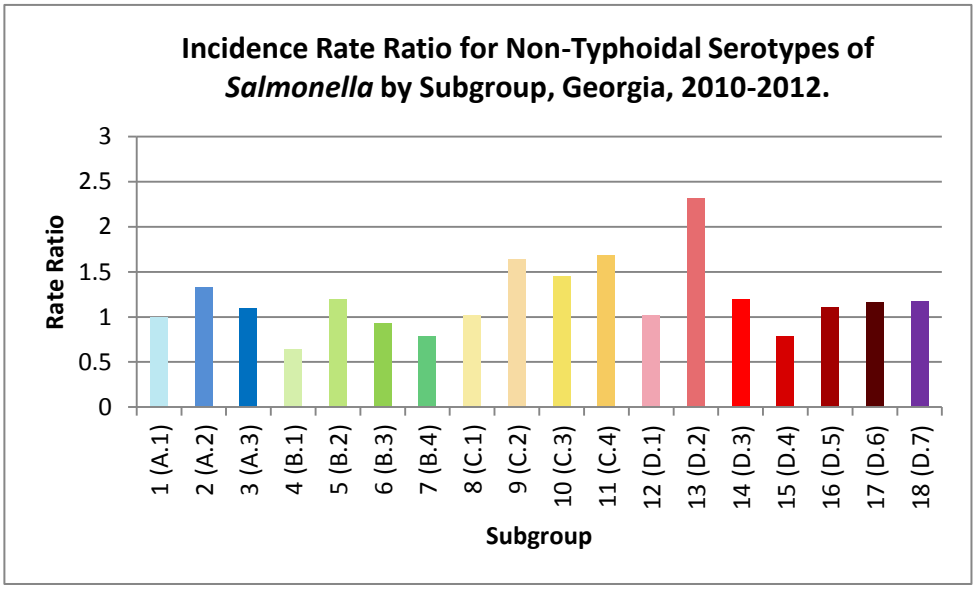
Figure 2. Total number of salmonellosis cases by serotype and year of onset, Georgia, 2003-2012.



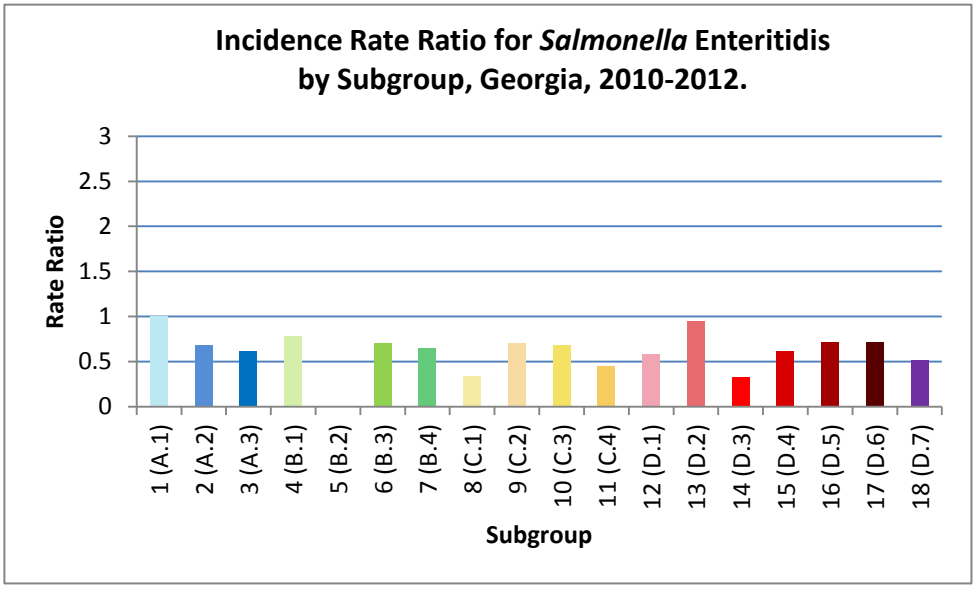
Year	Newport	Javiana
2003	361	266
2004	278	245
2005	269	223
2006	216	181
2007	269	242
2008	344	299
2009	386	412
2010	542	576
2011	465	527
2012	450	526

Figure 3. Incidence rate ratios for all non-typhoidal and the four main serotypes of *Salmonella enterica* by subgroup, Georgia, 2010-2012.

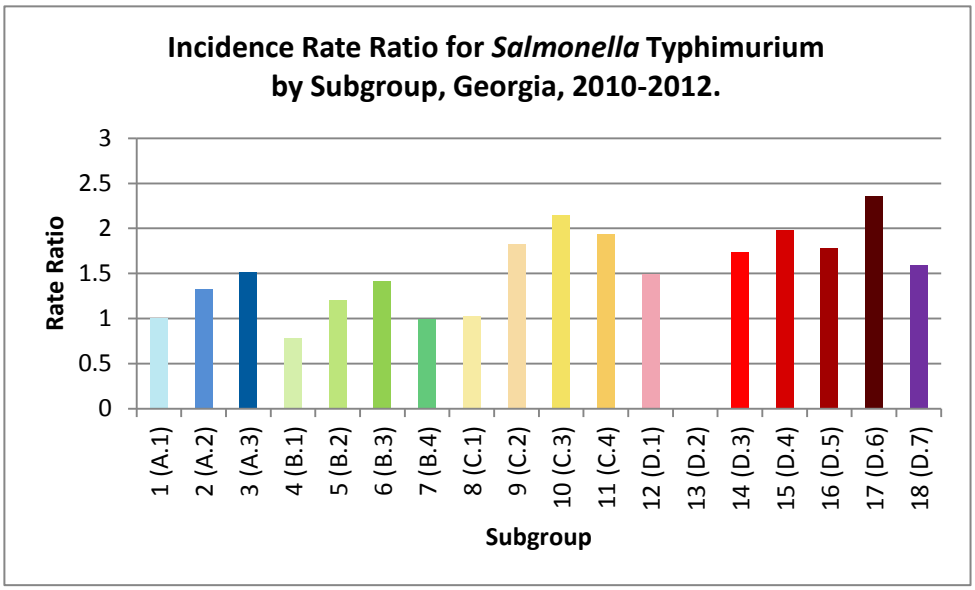
A



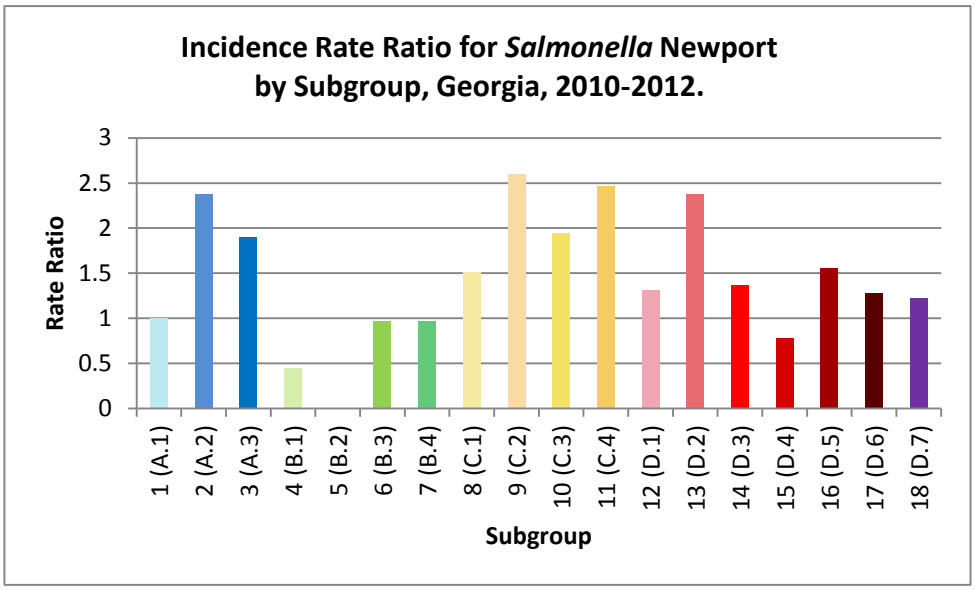
B



C


Incidence Rate Ratio for *Salmonella* Typhimurium
by Subgroup, Georgia, 2010-2012.
Rate Ratio
3
2.5
2
1.5
1
0.5
0
1 (A.1)
2 (A.2)
3 (A.3)
4 (B.1)
5 (B.2)
6 (B.3)
7 (B.4)
8 (C.1)
9 (C.2)
10 (C.3)
11 (C.4)
12 (D.1)
13 (D.2)
14 (D.3)
15 (D.4)
16 (D.5)
17 (D.6)
18 (D.7)
Subgroup

