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Incidence Of Salmonella And Neighborhood Poverty Level In Connecticut, 2000-2011

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ABSTRACT

Background: Surveillance by the FoodNet program has shown that *Salmonella,* unlike other foodborne illnesses, has increased during the past fifteen years within the United States. Little work has been done to examine the role of socioeconomic factors in incidence of *Salmonella.* Neighborhood poverty level, measured as the percentage of people living below the poverty line, at the census tract level has been accepted as a useful indicator of socioeconomic status. This study utilized geographic information system (GIS) technology and census tract data to examine the variation in *Salmonella* incidence among census tracts in Connecticut. The objectives of this study were to examine: 1) the relationship between the incidence of all *Salmonella* serotypes and neighborhood poverty level (overall, by age group, and over time), and 2) whether the association between the incidence of *Salmonella* and neighborhood poverty level differs by serotype for the four most common serotypes seen in Connecticut from 2000-2011.

Methods: There were 5204 of 5484 (94.9%) reported cases of *Salmonella* from 2000-2011 that were geocoded and categorized into the appropriate poverty level. Census tracts were divided into four different levels of neighborhood poverty level representing the percentage of individuals living below the poverty line using information from the 2000 and 2010 censuses and the American Community Survey: 0 – 4.9%, 5 – 9.9%, 10 – 19.9%, and ≥20%. Age-adjusted incidence rates were calculated for each poverty level for the overall time period and for 2000-2005 and 2006-2011. We further stratified the data by age group (<5, 5-9, and ≥10 years old) and examined age-specific incidence rates overall and by time period. Age-adjusted incidence rates by neighborhood poverty level were also examined for the four most prevalent *Salmonella* serotypes in Connecticut for the overall time period and then for 2000-2005 and 2006-2011.

Results: There was a clear gradient for the association between neighborhood poverty level and incidence of *Salmonella* in Connecticut from 2000-2011; incidence increased with decreasing neighborhood poverty level. Using the 0 – 4.9% poverty group as the reference, the age-adjusted incidence rate ratios for 2000-2011 were 0.94 for the 5 – 9.9% group, 0.92 for the 10 – 19.9% group, and 0.81 for the ≥20% group. This trend persisted over time though there were differences according to age group and serotype. Those individuals younger than five years old and those with *Salmonella heidelberg* exhibited the opposite gradient (increasing incidence with increasing neighborhood poverty level). The gradient of lower incidence with increasing poverty level seen across all *Salmonella* for the entire 2000-2011 time period was also present for those with *S. newport, S. enteriditis,* and individuals greater than five years old. No association with neighborhood poverty level was seen for *S. typhimirium.*

Conclusions: *Salmonella* incidence overall for 2000-2011 increased with decreased neighborhood poverty. An exception was children less than five years for whom incidence increased with increased neighborhood poverty. Different *Salmonella* serotypes exhibited different trends in incidence related to neighborhood poverty level. We believe that these findings could be utilized in prevention efforts and in designing interventions geared toward specific populations by taking into account age, neighborhood poverty level, and the different trends for the four most prevalent *Salmonella* serotypes. Research into possible explanations for different incidence rates among serotypes by poverty level could provide additional insight.

BACKGROUND & RATIONALE

In the United States, an estimated 48 million illnesses, 128,000 hospitalizations, and 3,000 deaths annually can be attributed to the consumption of contaminated food products.[i, ii] In 2009, the Council on Agricultural Science and Technology prepared a report that concluded that foodborne pathogens can resist even the most aggressive methods geared toward prevention of transmission because they can contaminate food at any point in the supply chain: during the growing, picking, processing, packaging, transportation, preparation, cooking, serving, and/or storage stages.[iii]

Scallan et al. (2011) reported that *Salmonella* alone causes approximately one million foodborne infections each year[iv] and costs $365 million in direct medical expenditures annually.[v] In 2011, the *Vital Signs* report published by the Centers for Disease Control and Prevention (CDC) stated that, unlike other foodborne illnesses, there had been no notable progress in preventing infection with *Salmonella* during the previous fifteen years.[vi]

The FoodNet project is a cooperative partnership among the Centers for Disease Control and Prevention, the state health departments, and academic centers in ten states, including Connecticut. FoodNet is an active surveillance system that collects information on nine different, mostly bacterial foodborne illnesses within the United States, by tracking and monitoring the trends of those cases with laboratory-confirmed illness in each site's catchment area.[vii] The ten-state catchment area includes approximately 15% of the population of the United States. (This catchment area includes the entirety of seven of the states and selected counties within each of the following states: CA, CO, and NY).[viii] In addition to *Salmonella,* the eight other pathogens causing foodborne diseases monitored by FoodNet include: *Campylobacter*, *Cryptosporidium*, *Cyclospora*, *Listeria*, *Salmonella*, Shiga toxin-producing *E. coli* O157 and non-O157, *Shigella*, *Vibrio,* and *Yersinia*.[ix]

According to the CDC *Vital Signs* report, infection with *Salmonella* has actually *increased* by an estimated 10% in recent years. [x] Six of the nine foodborne illnesses monitored and investigated by the FoodNet Project for this CDC report had seen significant reductions of over 20% during this same time period, while infections with *E.coli* declined by 50%.[xi] It is currently unclear why incidence increased only for *Salmonella.* Furthermore, of all of the deaths and hospitalizations attributed to the nine foodborne illnesses tracked by the CDC's FoodNet program, *Salmonella* alone was responsible for 2,300 hospitalizations and 29 deaths in 2010, accounting for 54 percent of the hospitalizations and 43 percent of the deaths that were reported and confirmed in the FoodNet catchment area.[xii] Yet, these numbers only represent the reported and confirmed cases of *Salmonella* and it is generally believed that surveillance efforts detect only a portion of foodborne illness in the United States. For example, many individuals infected with *Salmonella* may have mild symptoms or may decide not to seek the help of a health professional for their illness, and health care providers seeing patients with gastrointestinal illness may not order a diagnostic test. The CDC believes that for each infection confirmed, there are 29 infections of *Salmonella* that go unconfirmed.[xiii]

Previous research has identified several modes and many different vehicles for transmission of *Salmonella*. *Salmonella* is particularly adept at being transmitted either through contaminated water or food. The Food and Drug Administration notes that *Salmonella* can contaminate the following vehicles of transmission: meat, farm-irrigation water (thus contaminating produce in the field), soil and insects, factory equipment, hands, and kitchen surfaces and utensils.[xiv] Historically, *Salmonella* infection was associated with consumption of animal derived foods, such as chicken and eggs; however, more recently, there have been a number of outbreaks associated with fresh produce. The Food and Drug Administration notes that many food items have been associated with outbreaks of *Salmonella,* including food items as diverse as: meats, poultry, eggs, milk and dairy products, fish, shrimp, spices, yeast, coconut, sauces, freshly prepared salad dressings made with unpasteurized eggs, cake mixes, cream-filled desserts and toppings that contain raw egg, dried gelatin, peanut butter, cocoa, produce (fruits and vegetables, such as tomatoes, peppers, and cantaloupes), and chocolate. [xv] Additionally, cross-contamination, which could occur if *Salmonella* were spread from a contaminated source to a previously uncontaminated one, can occur at any point, even during the preparation of food if potentially contaminated food is not separated from other food or prepared appropriately. *Salmonella* has also been associated with contact with different types of animals, including pets. Moreover, Younas et al. (2010) found that among children ten years old or younger, after adjustment for race and income, *Salmonella* infections were associated with attendance at daycare, contact with cats, and contact with reptiles during the three-day period before illness onset.[xvi]

