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The SEEDs of Two Gastrointestinal Diseases: SocioEconomic, Environmental, and Demographic Factors Related to Cryptosporidiosis and Giardiasis in Massachusetts

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Abstract

Objectives—We assessed associations between community-level socioeconomic, demographic, and environmental characteristics, and the presence of two potentially waterborne infectious diseases, cryptosporidiosis and giardiasis, as reported to the Massachusetts Department of Public Health.

Methods—We created a series of maps showing the spatial distribution of cryptosporidiosis and giardiasis in Massachusetts (1993–2002) overall and by age, using logistic regression to analyze associations between community-level characteristics and the presence of at least one reported case of each disease. This analysis was repeated for communities with predominantly private water supplies.

Results—After adjusting for population size, higher population density and larger average household sizes were associated with increased odds of reported cases of cryptosporidiosis. Giardiasis was also associated with high population density, but was not associated with household size. In the elderly, income was positively associated with the presence of giardiasis.

Discussion—These findings suggest that greater population density and larger household sizes may increase the likelihood of protozoan gastrointestinal infection. The results emphasize the necessity to account for distal factors, such as demographic characteristics, that may ultimately play a role in the transmission or reporting of disease.

Keywords

Cryptosporidiosis; giardiasis; socioeconomics; demographics; water source

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Introduction

Cryptosporidiosis and giardiasis are widely recognized as potentially waterborne infections (Steiner et al., 1997). Over the period from 1999 to 2002, there were nearly 13,000 laboratory-confirmed cases of cryptosporidiosis (Hlvasa and Watson I, 2005) and over 80,000 giardiasis cases in the United States (Hlvasa and Watson II, 2005). Cryptosporidiosis is responsible for over 1,000 annual hospitalizations, while giardiasis induces over 5,000 annual hospitalizations (Mead et al., 1999; MMWR, 2007). These diseases, in rare instances, can also cause death (Mead et al., 1999), especially among the frailest populations. Despite efforts to improve sanitation and public health infrastructure, these gastrointestinal infections still pose a significant public health threat (Marshall et al., 1997).

The biology of these parasites and biological mechanisms of infection are well documented (O'Donoghue, 1995; Adam, 2001; Griffiths, 1998). Recent research has shown that incidence rates of gastrointestinal infections may be related to drinking water source (Furtado et al., 1998). Factors that may contribute to contamination of drinking water sources with pathogens include farm runoff and heavy rainfall (Sischo et al., 2000; Kistermann et al., 2002). Incidence of gastrointestinal infections vary spatially and temporally (Chui et al., 2006). CDC data suggest that the reported rates of cryptosporidiosis and giardiasis vary widely by state and by season (Steiner et al., 1997; Hlvasa et al. I, 2005; Dietz and Roberts, 2000; Lee et al., 2002).

Spatial and temporal variations in reported rates of laboratory-confirmed cryptosporidiosis and giardiasis cases in Massachusetts have also been demonstrated by Naumova et al. There was also an association between drinking water source and incidence rates of these infections. Some variability may be attributed to variability in reporting practices. As a logical extension of the Naumova et al. paper, we hypothesize that certain town-level socioeconomic, demographic, and environmental factors may affect the reported rates of these infections. This observed spatial variability in incidence rates may be due to the real underlying variability in disease incidence, differences in reporting, or both. Differences in reporting of disease may be associated with better access to health care or different rates of testing for these parasites based on certain characteristics. For example, in general, the wealthy tend to utilize health care services more than the poor (Lasser et al., 2006).

Cryptosporidiosis and giardiasis are reportable diseases in the United States and in Massachusetts. However, current state surveillance data do not provide specific socioeconomic and demographic information on individuals who contracted these reportable diseases. We utilized town/city-level socioeconomic, demographic, and environmental proxies in place of individual-level, case-specific data. This approach has been widely used and publicized in many public health studies and can provide insight as to the environmental factors that may act as distal causes of disease. Examples include studies of social epidemiology and overall health status (Xu, 2006), chronic diseases (Diez-Rouz et al., 1997), cancer (Sanderson et al., 2006), and infectious diseases (Aral et al., 2005; Koopman and Longini, 1994). In one recent study, negative health outcomes across the lifespan were more likely to occur in areas of high socioeconomic inequality than in areas where wealth was distributed more uniformly (Krieger et al., 2005). For example, AIDS incidence was found to be related to economic deprivation in a study of Massachusetts block groups (Zierler et al., 2000).