D


Incidence Rate Ratio for *Salmonella* Newport
by Subgroup, Georgia, 2010-2012.
Rate Ratio
3
2.5
2
1.5
1
0.5
0
1 (A.1)
2 (A.2)
3 (A.3)
4 (B.1)
5 (B.2)
6 (B.3)
7 (B.4)
8 (C.1)
9 (C.2)
10 (C.3)
11 (C.4)
12 (D.1)
13 (D.2)
14 (D.3)
15 (D.4)
16 (D.5)
17 (D.6)
18 (D.7)
Subgroup

E

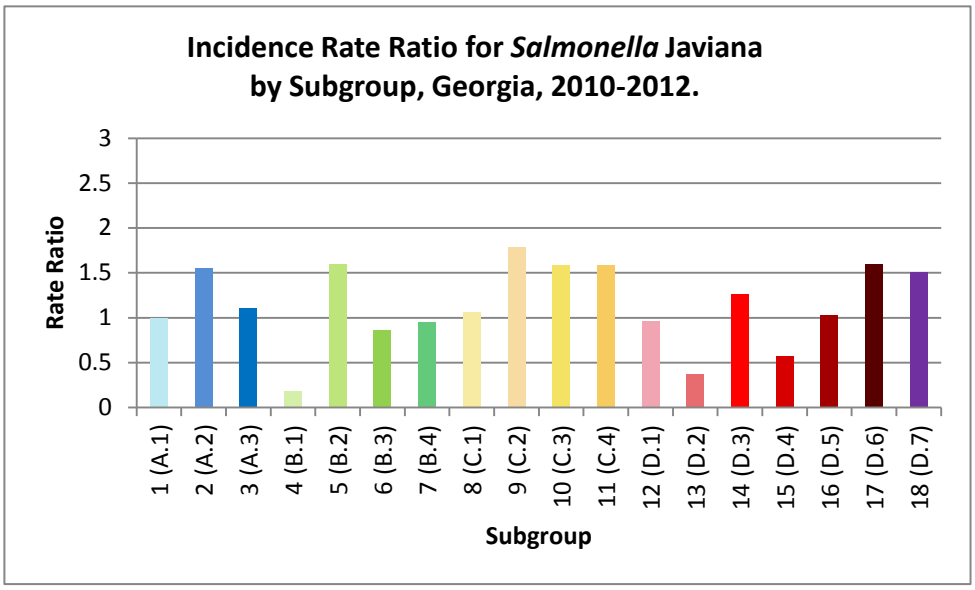
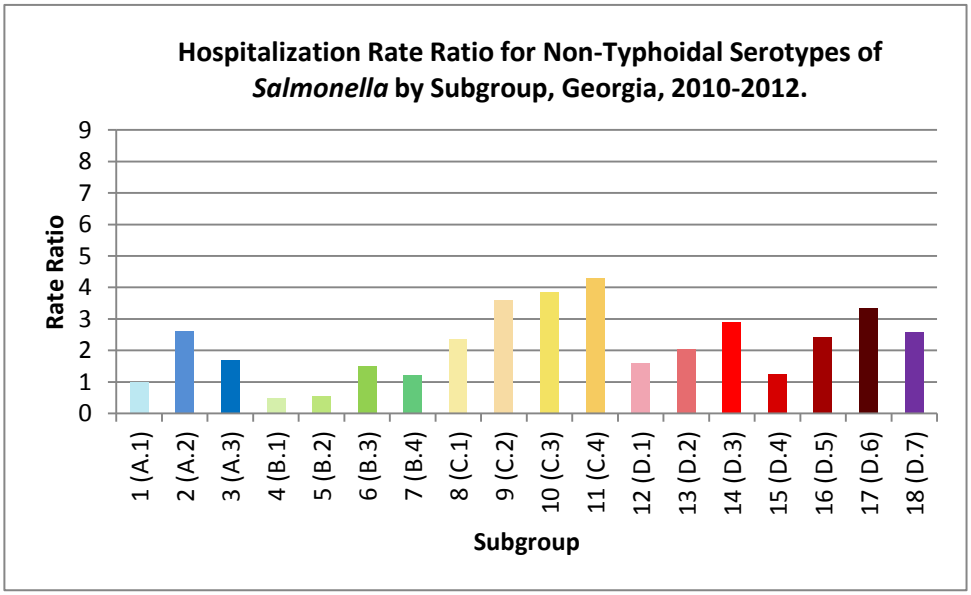
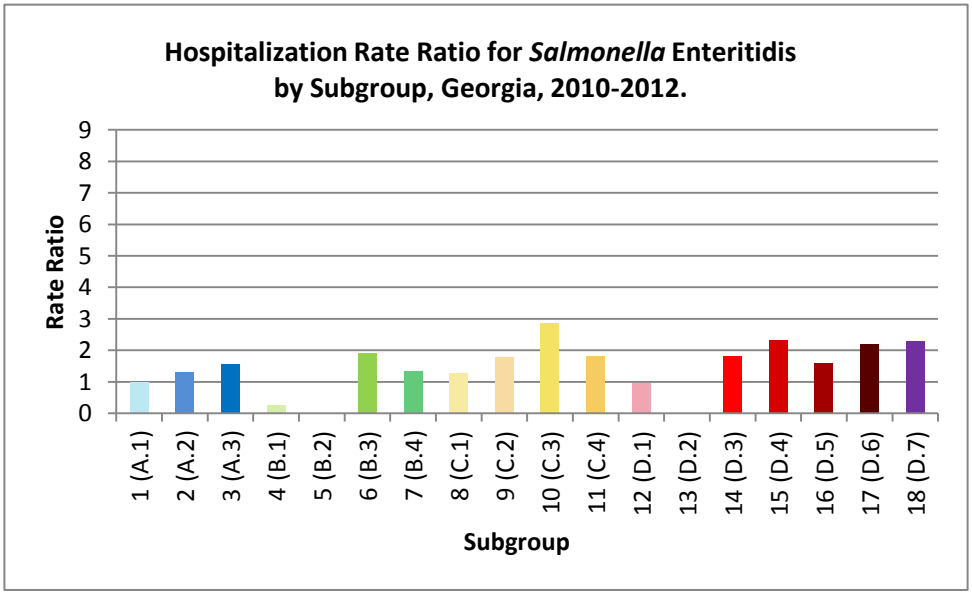

Incidence Rate Ratio for *Salmonella* Javiana
by Subgroup, Georgia, 2010-2012.
Rate Ratio
3
2.5
2
1.5
1
0.5
0
1 (A.1)
2 (A.2)
3 (A.3)
4 (B.1)
5 (B.2)
6 (B.3)
7 (B.4)
8 (C.1)
9 (C.2)
10 (C.3)
11 (C.4)
12 (D.1)
13 (D.2)
14 (D.3)
15 (D.4)
16 (D.5)
17 (D.6)
18 (D.7)
Subgroup

Figure 4. Hospitalization rate ratios for all non-typhoidal and the four main serotypes of *Salmonella enterica* by subgroup, Georgia, 2010-2012.