Surprisingly little work has been done to describe and monitor the magnitude and trends in disparities of diseases under public health surveillance by socioeconomic status. This is in part due to the fact that most disease surveillance systems do not collect data on socioeconomic status. The Public Health Disparities Geocoding Project was developed to redress the paucity of surveillance data including socioeconomic measures in order to better monitor and address socioeconomic disparities that impact health and health outcomes. This project determined that the area-based socioeconomic measures (ABSM) could be used whenever residential address data was available in the surveillance system. They found that the ABSM that best captured the impact of socioeconomic disparities in health and health outcomes was poverty measured at the census tract level. Their rationale for this conclusion stated that poverty at the census tract level "consistently detected expected socioeconomic gradients in health across a wide range of health outcomes, among both the total population and diverse racial/ethnic-gender groups, yielded maximal geocoding and linkage to area-based socioeconomic data [and] was readily interpretable to and could feasibly be used by state health department staff."[xvii] There is a growing literature using area-based poverty at the census tract level as an indicator for socioeconomic disparities in health. This study will assess whether there are disparities in *Salmonella* incidence related to area-based poverty measured at the census tract level.

The incidence for demographic groups other than children, who tend to be the ones most affected by *Salmonella*, has not been well described in the literature. This is partially because surveillance often does not collect information to measure race/ethnicity well and does not routinely collect information to measure socioeconomic status. Of the few studies that have looked at socioeconomic status, findings have proved interesting, but need to be confirmed in other parts of the United States since those studies are geographically limited in scope. For example, Younas et al. (2007) looked at the role of various socioeconomic characteristics in Salmonella infections by block level group in Michigan. The investigators reported that a greater number of *Salmonella* infections were seen among those with higher education compared to those with lower education, which the study suggested might be indicative of better access to and availability of care among those who are more educated since education is often positively correlated with income and increased access to care.[xviii] Similarly, a 2008 study from Denmark also showed that those with higher incomes had a higher incidence of *Salmonella,* which the researchers attributed to higher levels of travel, diet, and medical care seeking behaviors that they believe to be correlated with income level, education, and familial factors.[xix] Travel has been implicated as a risk factor for *Salmonella* infections in several other studies as well.[xx,xxi]

It is evident from the aforementioned 2011 CDC *Vital Signs* report that the direct and indirect health and economic burdens associated with *Salmonella* infections notably impact a significant proportion of the United States' population each year. Taken together with the fact that the number of infections attributed to the majority of the other foodborne illness infections in the United States monitored by FoodNet has decreased while *Salmonella* incidence has increased in recent years, it is important to determine risk factors and potential associations that may explain this phenomenon such that we may better address and prevent more *Salmonella*-associated illness in the future. The objectives of this study were to: 1) examine the relationship between the incidence of all *Salmonella* serotypes and neighborhood poverty level and to then determine if the relationship is present among all age groups and whether it has changed over time, and 2) investigate associations between the incidence of *Salmonella* and neighborhood poverty level by serotype for the four most common serotypes in Connecticut from 2000-2011 (*S. enteriditis, S. typhimirium +variants, S. Heidelberg, and S. Newport)*.

METHODS

Study Participants

This analysis utilized FoodNet data collected in Connecticut between 2000-2011 inclusive on incident cases of *Salmonella*, regardless of serotype. Surveillance is conducted through lab reporting, audits for completeness, and isolates sent to the Connecticut Department of Public Health for serotyping. These data are supplemented by information from patient interviews using the standard Connecticut General Enteric Disease Interview Form (GEDIF). It has only been more recently that attempts have been made to interview all patients.

Demographic information regarding unduplicated, laboratory-confirmed cases of *Salmonella* was taken from the case report forms. This information included age, gender, race/ethnicity, international travel, full street address of the case, serotype as well as specific clinical information regarding the case patient's symptoms and information regarding potential exposures.

Geocoding Process

This study utilized the Geographic Information System (ArcGIS) software package developed by the Environmental Systems Research Institute (ESRI). Using this program, geographic coordinates were assigned to the full street addresses of the case patients for all of the incident *Salmonella* cases. This process was completed using the United States Street Locator as a reference network to match the address for each individual case patient. For automatic matching of records, the default program settings were used. Records were matched interactively through manual inspection by correcting evident typographical errors and checking records using reverse phone number look-up services. Records that were matched automatically or through manual inspection were included in this analysis.

For the geocoded cases, we then proceeded to link them to census tracts. This was completed by utilizing the U.S. Census Bureau TIGER/Line® Shapefile for census tracts in Connecticut. This Shapefile was downloaded from the University of Connecticut's Map and Geographic Information Center and projected using the North American Datum of 1983 state plane coordinate system (Lambert conformal conic projection) within the ArcGIS program. Geocoded cases were matched to census tracts using a spatial join in ArcGIS. Cases occurring 2000-2005 were spatially joined to census tracts utilizing the 2000 census, while cases occurring

2006-2011 were joined to census tract designations from the 2010 Census. This information was then imported into the SAS statistical package for statistical analyses.

Statistical Analysis

Consistent with the conclusions of the Public Health Disparities Geocoding Project, this study examined *Salmonella* incidence in Connecticut using census tract poverty levels.

Cases were categorized into the following age groups: less than five years old, five to nine years old, and ten years old and greater; these categories were selected because children tend to contract *Salmonella* more frequently than adults. Since data covered the period from 2000 to 2011, population counts for each age category were averaged for the twelve-year period using data obtained from both the 2000 and 2010 US censuses. Examination of crude results suggested no notable difference in incident rates among individuals aged above ten years and were thus collapsed into one category. Population counts were averaged for male and female using data obtained from both the 2000 and 2010 US censuses in order to examine the incidence of *Salmonella* during the twelve year time period for males and females.