Methods

We applied an ecological approach to investigate the basic relationships between socioeconomic, demographic, and environmental indicators at the town/city level and town-specific information on cryptosporidiosis and giardiasis. We used the Massachusetts reportable diseases surveillance data for the period 1992 to 2002 and also derived a set of socioeconomic,

demographic, and environmental proxies from the 1990 and 2000 US Census databases at the town/city level. As of June 2007, there were 351 cities and towns in Massachusetts. According to the 2000 US Census, their population sizes ranged from 55 to nearly 600,000 people. We modeled the outcomes as the presence or absence of cryptosporidiosis and giardiasis cases in each city or town during 1992 to 2002. We examined the potential associations between several key explanatory variables and these binary outcome variables using logistic regression models, controlling for population size, since the odds of observing at least one case is directly proportional to population size. To supplement these analyses, we produced a set of maps delineating disease rates and explanatory variables by city and town in order to show spatial patterns in the diseases and in sociodemographic characteristics.

We abstracted all laboratory-confirmed cases reported to the Massachusetts Department of Public Health (MDPH). Average annual incidence rates of cryptosporidiosis were estimated using 9.6 years of data (January 1, 1993 to July 31, 2002), and average annual incidence rates of giardiasis rates were estimated using 10.6 years of data (January 1, 1992 to July 31, 2002). We abstracted data on the total population of each town and for each of the three age groups, 0–17 years, 18–64 years, and 65 years and older, from the 1990 and 2000 US Census databases. The average population sizes used in this analysis were estimated by linear interpolation to the midpoint of each time interval. We calculated total and age-specific incidence rates of both infections for each city and town and used these rates to create state maps. We also created sets of binary variables to indicate whether or not each city or town reported at least one case of cryptosporidiosis or giardiasis during the corresponding time period in the general population and each age group.

Other explanatory variables were based on information extracted from the 2000 US Census of Population and Housing. The final data set used in the analysis included the following explanatory variables: population size, population density, median per capita income, average number of people per household, percent of households in each town with a private water supply, number and percent of households with a septic tank as the primary means of sewerage, the total dependency ratio (the ratio of the population less than 18 years of age plus the population age 65 and above to the population age 18 to 64 years of age), and the HIV/AIDS prevalence in 2002, which was extracted from the Massachusetts Community Health Information Profile (MassCHIP). The Department of Environmental Protection provided a list of water boil advisories which were issued in Massachusetts for the years 1992–2002; we controlled for these in the analysis by including an indicator of whether a water boil advisory was issued for each town and included this variable in the adjusted models.

From the Census data described above, we derived a binary variable that indicated what type of water supply- private or public- the majority of households in each town use. We also created a variable to reflect the density of septic tanks in each town that was calculated as the number of septic tanks per square mile. Using MDPH data, we obtained the prevalence of HIV infection in each city and town, and used that to create a binary variable indicating whether each city and town had a non-zero HIV infection prevalence. This was not a primary exposure of interest, but was included in the model because of the increased likelihood of testing and reporting of cryptosporidiosis given HIV infection (Rotterdam and Tsang, 1994).

Statistical Analysis

Using ArcMap 8.2 GIS software, we produced a series of maps, which reflect geographical distributions of cryptosporidiosis and giardiasis in Massachusetts. We also mapped four key explanatory variables, septic tank density, median per capita income, population density, and type of water supply.

All statistical analysis was performed using SAS version 9.1. Associations among the predictor variables were assessed using Spearman correlations and chi-square tests where appropriate. The associations between the exposure variables and the presence of cases of cryptosporidiosis or giardiasis were examined using unconditional logistic regression models. For this analysis, the explanatory variables that exhibited a strong right skewness, such as average per capita income, and population density, were natural log-transformed. For each outcome, we selected the “best model” using likelihood ratio tests and data for all ages, and used those explanatory variables for analyses for each age group. We then performed a sub-analysis just for cities and towns with a majority of households receiving a private water supply, this time including the septic tank density variable in the model. The results of these analyses are sets of odds ratios that indicate the relative change in odds of a reported case of either cryptosporidiosis or giardiasis, given a one-unit increase in the exposure variable.

Results

In 2002, the reported incidence of cryptosporidiosis in Massachusetts (1.2 per 100,000 person-years) was comparable to the national cryptosporidiosis incidence (1.0 per 100,000 person-years) (Hlvasa and Watson I, 2005). For giardiasis, the 2002 reported rate in Massachusetts (14.6 per 100,000 person-years) was nearly twice as high as the overall national rate (7.4 per 100,000) (Hlvasa and Watson II, 2005).