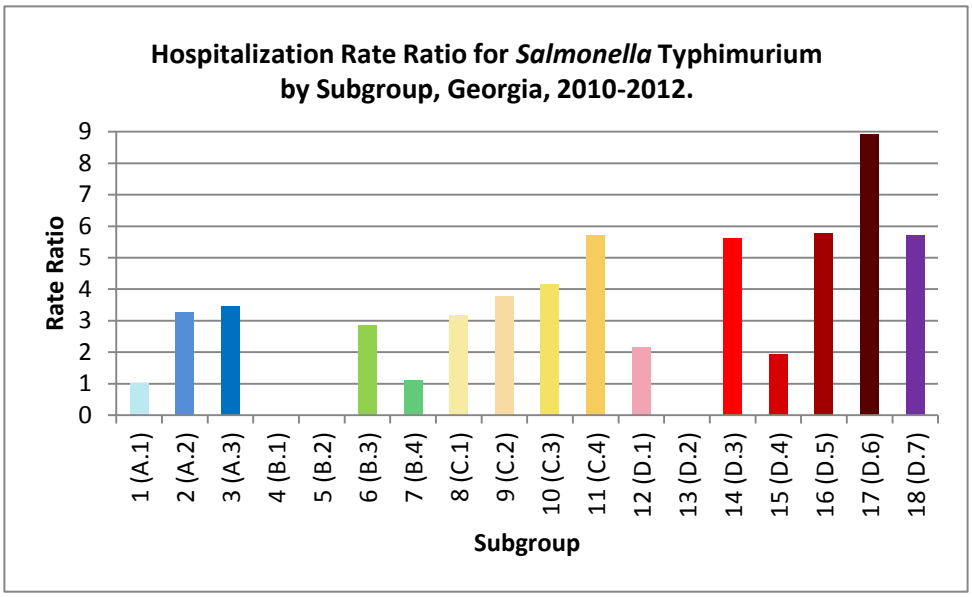
A



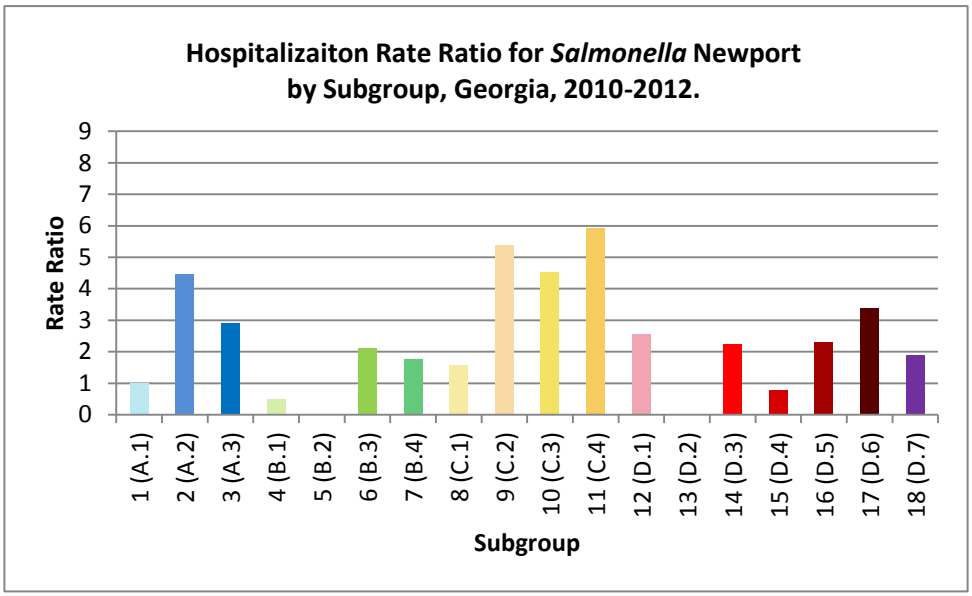
B



C


Hospitalization Rate Ratio for *Salmonella* Typhimurium
by Subgroup, Georgia, 2010-2012.
Rate Ratio
0
1
2
3
4
5
6
7
8
9
1 (A.1)
2 (A.2)
3 (A.3)
4 (B.1)
5 (B.2)
6 (B.3)
7 (B.4)
8 (C.1)
9 (C.2)
10 (C.3)
11 (C.4)
12 (D.1)
13 (D.2)
14 (D.3)
15 (D.4)
16 (D.5)
17 (D.6)
18 (D.7)
Subgroup

D


Hospitalizaiton Rate Ratio for *Salmonella* Newport
by Subgroup, Georgia, 2010-2012.
Rate Ratio
0
1
2
3
4
5
6
7
8
9
1 (A.1)
2 (A.2)
3 (A.3)
4 (B.1)
5 (B.2)
6 (B.3)
7 (B.4)
8 (C.1)
9 (C.2)
10 (C.3)
11 (C.4)
12 (D.1)
13 (D.2)
14 (D.3)
15 (D.4)
16 (D.5)
17 (D.6)
18 (D.7)
Subgroup

E

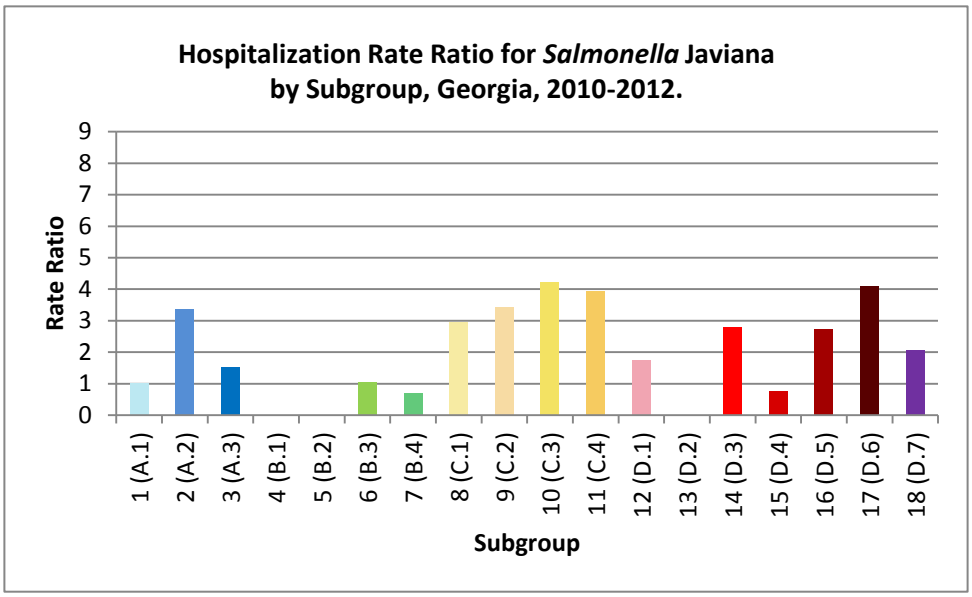

Hospitalization Rate Ratio for *Salmonella* Javiana
by Subgroup, Georgia, 2010-2012.
Rate Ratio
0
1
2
3
4
5
6
7
8
9
1 (A.1)
2 (A.2)
3 (A.3)
4 (B.1)
5 (B.2)
6 (B.3)
7 (B.4)
8 (C.1)
9 (C.2)
10 (C.3)
11 (C.4)
12 (D.1)
13 (D.2)
14 (D.3)
15 (D.4)
16 (D.5)
17 (D.6)
18 (D.7)
Subgroup

Figure 5. Case fatality rate ratios for all non-typhoidal serotypes of *Salmonella enterica* (including the four main serotypes) by main group, Georgia, 2010-2012.