Poverty level by census tract was delineated into 4 categories: 0 – 4.9%, 5 – 9.9%, 10 – 19.9%, and 20% or over.[26] In both 2000 and 2010, seven census tracts (<1%) could not be assigned to a poverty category due to missing data. As a result, these tracts were excluded from calculations. For incident cases that occurred between 2000 and 2005, cases were linked to the 2000 Census data census tract-specific poverty in order assign each case one of the four poverty levels. Likewise, for incident cases that occurred between 2006 and 2011, cases were linked to census tract-specific poverty level found in the 2006-2010 American Community Survey data to assign each case a census tract poverty level. Once each case was assigned a poverty level, the cases in each poverty level were aggregated to determine the numerator for each poverty category for each of the two time periods. Denominator data for each poverty category were obtained utilizing the 2000 and 2010 censuses for population counts in Connecticut by poverty level and age. Using case counts and denominator information, crude incidence rates of *Salmonella* were calculated by poverty level as well as poverty level by age. To determine if crude incident rates were confounded by age, age-adjusted rates were calculated using direct standardization where weighting factors were obtained from the U.S. 2000 Standard Million.[xxii] Age-adjusted incidence rate ratios were determined in reference to the 0 – 4.9% poverty level as the reference category.

Annual average incidence rates by poverty level were also calculated for the four most common serotypes of *Salmonella (spp. enteriditis, heidelberg, newport,* and *typhimirium),* utilizing the average annual population count for each poverty level during each time period (2000-2005 and 2006-2011) as the denominator.

Frequency analyses described the demographic characteristics by geocoded status and the frequency of cases among different racial and ethnic groups by three-year intervals. Statistical testing compared percentages and *Salmonella* incidence across groups using chi-square analyses and chi-square for trend analyses tested for gradients in the incidence by poverty level of *Salmonella* overall and by serotype for the four most common serotypes in Connecticut during this period.

RESULTS

During the twelve-year period beginning in January of 2000 and ending in December of 2011, there were 5,484 incident cases of all serotypes of *Salmonella* reported and confirmed within Connecticut. Information regarding the serotype was available for all but one incident case. The most frequently observed serotypes were: *Salmonella enteriditis* (n=1,416, 25.8%), *Salmonella typhimirium and its variants* (n=1,044, 19.1%), *Salmonella newport* (n=375, 6.8%), and *Salmonella heidelberg* (n=189, 3.5%). Of these cases 5,204 cases (94.9%) were geocoded through automatic or interactive matching through manual inspection. Geocoded incident cases of *Salmonella* were not statistically different than incident cases that were not geocoded with regard to their distribution by age, sex, or race (Table 1). A higher number of cases that did not successfully match automatically or interactively after manual inspection occurred during the earlier years of surveillance (8.1% in 2000-2002 vs 3.0% in 2009-2011; $p<0.001$, data not shown).

Almost one-third (32.8%) of race-ethnicity data for incident *Salmonella* cases in Connecticut were missing or unknown from 2000 to 2011. Race-ethnicity data was then examined in three-year intervals to see whether or not the percentage of missing data decreased over time. There were high percentages of missing data across the four intervals; however, the percentage of missing data in the last interval from 2009-2011 (22.6%) was almost half that of the first interval from 2000-2002 (41.8%); (Table 2; $p<0.001$).

Incidence by age, sex, race/ethnicity, and over two six-year time periods were examined (Table 3). Only age and time period had statistically significant findings. Younger children had higher rates than persons 10 years and older. Those less than five years old had a 3.42-fold higher incidence and those 5-9 years had a 1.45-fold higher rate. The rate in the second year six years of the study period (2006-2011) was 7% higher than in the first. There were no statistical differences in incidence by sex or race/ethnicity.

Overall crude average annual *Salmonella* incidence across the entire twelve-year period illustrated that those individuals in areas with a higher percentage of individuals living below the poverty line had a lower incidence of illness compared to those living in neighborhoods with a lower percentage of individuals below the poverty level, a relationship that holds through each of the four poverty groups. This gradient was maintained and differences in incidence among poverty levels were amplified after age-adjustment as *Salmonella* incidence rates overall in neighborhoods with greater than 20% poverty was less than in neighborhoods with lower neighborhood poverty levels. The age-adjusted average annual incidence rates were 13.2 cases per 100,000 for the 0-4.9% poverty level, 12.4 for the 5-9.9% poverty level, 12.1 for the 10-19.9% poverty level and 10.6 for the greater than 20% poverty level (Table 4, $p<0.001$, chi-square for trend).

Examining the average annual incidence of *Salmonella* overall categorized according to neighborhood poverty level by each of the two six-year intervals demonstrated the same trend in each time period (Tables 4, 6, 8). From 2006-2011, incidence rates were higher across all of the poverty levels compared to 2000-2005.

Stratification by age group indicated that individuals between 5 and 9 years old and greater than 10 years old exhibited the same gradient for the association between higher incidence and lower neighborhood poverty level as seen across all of the cases from 2000 and 2011. However, the reverse gradient was seen for the less than five age group; incidence tended to increase with increasing neighborhood poverty level for this group. Incidence in this age group was 34.0 cases per 100,000 for the 0-4.9% poverty level, 32.7 for the 5-9.9% poverty level, 43.8 for the 10-19.9% poverty level and 39.9 for the greater than 20% poverty level (Table

5; $p<0.001$). These same trends were seen when examining the data in six-year intervals (Tables 7, 9).

The average age-adjusted annual incidence rates differed among the four most common *Salmonella* serotypes categorized according to poverty level during the entire twelve-year period. *Salmonella enteriditis* followed a similar gradient as that of overall *Salmonella* incidence rates. Those within the greater than 20% neighborhood poverty level experienced average age-adjusted annual incidence rates that were 0.68 times that of the 0-4.9% neighborhood poverty level. *Salmonella newport* also demonstrated a similar gradient in that average age-adjusted annual incidence rates decreased with increasing neighborhood poverty level (Table 10). The incidence of *Salmonella newport* in the greater than 20% poverty level was almost half of the rate experienced by those living in the less than 5% neighborhood poverty level (Table 10). The gradient for *Salmonella heidelberg* was in the opposite direction, with average age-adjusted annual incidence increasing with increased neighborhood poverty level; those in the highest neighborhood poverty level had an average age-adjusted annual incidence rate that was 1.99 times that of the lowest neighborhood poverty level (Table 10). There was no significant difference according to neighborhood poverty level for *Salmonella typhimirium.*

We also examined whether the associations between census tract poverty level and average age-adjusted annual incidence rates among each of the four most common *Salmonella* serotypes changed over time from 2000-2005 and 2006-2011. For each, the trend relationships described above were consistent across the two time periods (Tables 10-12). However, the difference in incidence among the poverty levels was much less pronounced for *Salmonella heidelberg* from 2006-2011 compared to 2000-2005 (Table 12). During this time, there was a

44% decrease in the number of *Salmonella heidelberg* cases, with the biggest decrease among those in the highest poverty group.