Visual Analysis of Maps

The reported rates of cryptosporidiosis (Fig. 1) and giardiasis (Fig. 2) in Massachusetts were highest in the area between Boston and Worcester. These patterns were fairly consistent across the age categories. Giardiasis rates in children tended to be higher than giardiasis rates for non-elderly adults and the elderly. On the other hand, there were relatively few cities and towns that reported any cases of cryptosporidiosis in children.

Figure 3 shows the spatial distribution of four key sociodemographic and environmental factors considered in the analysis. Water supply type was predominantly public in much of eastern Massachusetts and predominantly private in most of western Massachusetts. Visual examination of disease incidence maps suggests that reported rates of both cryptosporidiosis and giardiasis tend to be higher in communities with a predominantly public water supply compared to communities with a predominantly private water supply. Septic tank density is higher in western Massachusetts and lower in the Boston metropolitan area, as well as in areas surrounding Worcester and Springfield, the second- and third-most populous cities in the state. In eastern Massachusetts, the average income was highest in the cities and towns approximately 10 to 40 miles west of Boston. This same area also had some of the highest incidence rates of both diseases. Population density is the highest in the Boston metropolitan area in eastern Massachusetts.

All Cities and Towns

Descriptive statistics for each of the explanatory variables used in the final logistic regression models and the results of trend tests are shown in Table 1. The average annual town rate of cryptosporidiosis was 0.78 cases per 100,000, and the average annual town rate of giardiasis was 11.7 cases per 100,000. There were significant positive associations between reported cryptosporidiosis rates and several explanatory variables, including population density, population size, household size, and median per capita income. Reported cryptosporidiosis rates decreased significantly with increasing septic tank density. Although not evident in the overall population, the reported giardiasis rates in both children and the elderly were also positively associated with the total dependency ratio. Such a relationship was not significant

between the dependency ratio and the giardiasis rates. There was no significant relationship between the presence of a water boil advisory and giardiasis.

Septic tank density was strongly negatively correlated with the population size ($\rho = -0.617$, $p < 0.0001$) and population density ($\rho = -0.806$, $p < 0.001$). Septic tank density was also weakly correlated with the total dependency ratio ($\rho = -0.147$, $p = 0.006$). This suggests that locations with mostly public water supplies tend to have more children and/or elderly than places with a high concentration of private water supplies. Median per capita income was weakly but positively associated with household size ($\rho = 0.188$, $p < 0.001$) and negatively associated with the HIV infection rate ($\rho = -0.320$, $p < 0.001$).

The results of the logistic regression analysis for all cities and towns in Massachusetts are shown in Table 2. After adjusting for population size, boil water advisories and other covariates, the odds of reporting at least one case of cryptosporidiosis in the general population were higher in cities and towns with higher population densities. A doubling in population density is significantly associated with having at least one case of cryptosporidiosis, with an odds ratio of 1.47 (95% CI 1.15–1.86). This relationship was also significant in adults and the elderly, but was not significant in children. Average household size was significantly associated with the odds of observing a reported case of cryptosporidiosis overall (OR = 6.25, 1.87–20.89), for adults (OR = 3.64, 1.10–12.08) and for the elderly (OR = 10.52, 2.51–44.11). Cities and towns reporting at least one HIV infection were more likely than those not reporting HIV infection to report at least one case of cryptosporidiosis in non-elderly adults (OR = 3.22, 1.57–6.61).

For giardiasis, there were only two sociodemographic variables significantly related to reporting at least one case of disease. Similar to cryptosporidiosis, the odds of a city or town reporting at least one case of disease were higher in places of high population density. This relationship was evident for the population as a whole (OR = 1.93, 1.12–3.42) per doubling in population density, for children (OR = 1.58, 1.10–2.26), and for the elderly (OR = 1.62, 1.24–2.11). For the elderly, the odds of a city or town reporting at least one case of giardiasis was higher where the median per capita income was higher. A doubling of income was associated with an odds ratio of having a reported case of giardiasis of 2.77 (95% CI=1.25–6.13).

Cities and Towns with Predominantly Private Water Supplies

This model could not be applied to cryptosporidiosis in children because no city or town with a majority of houses receiving private water reported a case of cryptosporidiosis in children less than 18 years of age. Population density was the only predictor that was significantly associated with the presence of at least one reported case of cryptosporidiosis or giardiasis in cities and towns with mostly private water supplies. Doubling of population density was associated with a 7.32-fold increase in the odds of the presence of at least one cryptosporidiosis case in the general population (95% CI 1.09–47.80). For giardiasis, doubling the population density was positively associated with the presence of at least one reported case in the general population (OR = 5.57, 1.96–15.82), in children (OR = 8.69, 2.26–33.42), and in non-elderly adults (OR = 3.36, 1.15–9.79); this association was not significant in the elderly (OR = 5.68, 0.70–46.19). Septic tank density was not significantly associated with reported cases of giardiasis or cryptosporidiosis in the full models. Likewise, household size, total dependency ratio, and reported HIV infection cases were not significantly associated with disease presence when adjusting for other variables in the models.