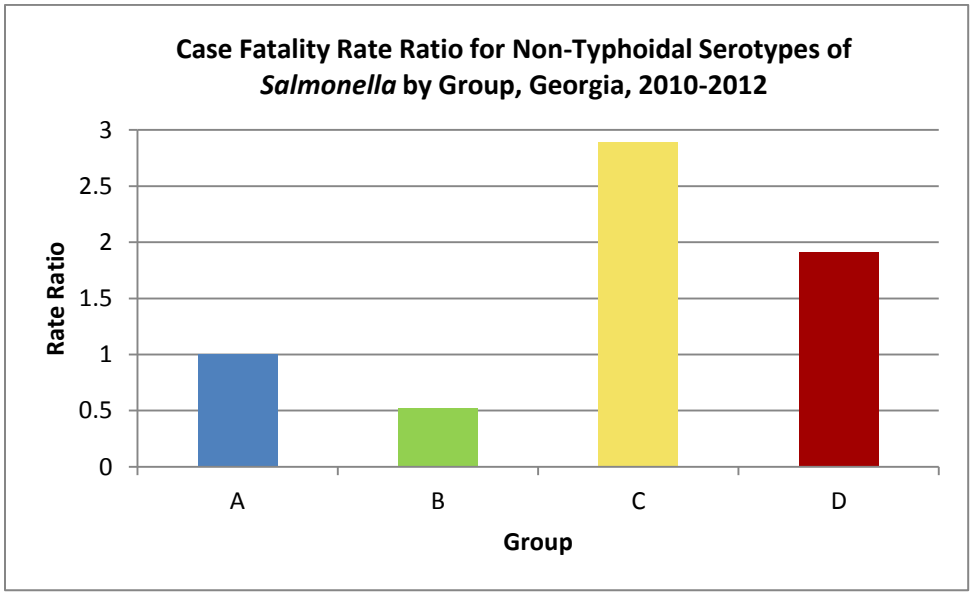
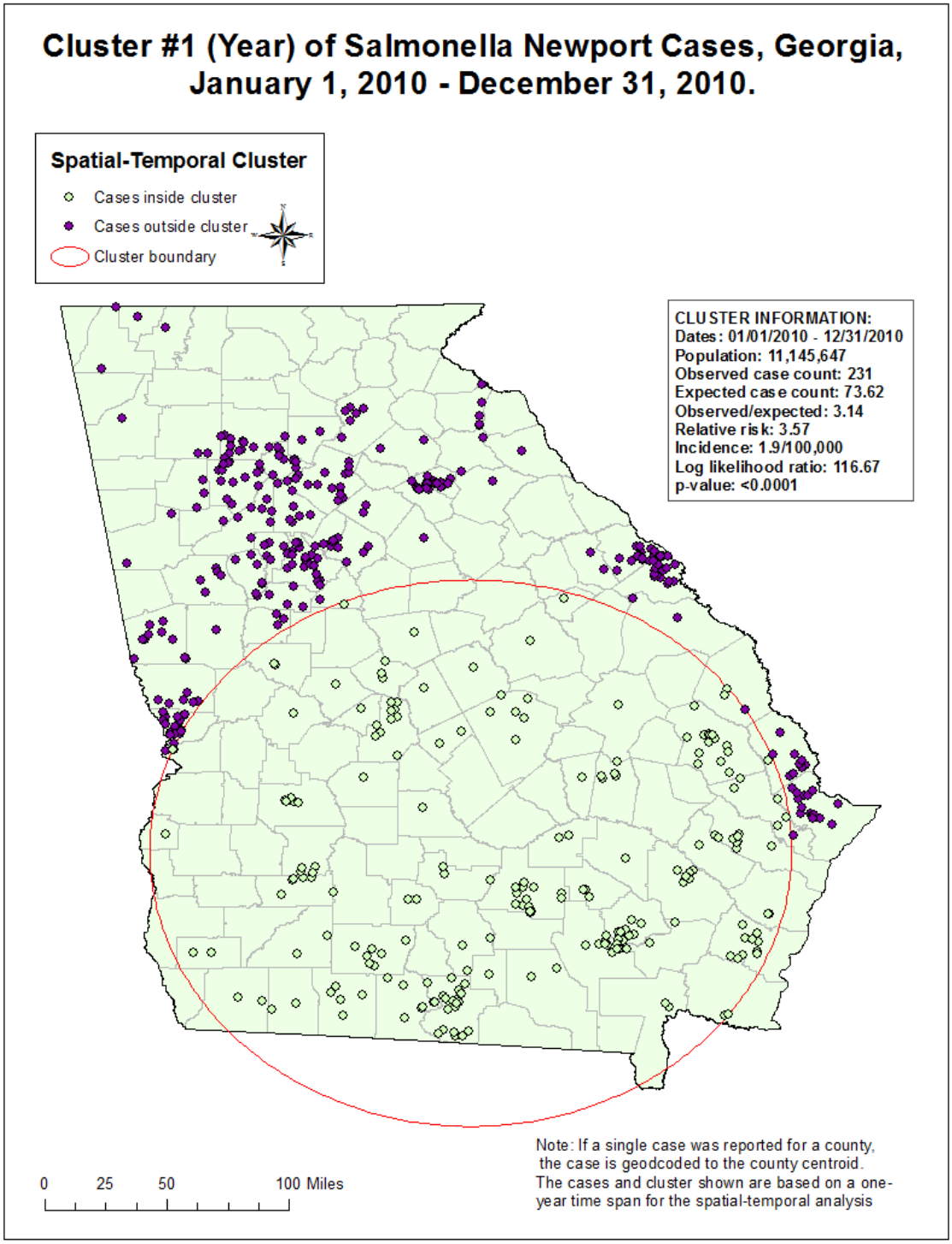
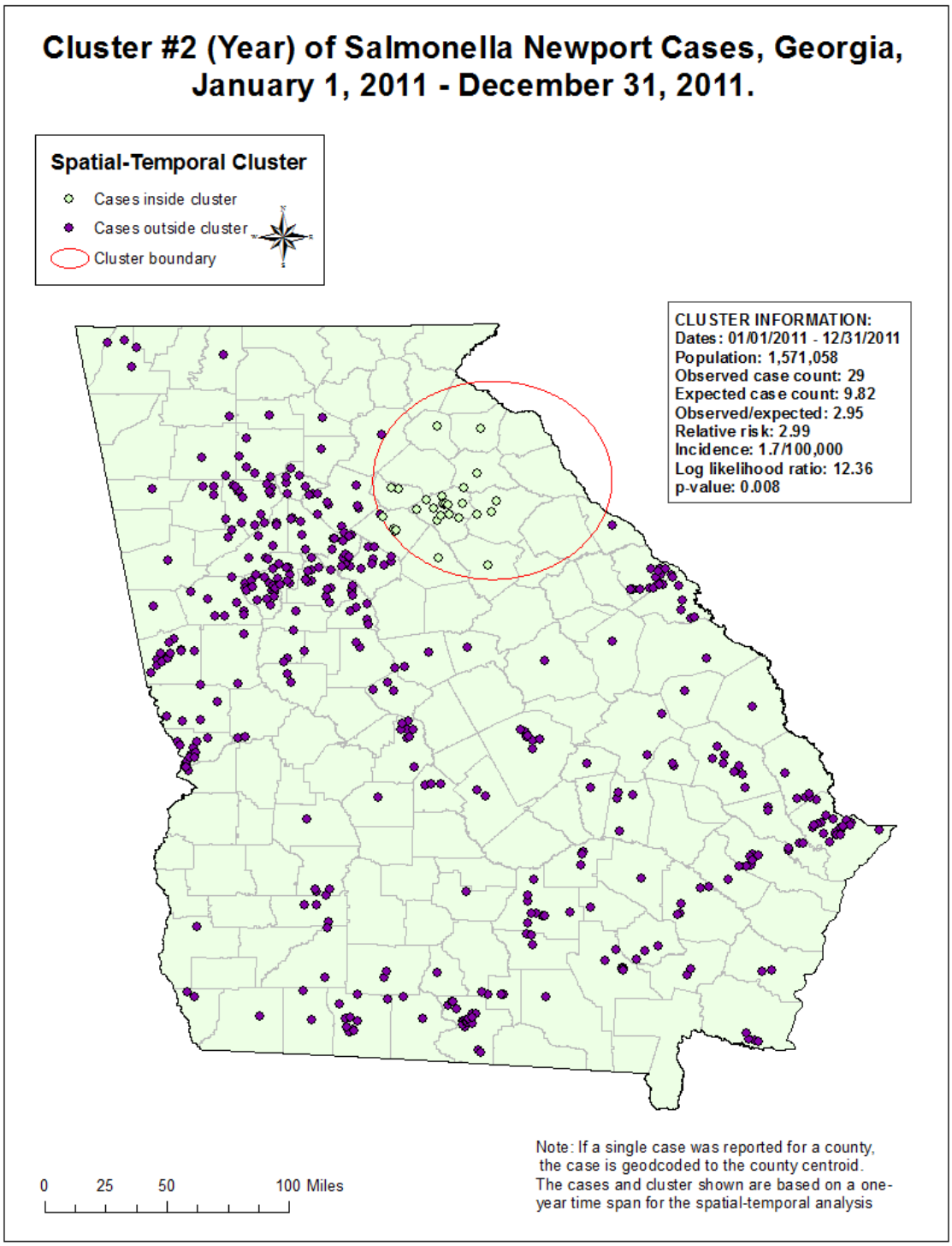


Figure 6. Map of *Salmonella* Newport cases and spatial-temporal cluster #1 using a one-year time interval for analysis, Georgia, January 1, 2010- December 31, 2010.