DISCUSSION

This is one of the few studies done in the United States examining the relationship between *Salmonella* and socioeconomic status. Our main finding was that the incidence of *Salmonella* overall (all serotypes) increased with decreasing neighborhood poverty during 2000-2011. Those living in areas with the lowest neighborhood poverty levels (<5% of the population living below the poverty line) had the highest incidence of salmonellosis, an incidence that was 1.25 times higher than those who resided in census tracts with the highest levels of neighborhood poverty (≥20% of the population living below the poverty line). Compared to other demographic features, only age was a stronger predictor of incidence. Those who were in the youngest age group (<5 years old) were 3.44 times more likely than those in the oldest age group (≥10 years old) to contract *Salmonella* during the twelve-year period. Other key findings were that different *Salmonella* serotypes exhibited different trends in incidence related to neighborhood poverty level. Specifically, *Salmonella newport* and *Salmonella enteriditis* demonstrated the same gradient of lower incidence with increasing poverty level seen across all *Salmonella* during 2000-2011 while those with *Salmonella heidelberg* exhibited the opposite gradient (increasing incidence with increasing neighborhood poverty level). No association with neighborhood poverty level was seen for *Salmonella typhimirium.* These findings were present in both the first and second halves of the study period.

One study in Michigan found increased incidence of *Salmonella* with higher education and income levels.[xxiii] There are several reasons why individuals in census tracts with lower neighborhood poverty levels may have higher incidence of *Salmonella* than those who reside in areas with higher neighborhood poverty levels. First, those in areas with lower neighborhood poverty levels may have increased access to care, may be more likely to have tests done on specimens, may be more likely to present at a hospital, acute care center, or doctors' office regardless of severity of disease while those in lower socioeconomic brackets may only seek care or get diagnostic tests when their illness is deemed serious or is prolonged. However, an earlier analysis using FoodNet population survey data that examined the frequency of seeking care and obtaining a diagnostic specimen among those reporting diarrhea in Connecticut actually suggested that those in lower socioeconomic brackets were *more likely* to seek care and submit a stool specimen than those in higher socioeconomic brackets.[xxiv] Thus, this hypothesis seems less plausible. Second, the prevalence of known salmonellosis risk factors, such as international travel; eating out at restaurants rather than eating at home; consuming particular food items like undercooked eggs, meat, and so forth among non-outbreak associated salmonellosis, may differ according to socioeconomic bracket. For example, a 2011 analysis that examined *Campylobacter* in Connecticut found that some known risk factors for *Campylobacter* differed according to socioeconomic status, which may have played a small role in the gradient between neighborhood poverty level and *Campylobacter* incidence observed in that study.[xxv] Examining whether or not the prevalence of certain risk factors for *Salmonella* differs according to socioeconomic level could be informative in assessing the gradients observed between incidence and neighborhood poverty level.

It is unclear why poor young children experience increased incidence of *Salmonella* in comparison to wealthier children that are the same age. Younger children in these areas with higher poverty levels may have higher levels of *Salmonella* incidence due to more crowded living conditions where cross-contamination may be more likely to occur and where there may be less awareness regarding food safety and cross-contamination. If true, this suggests that information and interventions targeted toward reducing *Salmonella* incidence overall may need to account for differences in age within different poverty levels. Prevention efforts can be targeted toward different areas based on neighborhood poverty level and age group. However, studies are needed to better understand the factors behind the age-specific associations of salmonellosis with socioeconomic status.

Examining incidence by serotype related to neighborhood poverty level over the entire twelve-year period indicated that there were marked differences in incidence among these four different serotypes. *Salmonella enteriditis*, for example, demonstrated the same gradient for the relationship between incidence and neighborhood poverty level as *Salmonella* overall, where incidence decreased with increasing neighborhood poverty level. Those in the lowest neighborhood poverty level were 48% more likely to contract *Salmonella enteriditis* than those in the highest neighborhood poverty level. For *Salmonella heidelberg*, the opposite relationship was observed, as those in highest neighborhood poverty level were 75% more likely to contract it than those in the in the lowest neighborhood poverty level. For *Salmonella newport*, those who resided in the lowest neighborhood poverty level (<5%poverty level) were twice as likely to contract *Salmonella newport* than those in the in the highest neighborhood poverty level. No significant change was observed in incidence for *Salmonella typhimirium* according to poverty level.

Little has been done examining whether each serotype has its own relationship with socioeconomic status. One 2008 study from Denmark examined the relationship between various foodborne illnesses including *Salmonella enteriditis, Salmonella typhimirium,* and other types of *Salmonella* with socioeconomic characteristics, including average gross annual income, educational attainment, and marital status. The Denmark study found that those with higher incomes had a higher incidence of *Salmonella enteriditis* and other types of *Salmonella,* which the researchers attributed to diet, higher levels of travel, and medical care seeking behaviors that they believe to be correlated with income level, education, and familial factors.[xxvi] However, in that study, the opposite trend was observed for *Salmonella typhimirium.*[xxvii] In the United States, a 2008 study used FoodNet data to examine outcomes and severity of illness by serotype (looking at the five most common serotypes across the FoodNet sites, which were the four serotypes examined in this study and *Salmonella javiana).* Though that study did not look at serotype incidence related to neighborhood poverty level, it did conclude that there are notable differences between the serotypes in pathogenicity, manifestation of symptoms, and outcomes.[xxviii] However, it is plausible that the differences observed between serotypes in terms of incidence according to poverty level may be the result of different ecologic niches and routes of exposure specific to each different serotype. These different niches and exposure routes may vary according to poverty level. For example, *Salmonella enteriditis* is most commonly associated with eggs and chickens while *Salmonella newport* has been associated most commonly with cattle and dairy products. However, a wide variety of different food products have been contaminated with each of these serotypes. Species-specific studies are needed to better understand transmission routes for these different serotypes, which potentially could also inform our understanding about each serotype's relationship with neighborhood poverty level.

These findings identify some areas for additional research. Risk factors related to neighborhood poverty levels should be examined, especially for children under five. Stratified analyses demonstrated that the relationship between incidence and neighborhood poverty level for these individuals is the opposite of the gradient seen for *Salmonella* overall and for the other two age groups, as incidence in the youngest age group increases with increasing level of poverty. Neighborhood level risk factors should be investigated for this age group in particular. Particular risk factors or living conditions may make younger children less than five particularly susceptible to illness in areas with higher levels of poverty. This same reversal of this socioeconomic gradient was seen for *Campylobacter* in a study done in Connecticut in 2011 at the Yale Emerging Infections program.[xxix] As the 2011 *Campylobacter* study suggested, the reversal in the socioeconomic gradient for incidence within this youngest group suggests that those who are younger in areas with higher levels of poverty may be exposed to or be more susceptible to a particular set of risk factors. Additionally, since the incidence by poverty level varied when stratified according to serotype for the four most prevalent serotypes, further research could be done to determine whether or not there are clear risk factors unique to each serotype to which those residing in certain neighborhood poverty levels are more or less susceptible.

There are several important limitations of this study. First, there is a lack of complete information for race/ethnicity for the cases over this time period. We were only able to assess whether or not the crude annual incidence was different among the various ethnic groups for 2009-2011, a period in which almost 80% of cases had race/ethnicity information. However, a larger percentage of race/ethnicity information was missing during the earlier nine years. As a result, we were unable to tease out and explore how incidence across the neighborhood different poverty levels looked when stratified according to race/ethnicity. This information could have been telling and potentially useful in the design of interventions, targeted educational information, and health-seeking behaviors.