Discussion

In Massachusetts, distal measures thought to influence person-to-person transmission of gastrointestinal infection were found to be associated with cryptosporidiosis in particular. After

controlling for population size, population density remained significantly associated with the presence of a reported case of cryptosporidiosis or giardiasis. This suggests that individuals living in densely populated communities may have a greater propensity to contract these infections than individuals living in more sparsely populated communities with similar population size. This observation is consistent with past research in emerging infectious diseases (Morse, 2004). This association may be through person-to-person spread (Guerrant, 1997), which is supported by the relationship between household size and reported disease cases, another measure of crowdedness. It is also possible that population density indicates some property of the physical infrastructure of a city or town, and may be related to the built environment and the consequences thereof (Northridge et al., 2003). Another possibility is acquired immunity from past contamination of public or private drinking water sources (Casemore, 2006), which is supported by the fact that in towns with a majority of households having a private water supply, there were no reported cases of cryptosporidiosis in children. Income was associated with cryptosporidiosis and giardiasis on its own, which may be counterintuitive because these diseases are often found in poorer, rural areas (Prado et al., 2006). However, income was not found to be associated with either disease in the full models, except for giardiasis in the elderly. The observed incidence of giardiasis is probably higher than that of cryptosporidiosis because: 1) giardiasis is simply more common than cryptosporidiosis, which is consistent with national disease estimates (Yoder and Beach I, 2007, Yoder and Beach II, 2007), 2) it is more easily transmitted, 3) the duration of infectivity is longer, and 4) it is more likely to be identified because testing is more readily available and cheaper.

This study is among the first to examine household size as an independent predictor of gastrointestinal infection. In all Massachusetts' cities and towns, average household size was also related to the presence of at least one case of cryptosporidiosis in the overall population, adults and the elderly. No association between household size and giardiasis was present, however, but this may have been due to loss of ability to detect strength of association due to outcome variable being dichotomous vs. continuous. These positive findings are consistent with the small body of literature suggesting a link between household size and cryptosporidiosis (Newman et al., 1994), but not for giardiasis. These findings suggest that reported disease is associated with crowdedness on the town and household levels, and not necessarily with water source. To that end, while *Giardia* and *Cryptosporidium* may generally be considered waterborne pathogens, they are also easily transmitted in household, day care, and other settings where there is close contact and potential breaches in hygiene which probably account for more of the transmission of infection in Massachusetts.

This study is ecological in nature and these results should be interpreted with caution. For example, this type of study does not allow for the examination of whether the people who had cryptosporidiosis or giardiasis use water from a private or public source. The aim of this study is not to draw inferences on the individual level; rather, it is intended as a hypothesis-generating study to identify potential area-level conditions that relate to the incidence of cryptosporidiosis and giardiasis.

Another limitation of this study is that the data contain only those cases that were subject to diagnostic testing, diagnosed, and effectively reported to the Massachusetts Department of Public Health. Cases of cryptosporidiosis and giardiasis may not be reported to the state for a variety of reasons. Even if people who experience severe diarrhea and other symptoms seek medical attention, their stool may not be tested for cryptosporidia or giardia, and they may not receive a specific diagnosis to be reported (Dietz and Roberts, 2000). These factors contribute to underreporting of these diseases. This underreporting may tend to occur more frequently in areas with certain characteristics that may limit care seeking, such as poverty or residence in an area where access to a medical facility is difficult (Chan et al., 2006). If the rate of reporting

is correlated with any of the explanatory variables used in this analysis, the observed associations may in part or even entirely be due to reporting bias. Further research should focus on collecting data that may characterize the rates of underreporting of these diseases in different locations, such as rural areas. Also, underreporting of cryptosporidiosis may be greater than underreporting of giardiasis because *Giardia lamblia* is easier to detect in feces through standard ova and parasite examination tests (Garcia, 1998), as well as through direct testing utilizing more generally available test methods that do not require the same degree of specialized expertise (e.g. enzyme immunoassay).