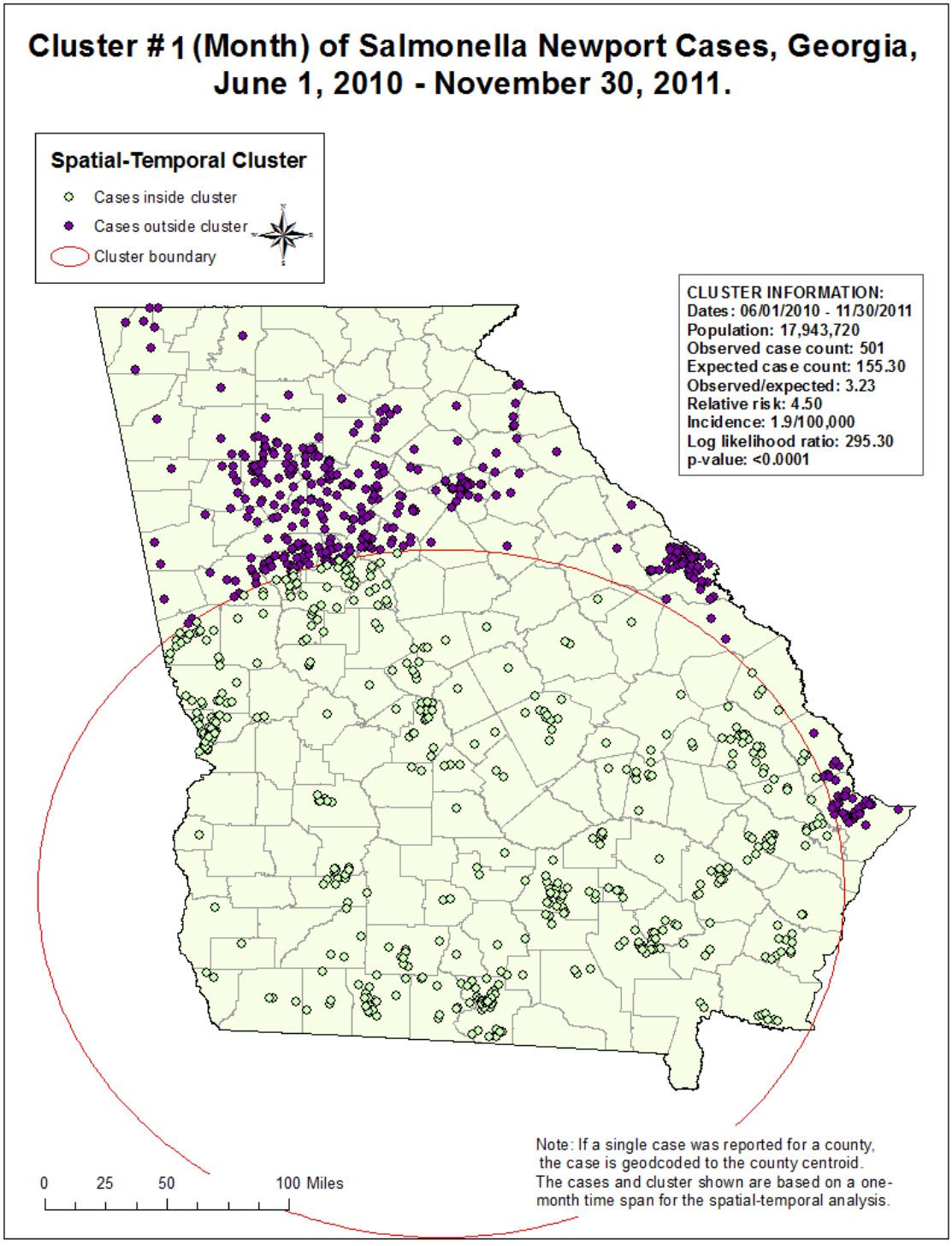
(33)

Figure 7. Map of *Salmonella* Newport cases and spatial-temporal cluster #2 using a one-year time interval for analysis, Georgia, January 1, 2011 – December 31, 2011.



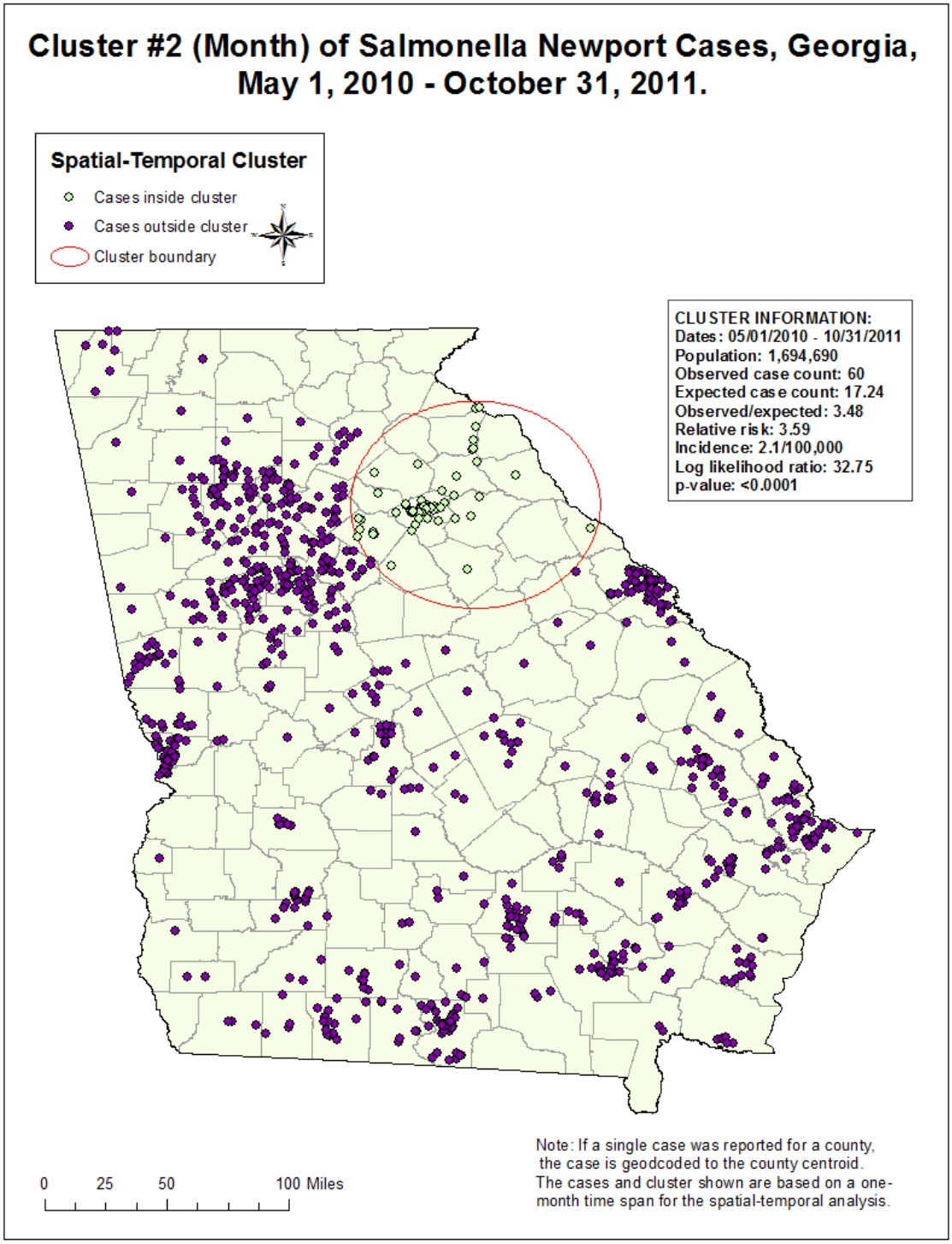
(33)

Figure 8. Map of *Salmonella* Newport cases and spatial-temporal cluster #1 using a one-month time interval for analysis, Georgia, June 1, 2010 – November 30, 2011.