Second, little is known about whether or not there is a socioeconomic gradient in terms of the way in which individuals of different socioeconomic backgrounds perceive diarrheal illness and seek medical attention for these illnesses. Such information would be useful in determining whether there are differential probabilities for getting a confirmed diagnosis of salmonellosis among individuals in different socioeconomic strata in Connecticut. For example, not all individuals (in fact, previously mentioned estimates suggest a relatively small percent) seek help for diarrheal illness, particularly illness that is less severe in nature. As a result, it is plausible that those cases that were detected, confirmed, and reported to the state may not be representative of the true incidence of *Salmonella* within Connecticut during this time period. Given a nearly 30:1 illness to diagnosis ratio, differences in the association between neighborhood poverty level and *Salmonella* incidence could be explained by differential health care. However, there have been previous analyses of the Connecticut population using FoodNet data for the years examined by our study that did not demonstrate differential health care seeking behavior by poverty level for different diagnoses. These analyses were trying to determine whether or not wealth impacted the probability of having an organism-specific diagnosis. No significant difference was observed, but the numbers were small.

Additionally, it was not possible to geocode seven of the census tracts. However, this accounted for less than 1% of the census tracts surveyed in this study. Another limitation of this study is its geographical scope. A further study that looks at undertaking this type of analysis across all of the FoodNet sites or across the United States would alleviate this limitation and provide us with a better idea of whether or not the trends observed here are representative of the United States as a whole. A final limitation of this analysis is that it used poverty measured at the census tract level, not individual level socioeconomic status. Thus, the results of this analysis should be understood and interpreted within this context.

Overall, this study did illustrate that the incidence of *Salmonella* infection overall and by serotype (for the four most common types) tends to vary in a fairly predictable manner with respect to neighborhood poverty level, delineated according to poverty level categories suggested by the Public Health Disparities Geocoding Project. This study provides additional evidence that using area-based socioeconomic measures, such as neighborhood poverty level, may be useful in investigating the incidence of *Salmonella* and other foodborne related illnesses, which could then be used to properly plan and target specific interventions for particular age groups within neighborhoods.

TABLES AND FIGURES

Table 1. Demographic characteristics of *Salmonella* cases by geocoding status, Connecticut, 2000-2011

Characteristic	Geocoded[a] Yes (n = 5204)	Geocoded[a] No (n = 280)	p[b]
Age Group			0.640
0 – 4	931 (17.9)	53 (18.9)	
5– 9	431 (8.3)	19 (6.8)	
10&Up	3842 (73.8)	208 (74.3)	
Sex (n=5,483) [c]			
Male	2476 (47.6)	134 (47.9)	0.930
Female	2727 (52.4)	146(52.1)	
Race/Ethnicity [c]			0.210
Hispanic	481(9.2)	15 (5.4)	
Non-Hispanic White	2535(48.7)	131 (46.8)	
Non-Hispanic Black	319 (6.1)	20 (7.1)	
Asian	150 (2.9)	8 (2.9)	
American Indian/ Alaskan Native/Other	25 (0.5)	1 (0.4)	
Missing/Unknown	1694 (32.6)	105 (37.5)	
Outbreak			
Yes	341 (6.6)	9 (3.2)	0.061
No	4854 (93.3)	270 (96.4)	
Unknown	8(0.2)	1 (0.4)	
Year (3-year intervals)			
2000-2002	1221 (23.5)	108 (38.6)	<0.001
2003-2005	1248 (24.0)	83 (29.6)	
2006-2008	1384 (26.6)	47 (16.8)	
2009-2011	1351 (26.0)	42 (15.0)	

[a] Table values are n (column %).
[b] P-value is for χ^2 test.
[c] Numbers do not sum to total due to missing data

Table 2. Missing Race-Ethnicity of *Salmonella* cases by 3 year intervals, Connecticut, 2000-2011

Race/Ethnicity	2000-2002 (n, %)	2003-2005 (n, %)	2006-2008 (n, %)	2009-2011 (n, %)	Total Count (n, %)	P-value
Hispanic	107 (8.1)	102 (7.7)	144 (10.1)	143 (10.3)	496 (9.0)	<0.001
Non-Hispanic White	561 (42.2)	607 (45.6)	741 (51.8)	757 (54.3)	2666(48.6)	
Non-Hispanic Black	67 (5.0)	86 (6.5)	84 (5.9)	102 (7.3)	339 (6.2)	
Asian	37 (2.8)	37 (2.8)	31 (2.2)	53 (3.8)	158 (2.9)	
American Indian/Alaskan Native/Other	1 (0.1)	0 (0.0)	2 (0.1)	23 (1.7)	26 (0.5)	
Missing/ Unknown	556 (41.8)	499 (37.5)	429 (30.0)	315 (22.6)	1799 (32.8)	

Table 3. Incidence and relative risk of *Salmonella* by demographic characteristics, Connecticut, 2000-2011

Characteristic	# Cases (%)	Crude Average Annual Incidence* (over 12 year period)	Relative Risk	p[b]
Age Group				<0.001
0 – 4	931 (17.9)	36.2	3.42	
5– 9	431 (8.3)	15.3	1.45	
10&Up	3842 (73.8)	10.5	1.0 (reference)	
Sex (n=5,483) [c]				0.165
Male	2476 (47.6)	12.2	1.0 (reference)	
Female	2727 (52.4)	12.7	1.04	
Race/Ethnicity (n=1,393) [c,d]				0.449
Hispanic	143 (10.3)	9.9	1.01	
Non-Hispanic White	757 (54.3)	9.8	1.0 (reference)	
Non-Hispanic Black	102 (7.3)	9.5	0.97	
Asian	53 (3.8)	12.2	1.25	
American Indian/ Alaskan Native/Other	23 (1.7)	-	-	
Year (6 year intervals)				0.002
2000-2005	2469 (47.4)	12.1	1.0 (reference)	
2006-2011	2735 (52.6)	12.9	1.07	

*Per 100,000 population (of males or females)
[a] Table values are n (column %).
[b] P-value is for χ^2 test.
[c] Numbers do not sum to total due to missing data
[d] For 2009-2011 data only, not including missing/unknown (n=315; 22.6%); the American Indian/Alaskan Native/Other group was not included in the χ^2 analysis because of the small sample size

Table 4. Overall *Salmonella* Incidence categorized by poverty level, Connecticut, 2000-2011

	Neighborhood Poverty Level				p-value
	0 – 4.9%	5 – 9.9 %	10 – 19.9%	≥20%	
2000-2011					
Crude Average Annual Incidence	12.9	12.2	11.9	11.7	
Age-Adjusted Average Annual Incidence	13.2	12.4	12.1	10.6	<0.001
Age-Adjusted Incidence Rate Ratio [b]	1.0	0.94	0.92	0.81	