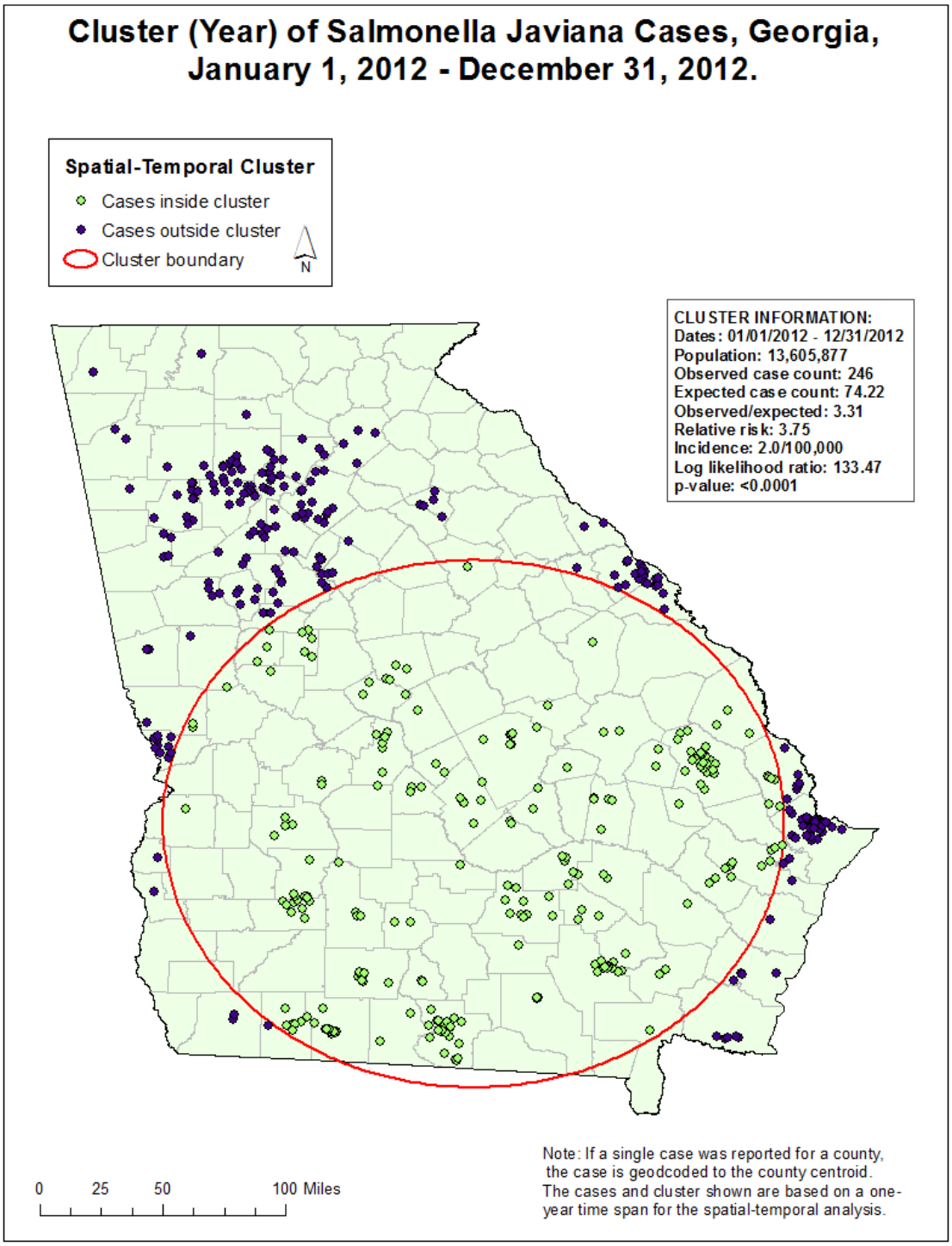
(33)

Figure 9. Map of *Salmonella* Newport cases and spatial-temporal cluster #2 using a one-month time interval for analysis, Georgia, May 1, 2010 – October 31, 2011.



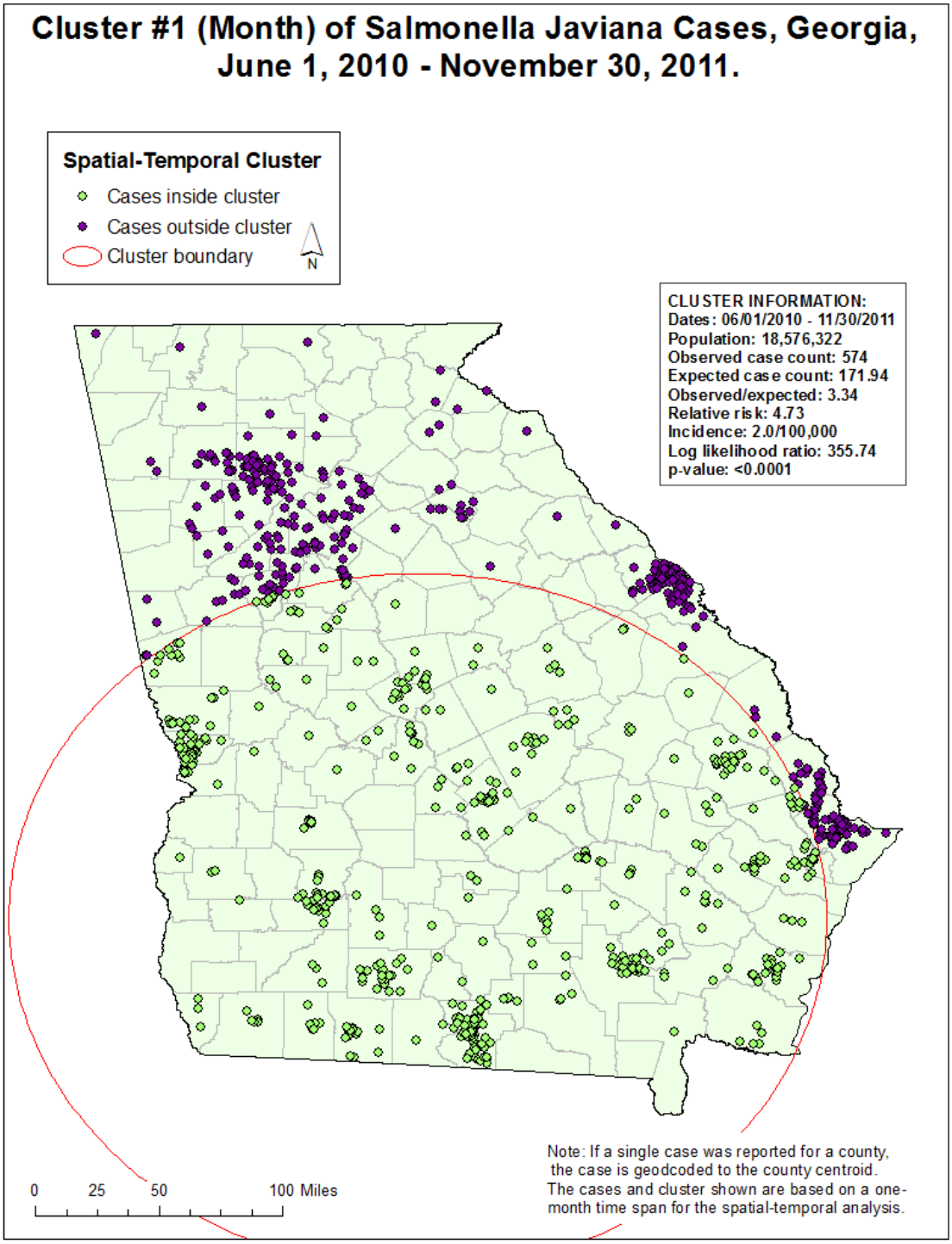
(33)

Figure 10. Map of the *Salmonella* Javiana cases and a spatial-temporal cluster using a one-year time interval for analysis, Georgia, January 1, 2012 - December 31, 2012.



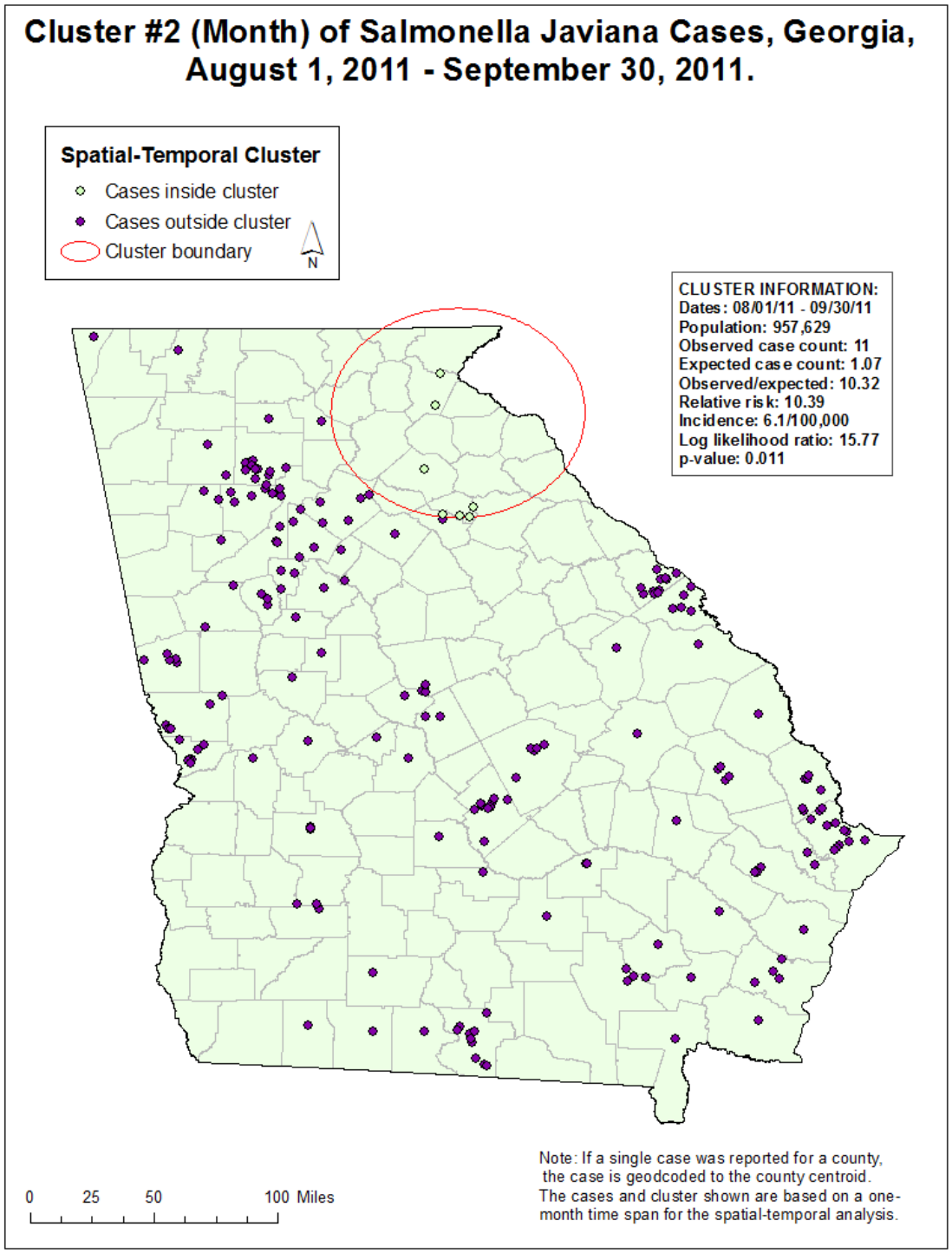
(33)

Figure 11. Map of *Salmonella* Javiana cases and spatial-temporal cluster #1 using a one-month time interval for analysis, Georgia, June 1, 2010 – November 30, 2011.



(33)

Figure 12. Map of *Salmonella* Javiana cases and spatial-temporal cluster #2 using a one-month time interval for analysis, Georgia, August 1, 2011 – September 30, 2011.



(33)

III. Summary, Public Health Implications, Possible Future Directions

The purpose of this study was to evaluate the association between socioeconomic status and incident cases, hospitalizations, and deaths due to salmonellosis between 2010 and 2012 for residents of Georgia. Socioeconomic status was estimated for each case based on address and the sociodemographic groups identified by the Georgia Department of Public Health for the state of Georgia. Poisson regression models were utilized to estimate the incidence and hospitalization rate ratios by serotype and the four groups, or eighteen subgroups, using the group/subgroup with the highest socioeconomic status as the reference category. Case fatality rate ratios were estimated for the four groups and the overall, non-typhoidal serotype category, with the highest socioeconomic group as the referent. In addition, the distribution of cases of *Salmonella* Newport and Javiana was described using spatial-temporal analyses.

The patterns of incidence rate ratios varied across the subgroups for the different serotypes. Relative to the highest socioeconomic status subgroup, all of the subgroups had lower incidence rate ratios for *Salmonella* Enteritidis. In contrast, cases in the two lowest socioeconomic status groups had higher incidence rate ratios for *Salmonella* Typhimurium. Cases in the two lowest socioeconomic groups had higher rate ratios for *Salmonella* Newport and Javiana. The rate ratios for hospitalization and case fatality were highest for the lower middle socioeconomic group (C). This coincides with the increased illnesses in this group due to *Salmonella* Newport and Javiana, both of which resulted in a greater proportion of hospitalizations and deaths than other serotypes. The spatial-temporal analysis provided further evidence of an increased burden on cases in this group. The analysis identified large groups that spanned a region of the state

populated by cases sharing the sociodemographic characteristics of the lower middle socioeconomic group.

The results of this study are similar to others showing variability in the association of socioeconomic status depending on the measures of status and the serotypes included for analysis. Most of the studies thus far have focused either on all non-typhoidal serotypes or on *Salmonella* Enteritidis. The variability in the rate ratios for incidence, hospitalization, and case fatality across the serotypes emphasizes the importance of considering these outcomes by the different serotypes rather than as the overall category of non-typhoidal *Salmonella*. These serotypes and many of the other non-typhoidal serotypes have known differences in reservoirs and exposure risks (46). Consequently, summarizing the data at the subspecies level may miss important risk differences for different populations and implications for prevention or intervention.

Given the high proportion of hospitalizations and deaths due to *Salmonella* Newport and Javiana, further investigation into the exposure risks associated with these serotypes may be beneficial to public health. The lower middle socioeconomic group, which was most affected by *Salmonella* Newport and Javiana, is described as including persons in farming, construction, and production living in rural areas. The hypothesis of environmental exposures as the source for infection needs further investigation to mitigate further illness in this population.

This study highlighted the utility for spatial-temporal analysis to complement otherwise purely statistical evaluations of risks and outcomes. In the future, these analysis strategies could be beneficial for prospective case finding as cases emerge in an area, particularly when awaiting the confirmatory PFGE patterns. For the surveillance data utilized in this study, spatial-temporal analyses also could be conducted

retrospectively to evaluate the accuracy of case-finding for groups and track patterns or trends associated with groups.

IV. Appendices

A. Description of the Sociodemographic Groups and Subgroups

Group A includes three subgroups, all of which have an income above the state mean. Cases in this group are characterized by at least some college level education, with occupations ranging from white-collar and sales positions to executive and professional level positions. Most of the cases are identified as White or Asian, with a family structure in the household. These cases are further characterized as living in the exurban and suburban areas of the state. The distribution of these cases across Georgia is therefore mostly in the metropolitan areas of Atlanta, Athens, Columbus, Macon, Augusta, Albany, Savannah, and Valdosta (37).

Group B includes four subgroups with varying income levels relative to the state mean income level. Cases in the B.1 subgroup are described as having college level education, and working in managerial or professional level positions. Cases in this subgroup differ from those in group A because they are generally younger, and more likely to be single and live in urban areas. Cases in subgroup B.2 represent military personnel and their families, which are generally younger (18-34), White, and have some college education. Cases in subgroups B.3 and B.4 were described has having income levels below the state mean. Those in B.3 have some college or are college graduates, have a higher proportion of Asian and multiracial than in the general population, and are more likely to live in suburban or urban areas. Cases in subgroup B.4 represent college students, with high school and some college education, a younger age range (18-24), and no family structure. The group B subgroups are generally distributed near metro areas, military bases, and colleges or universities.

Group C includes four subgroups that span most of the geographic area of Georgia (37). Cases in these subgroups represent the lower middle socioeconomic status, with income levels at or below the state average. Cases in these subgroups are characterized by some high school to high school completion for education. The primary occupations include farming, construction, and production, with some service, sales, and managerial positions. The general age range is older than in other groups, ranging from 45-64, and cases are predominantly White or African-American. Cases in group C are more likely to have a family structure and live in the rural areas of Georgia.

Group D includes seven subgroups in the lowest socioeconomic status level. In general, the cases are characterized as having some high school to high school completion, and to be working in mostly service occupations. The racial distribution is mostly African-American, with some mixed race and Hispanic areas. Family structure varies from single, to single-parent, to family households. Most cases in this group fall in the youngest (18-34) or oldest (55-60+) age groups. The exception is for subgroup D.2, which is comprised of military personnel and their families. Some of the cases in subgroup D.2 have some college to a college education. They are more likely to be in the lowest age group (18-34), to have a family structure, and be White or African-American. Subgroups in group D are located in urban, suburban, and rural areas of the state (37).

B. Model Selection Tables

Table B.1. Model selection for case counts by subgroup (1-18) and year of onset (2010, 2011, 2012).