*Per 100,000 population
[a] The p-value is for the χ^2 for trend test.
[b] Reference Category for the incidence rate ratio is the 0-4.9% poverty level

Table 5. Overall *Salmonella* incidence rates* and ratios categorized by census tract level poverty and age, Connecticut, 2000-2011

	Neighborhood Poverty Level				p-value [b]
	0 – 4.9%	5 – 9.9 %	10 – 19.9%	≥20%	
Less than 5 Years Old					
*Total Population***	1,261,728	519,954	422,154	368,838	
Number of Cases	429	170	185	147	
*Average Annual Incidence**	34.0	32.7	43.8	39.9	<0.001
Incidence Rate Ratio	1.0	0.96	1.29	1.17	
5-9 Years Old					
*Total Population***	1,484,790	540,798	425,622	365,994	
Number of Cases	262	66	57	46	
*Average Annual Incidence**	17.6	12.2	13.4	12.6	0.009
Incidence Rate Ratio	1.0	0.69	0.76	0.71	
Ten Years Old & Up					
*Total Population***	18,884,226	7,751,682	5,615,202	4,037,430	
Number of Cases	2106	842	530	364	
*Average Annual Incidence**	11.2	10.9	9.4	9.0	0.010
Incidence Rate Ratio [a]	1.0	0.97	0.85	0.81	

*Per 100,000 population
**Average number of people in each age group per year multiplied by 12
[a] Reference Category for the incidence rate ratio is the 0-4.9% poverty level
[b] The p-value is for the χ^2 for trend test.

Table 6. Overall *Salmonella* incidence rates* and ratios categorized by census tract level poverty Connecticut, 2000-2005

	Neighborhood Poverty Level				p-value[a]
	0 – 4.9%	5 – 9.9 %	10 – 19.9%	≥20%	
Total Population**	1,878,514	709,485	460,252	356,306	
Avg. Annual Number of Cases	1420	482	322	245	
Crude Avg Annual Incidence*	12.6	11.3	11.7	11.5	
Age-adjusted Avg Annual Incidence*	12.8	11.5	11.6	11.0	0.012
Avg Adjusted Annual Incidence Rate Ratio[b]	1.00	0.90	0.91	0.87	

*Per 100,000 population
**Average number of people in each age group in 2000 using 2000 Decennial Census Data.
[a] The p-value is for the χ^2 for trend test.
[b] Reference Category for the incidence rate ratio is the 0-4.9% poverty level

Table 7. Overall *Salmonella* incidence rates* and ratios categorized by census tract level poverty and age, Connecticut, 2000-2005

	Neighborhood Poverty Level				p-value [b]
	0 – 4.9%	5 – 9.9 %	10 – 19.9%	≥20%	
Less than 5 Years Old					
*Total Population***	118,493	43,138	32,654	29,059	
Number of Cases	248	91	76	71	
*Average Annual Incidence**	34.9	35.2	38.8	40.7	0.194
Incidence Rate Ratio	1.0	1.01	1.11	1.17	
5-9 Years Old					
*Total Population***	135,059	45,780	33,434	29,871	
Number of Cases	147	28	22	18	
*Average Annual Incidence**	18.1	10.2	11.0	10.0	0.002
Incidence Rate Ratio	1.0	0.56	0.60	0.55	
Ten Years Old & Up					
*Total Population***	1,624,962	620,567	394,164	2,937,069	
Number of Cases	1025	363	224	156	
*Average Annual Incidence**	10.5	9.7	9.5	8.7	<0.001
Incidence Rate Ratio[a]	1.0	0.93	0.90	0.83	

*Per 100,000 population
**Average number of people in each age group in 2000 using 2000 Decennial Census Data.
[a] Reference Category for the incidence rate ratio is the 0-4.9% poverty level
[b] The p-value is for the χ^2 for trend test.

Table 8. Overall *Salmonella* incidence rates* and ratios categorized by census tract level poverty Connecticut, 2006-2011

	Neighborhood Poverty Level				p-value[a]
	0 – 4.9%	5 – 9.9 %	10 – 19.9%	≥20%	
Total Population**	1,726,803	759,284	616,838	439,109	
Number of Cases	1377	596	450	312	
Crude Avg Annual Incidence*	13.3	13.1	12.2	11.8	
Age-adjusted Avg Annual Incidence	13.7	13.3	12.5	11.7	0.005
Avg Adjusted Annual Incidence Rate Ratio [b]	1.00	0.98	0.92	0.86	

*Per 100,000 population

**Average number of people in each age group using ACS Data 2006-2011.

[a] The p-value is for the χ^2 for trend test.

[b] Reference Category for the incidence rate ratio is the 0-4.9% poverty level

Table 9. Overall *Salmonella* incidence rates* and ratios categorized by census tract level poverty and age, Connecticut, 2006-2011

	Neighborhood Poverty Level				p-value [b]
	0 – 4.9%[a]	5 – 9.9 %	10 – 19.9%	≥20%	
Less than 5 Years Old					
*Total Population***	91,795	43,521	37,705	32,414	
Number of Cases	181	79	109	76	
*Average Annual Incidence**	32.9	30.3	48.2	39.1	0.021
Incidence Rate Ratio	1.0	0.92	1.47	1.19	
5-9 Years Old					
Total Population [b]	112,406	44,353	37,503	31,128	
Number of Cases	115	38	35	28	
*Average Annual Incidence**	17.1	14.3	15.6	15.0	0.514
Incidence Rate Ratio	1.0	0.84	0.91	0.88	
Ten Years Old & Up					
Total Population [b]	1,522,409	671,380	541,703	375,529	
Number of Cases	1081	479	306	208	
*Average Annual Incidence**	11.8	11.9	9.4	9.2	<0.001
Incidence Rate Ratio	1.0	1.00	0.80	0.78	

*Per 100,000 population.

[a] Reference Category for the incidence rate ratio is the 0-4.9% poverty level

[b] The p-value is for the χ^2 for trend test.

**Average number of people in each age and poverty group in 2010 using 2006-2010 ACS Data

Table 10. Incidence rates* for the four most prevalent type of *Salmonella* and ratios categorized by census tract level poverty, Connecticut, 2000-2011

	Neighborhood Poverty Level				p-value
	0 – 4.9%	5 – 9.9 %	10 – 19.9%	≥20%	
Total Population**	1,802,659	734,385	538,545	397,708	
Enteriditis					
Number of Cases (12-year period)	799	273	155	123	
*Average Annual Incidence**	3.7	3.1	2.4	2.6	
Age-Adjusted Avg Annual Incidence	3.7	3.1	2.4	2.5	<0.001
Incidence Rate Ratio [a]	1.0	0.83	0.64	0.68	
Heidelberg					
Number of Cases (12-year period)	74	40	30	34	
*Average Annual Incidence**	0.3	0.5	0.5	0.7	
Age-Adjusted Avg Annual Incidence	0.4	0.5	0.5	0.7	0.010
Incidence Rate Ratio [a]	1.0	1.34	1.37	1.99	
Newport					
Number of Cases (12-year period)	204	75	50	24	
*Average Annual Incidence**	0.9	0.9	0.8	0.5	
Age-Adjusted Avg Annual Incidence	1.0	0.9	0.8	0.5	<0.001
Incidence Rate Ratio [a]	1.0	0.90	0.82	0.53	
Typhimirium					
Number of Cases (12-year period)	504	213	164	119	
*Average Annual Incidence**	2.3	2.4	2.5	2.5	
Age-Adjusted Avg Annual Incidence	2.4	2.5	2.6	2.4	0.699
Incidence Rate Ratio [a]	1.0	1.04	1.08	1.00	

*Per 100,000 population

**Average number of people in each poverty level from 2000 and 2010 Decennial Censuses.

[a] Reference Category for the incidence rate ratio is the 0-4.9% poverty level

Table 11. Incidence of *Salmonella (spp. Enteriditis, Heidelberg, Newport, and Typhimirium)** and ratios categorized by census tract level poverty Connecticut, 2000-2005

	Neighborhood Poverty Level				p-value
	0 – 4.9%	5 – 9.9 %	10 – 19.9%	≥20%	
Total Population**	1,878,514	709,485	460,252	356,306	
Enteriditis					
Number of Cases (6-year period)	365	95	57	46	
*Average Annual Incidence**	3.2	2.2	2.1	2.2	
Age-Adjusted Avg Annual Incidence	3.3	2.3	2.1	2.1	<0.001
Incidence Rate Ratio [a]	1.0	0.7	0.6	0.6	
Heidelberg					
Number of Cases (6-year period)	49	25	15	25	
*Average Annual Incidence**	0.4	0.6	0.5	0.5	
Age-Adjusted Avg Annual Incidence	0.4	0.6	0.5	1.1	<0.001
Incidence Rate Ratio [a]	1.0	1.4	1.2	2.5	
Newport					
Number of Cases (6-year period)	113	41	23	12	
*Average Annual Incidence**	1.0	1.0	0.8	0.6	
Age-Adjusted Avg Annual Incidence	1.0	1.0	0.8	0.6	0.047
Incidence Rate Ratio [a]	1.0	1.0	0.8	0.6	
Typhimirium					
Number of Cases (6-year period)	292	99	83	58	
*Average Annual Incidence**	2.6	2.3	3.0	2.7	
Age-Adjusted Avg Annual Incidence	2.6	2.4	3.0	2.6	0.591
Incidence Rate Ratio [a]	1.0	0.9	1.1	1.0	

*Per 100,000 population

**Average number of people in each age group in 2000 using 2000 Decennial Census Data.

[a] Reference Category for the incidence rate ratio is the 0-4.9% poverty level

Table 12. Incidence of *Salmonella (spp. Enteriditis, Heidelberg, Newport, and Typhimirium)** and ratios categorized by census tract level poverty Connecticut, 2006-2011

	Neighborhood Poverty Level				p-value
	0 – 4.9%	5 – 9.9 %	10 – 19.9%	≥20%	
Total Population**	1,726,803	759,284	616,838	439,109	
Enteriditis					
Number of Cases (6-year period)	434	178	98	77	
*Average Annual Incidence**	4.2	3.9	2.7	2.9	
Age-Adjusted Avg Annual Incidence	4.2	3.9	2.7	2.9	<0.001
Incidence Rate Ratio [a]	1.0	0.9	0.6	0.7	
Heidelberg					
Number of Cases (6-year period)	25	15	15	9	
*Average Annual Incidence**	0.2	0.3	0.4	0.3	
Age-Adjusted Avg Annual Incidence	0.3	0.3	0.4	0.3	0.676
Incidence Rate Ratio [a]	1.0	1.4	1.7	1.4	
Newport					
Number of Cases (6-year period)	91	34	27	12	
*Average Annual Incidence**	0.9	0.8	0.7	0.5	
Age-Adjusted Avg Annual Incidence	0.9	0.8	0.7	0.5	0.029
Incidence Rate Ratio [a]	1.0	0.9	0.8	0.5	
Typhimirium					
Number of Cases (6-year period)	212	114	81	61	
*Average Annual Incidence**	2.1	2.5	2.2	2.3	
Age-Adjusted Avg Annual Incidence	2.2	2.6	2.3	2.3	0.752
Incidence Rate Ratio [a]	1.0	1.2	1.1	1.1	

*Per 100,000 population

**Average number of people in each age group in 2000 using 2010 ACS Data.

[a] Reference Category for the incidence rate ratio is the 0-4.9% poverty level

Figure 1. Average Annual Incidence of *Salmonella* overall in each age group per 100,000 population; Connecticut 2000-2011