Serotype	**Cases**		**Poisson**			**Negative Binomial**
	Mean	Variance	Value/DF	p-value	Scale (d-scale)	Dispersion estimate
All	140.6	21,510.4	1.4128	0.056	1.2231	0.0000
Enteritidis	11.8	140.8	1.6864	0.007	1.2986	0.0000
Typhimurium	12.0	147.7	1.1801	0.217	1.0863	0.0000
Newport	25.5	1,011.1	1.4724	0.037	1.2134	0.0000
Javiana	28.5	949.5	0.7189	0.886	0.8479	0.0000

Table B.2. Model selection for case hospitalization by subgroup (1-18) and year of onset (2010, 2011, 2012).

Serotype	**Cases**		**Poisson**			**Negative Binomial**
	Mean	Variance	Value/DF	p-value	Scale (d-scale)	Dispersion estimate
All	40.6	2,002.3	1.1801	0.2171	-	-
Enteritidis	3.9	17.6	1.6257	0.0120	1.2750	0.0000
Typhimurium	3.6	16.5	1.1529	0.2480	-	-
Newport	8.0	110.7	1.1665	0.2322	-	-
Javiana	8.4	70.1	0.8698	0.6845	0.9326	-

Table B.3. Model selection for case fatality by groups (1-4 or ABCD) and year of onset (2010, 2011, 2012).

Serotype	**Cases**		**Poisson**			**Negative Binomial**
	Mean	Variance	Value/DF	p-value	Scale (d-scale)	Dispersion estimate
All	3.08	5.54	0.8628	0.5214	-	-
Enteritidis*	0.08	0.08	-	-	-	-
Typhimurium	0.42	0.27	0.6596	0.9953	-	-
Newport	0.58	0.63	0.9569	0.9872	-	-
Javiana	0.42	0.45	0.3719	0.9907	-	-

* Model would not run for *Salmonella* Enteritidis.

C. Comparison of the Year of Onset, Outcomes, and Serotypes for Included and Excluded Cases

Table C.1. Year of onset and outcome for cases of salmonellosis included and excluded in the final analysis, Georgia, 2010-2012. (n=8,091)

Onset and Outcome	Included (n=7,590)		Excluded (n=501)		Chi-square
	No.	%	No.	%	p-value*
Year of onset					0.17
2010	2,627	34.6	163	32.5	
2011	2,500	32.9	155	30.9	
2012	2,463	32.5	183	36.5	
Hospitalization					
Yes	2,192	28.9	145	28.9	0.44
ER only	1,117	14.7	66	13.2	
No	4,197	55.3	285	56.9	
Not available	3	0.04	1	0.20	
Unknown	81	1.1	4	0.80	
Died					
Yes	37	0.5	2	0.40	0.10
No	7,127	93.9	482	96.2	
Unknown	426	5.6	17	3.4	

* Significance level of α=0.05.

Table C.2. Serotype for cases of salmonellosis included and excluded in the final analysis, Georgia, 2010-2012. (n=8,091)

Serotype	Included		Excluded		Total		Chi-square
	No.	%	No.	%	No.	%	p-value*
Total						100.0	0.07
All other**	3,384	44.6	244	48.7	3,628	44.8	
Enteritidis	636	8.4	37	7.4	673	8.3	
	650	8.6	54	10.8	704	8.7	
Typhimurium							
Newport	1,379	18.2	78	15.6	1,457	18.0	
Javiana	1,541	20.3	88	17.6	1,629	20.1	

* Significance level of α=0.05.
**All other includes all of the non-typhoidal serotypes excluding *Salmonella* Enteritidis, Typhimurium, Newport, and Javiana.

D. Emory University IRB Approval Letter

EMORY UNIVERSITY | Institutional Review Board

TO: Shannon Harney
Principal Investigator
Public Health

DATE: March 27, 2014

RE: **Expedited Approval**
IRB00072656
Association between sociodemographic variables and Salmonella incidence, hospitalization, and mortality rates in Georgia

Thank you for submitting a new application for this protocol. This research is eligible for expedited review under 45 CFR.46.110 and/or 21 CFR 56.110 because it poses minimal risk and fits the regulatory category F(5) as set forth in the Federal Register. The Emory IRB reviewed it by expedited process on 3/26/2014 and granted approval effective from **3/26/2014** through **3/25/2015**. Thereafter, continuation of human subjects research activities requires the submission of a renewal application, which must be reviewed and approved by the IRB prior to the expiration date noted above. Please note carefully the following items with respect to this approval:

- The IRB grants a complete waiver of HIPAA authorization
- The IRB grants a waiver of all elements of informed consent
- The following document is approved:
    - Study Protocol document, undated, uploaded into eIRB 2/22/2014

Any reportable events (e.g., unanticipated problems involving risk to subjects or others, noncompliance, breaches of confidentiality, HIPAA violations, protocol deviations) must be reported to the IRB according to our Policies & Procedures at www.irb.emory.edu, immediately, promptly, or periodically. Be sure to check the reporting guidance and contact us if you have questions. Terms and conditions of sponsors, if any, also apply to reporting.

Before implementing any change to this protocol (including but not limited to sample size, informed consent, and study design), you must submit an amendment request and secure IRB approval.

In future correspondence about this matter, please refer to the IRB file ID, name of the Principal Investigator, and study title. Thank you

Sam Roberts, BA CIP
Senior Research Protocol Analyst

This letter has been digitally signed

Emory University
1599 Clifton Road, 5th Floor - Atlanta, Georgia 30322
Tel: 404.712.0720 - Fax: 404.727.1358 - Email: irb@emory.edu - Web: http://www.irb.emory.edu/

E. Georgia Department of Public Health IRB Approval Letter

Georgia Department of Public Health

Brenda Fitzgerald, MD, Commissioner | Nathan Deal, Governor

2 Peachtree Street NW, 15th Floor
Atlanta, Georgia 30303-3142
www.health.state.ga.us

April 2, 2014

Melissa Tobin-D'Angelo
2 Peachtree Street, NW, #14-243
Atlanta, GA 30303

PROJECT #: 140205

PROJECT STATUS: APPROVED UNTIL 04/02/15

Dear Researcher,

The above-referenced project was reviewed by the DPH Institutional Review Board in accordance with expedited review procedures outlined in 45 CFR 46.110(b)(1) category **5**. The Board has **approved** this study until **04/02/15**.

The project involves access to the listed confidential information held by DPH:

- Case home addresses in order to assign sociodemographic clusters
- Case age at the onset of the disease

The Board has approved the **waiver** of the requirement for obtaining authorization from individuals for the release of confidential information about them, as described in the application. The Board has determined that:

- The use or disclosure of the confidential information involves no more than minimal risk to the privacy of individuals;
- An adequate plan exists to protect the identifiers from improper use and disclosure;
- An adequate plan exists to destroy the identifiers at the earliest opportunity consistent with conduct of research, unless there is a health or research justification approved by this Board for retaining the identifiers or such retention is otherwise required by law;
- Adequate written assurance exists that protects the confidential information from being reused or disclosed except (1) as required by law, (2) for authorized oversight of the research, or (3) for other research that is approved by the DPH IRB.
- The research could not practicably be conducted without the waiver or alteration; and,
- The research could not practicably be conducted without access to and use of the confidential information

If you wish to continue this project beyond the current approval period, please submit a "Continuing Review Application" before the above expiration date. If you do not submit a renewal application before the expiration date, the approval of your project will automatically terminate. Any involvement with human subjects must cease on the above date unless you have received approval from the Board to continue the project. It is the investigators responsibility to track the deadline.

Georgia Department of Public Health

Brenda Fitzgerald, MD, Commissioner | Nathan Deal, Governor

2 Peachtree Street NW, 15th Floor
Atlanta, Georgia 30303-3142
www.health.state.ga.us

This approval applies only to the protocol described in your application. IRB review and approval is required before implementing any changes in this project except where necessary to eliminate apparent immediate hazards to human subjects.

If you have any questions regarding this letter or general procedures, please contact the IRB Chair at irb@dhr.state.ga.us. Please reference the project # in your communication.

Best wishes in your research endeavors,

Brian Kirtland, Ph.D.

Digitally signed by Brian Kirtland, Ph.D.
DN: cn=Brian Kirtland, Ph.D., o=Georgia Department of Public Health, ou=Institutional Review Board, email=bckirtland@dhr.state.ga.us, c=US
Date: 2014.04.02 13:32:58 -04'00'