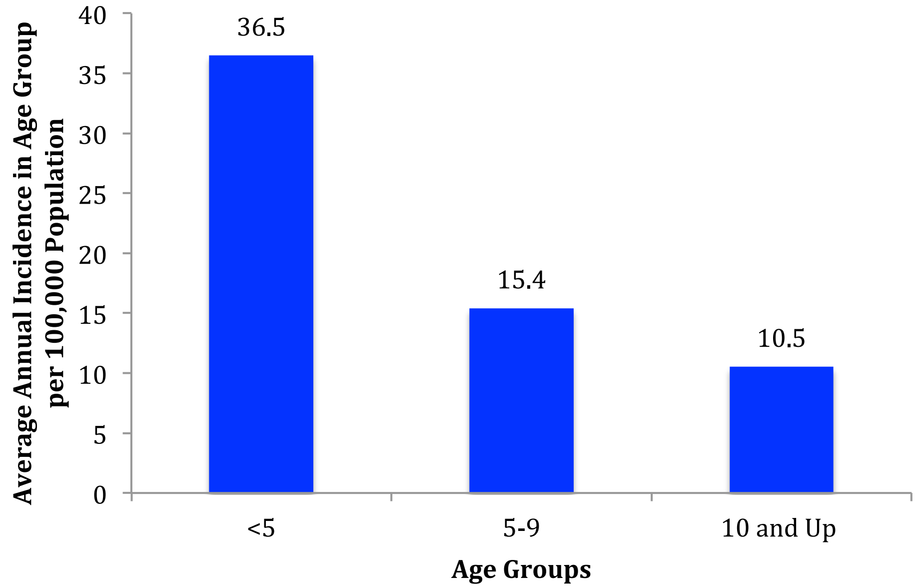


Figure 2. Age-adjusted *Salmonella* incidence per 100,000 population

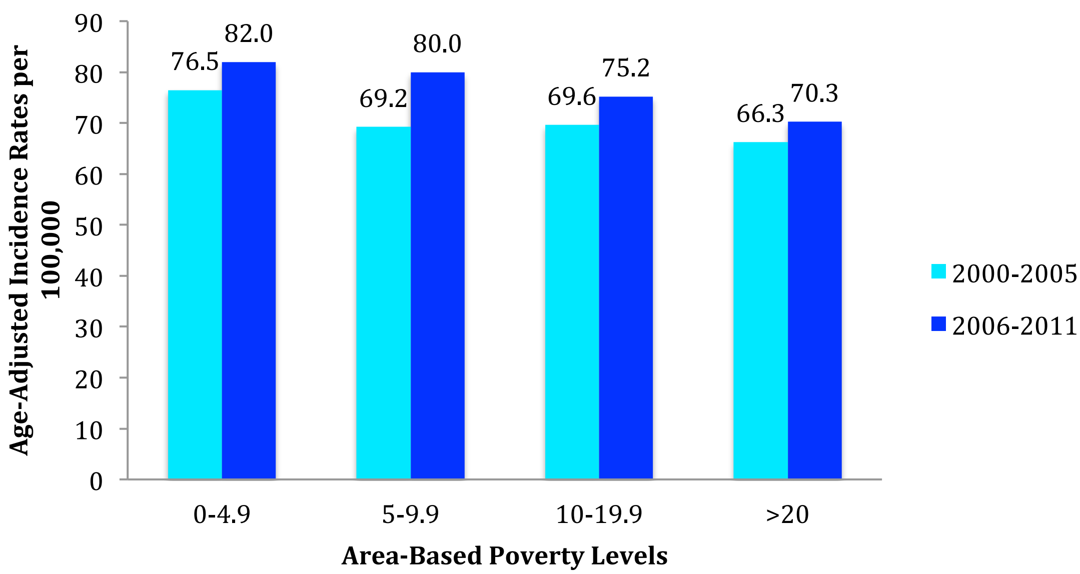


Figure 3. Association* of *Salmonella* Incidence With Neighborhood Poverty Level, Connecticut, 2000-2011

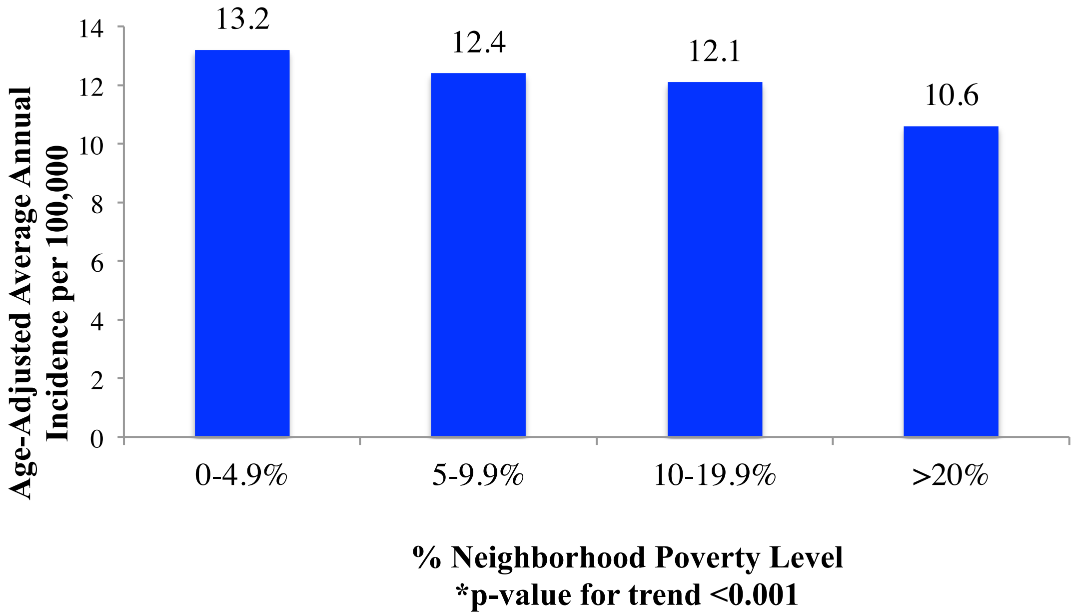
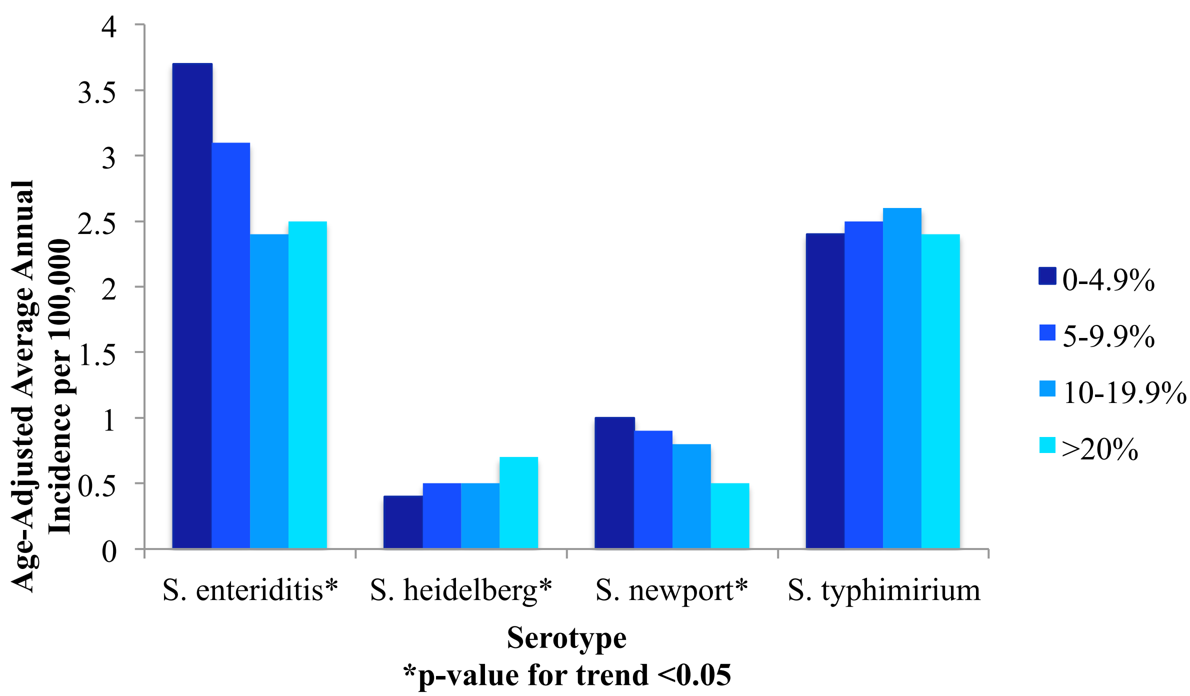


Figure 4. Association* of Salmonella Incidence With Neighborhood Poverty Level for the Four Most Common Serotypes, Connecticut, 2000-2011



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