As with any analysis where the outcome was transformed from a continuous or semi-continuous to a binary variable, we did not have the ability to detect relationships between these predictors and the level of cryptosporidiosis or giardiasis, only the presence or absence of these reported diseases. It is possible, therefore, that additional associations may exist between these socioeconomic and demographic predictors and the level of disease in each town, and may be evident in future research. Additionally, many of the predictor variables are strongly associated with each other. In particular, septic tank density and population density were strongly and negatively associated with each other. In order to warrant the construction of public infrastructure such as municipal water supplies and sewerage systems, there must be some impetus, such as larger numbers of people living closely to one another. Therefore, we would expect septic tank density and prevalence of private water supplies to be higher in areas of low population density, since there is little practical reason to provide public water or sewage in these areas. Future research can address these limitations to elucidate these relationships and explore some potential pathways through which these relationships occur. As research into the socioeconomic differences in infection moves forward, it should focus on exploring and explaining socioeconomic and demographic characteristics on the individual and area levels so as to better understand the distal, yet important factors necessary for infection.

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Figure 1.

Figure 1A. Annual average cryptosporidiosis (1993–2002) rates for all ages.

Figure 1B. Annual average cryptosporidiosis (1993–2002) rates for children (age 0–17).

Figure 1C. Annual average cryptosporidiosis (1993–2002) rates for non-elderly adults (age 18–64).

Figure 1D. Annual average cryptosporidiosis (1993–2002) rates for the elderly (age 65+).

Figure 2.

Figure 2A. Annual average giardiasis (1993–2002) rates for all ages.

Figure 2B. Annual average giardiasis (1993–2002) rates for children (age 0–17).

Figure 2C. Annual average giardiasis (1993–2002) rates for non-elderly adults (age 18–64).

Figure 2D. Annual average giardiasis (1993–2002) rates for the elderly (age 65+).

Figure 3.

Figure 3A. Predominant water supply type (based on majority of households)

Figure 3B. Septic tank density

Figure 3C. Population density

Figure 3D. Per capita income (1999)

Table 1

Summary statistics, mean, standard deviation and indication of trend significance, for selected explanatory variables by disease percentile (N = 351).

	Overall Mean (SD)	Cryptosporidiosis			Giardiasis			>75–100th		
		Trend	0–60th	>60–80th	>80–100th	Trend	0–25th		>25–50th	>50–75th
<i>Demographic</i>										
Population Density (population/sq. mi.)	1264 (2363)	***	751 (1649)	2410 (2648)	1666 (3278)	***	389 (544)	1155 (1736)	1655 (2411)	1857 (3477)
Population Size/1000	18.1 (37.3)	***	11.6 (18.1)	29.6 (21.9)	26.3 (72.6)	***	8.6 (10.9)	18.1 (23.0)	19.1 (20.8)	26.6 (66.1)
Dependency ratio	62.0 (9.2)	ns	61.6 (9.3)	62.9 (8.8)	62.3 (9.3)	ns	61.3 (9.4)	62.8 (9.2)	62.1 (8.1)	61.8 (10.0)
Average Household Size	2.59 (0.24)	**	2.56 (0.24)	2.60 (0.22)	2.65 (0.25)	**	2.51 (0.24)	2.62 (0.23)	2.58 (0.22)	2.63 (0.26)
HIV prevalence (per million)	190 (725)	ns	167 (427)	138 (97)	299 (1354)	ns	225 (689)	114 (92)	148 (139)	284 (1245)
<i>Socioeconomic</i>										
Median PC Income (000 \$)	27.2 (8.7)	***	26.1 (8.5)	27.6 (8.0)	30.4 (9.1)	***	24.5 (5.9)	24.7 (4.9)	26.9 (6.9)	32.8 (12.3)
<i>Environmental</i>										
Water Boil Advisory (yes/no), N (%)	28 (8.0)	ns	18 (8.5)	4 (5.7)	6 (8.6)	ns	8 (9.1)	6 (6.9)	8 (9.1)	6 (6.8)
Septic tank density (tanks/sq. mi.)	0.117 (0.096)	***	7.43 (6.98)	3.90 (5.10)	4.41 (4.30)	***	10.03 (7.92)	5.63 (6.12)	4.26 (4.62)	4.57 (4.54)

ns = p > 0.05

*

p < 0.05

p < 0.01

p < 0.001

Table 2

Odds ratios and 95% confidence intervals for selected covariates in logistic regression among all cities and towns in Massachusetts and those with predominantly private water supplies.

Cohen et al.

All cities and towns (N = 351)		Cryptosporidiosis				Giardiasis			
		Overall	Children	Adults	Elderly	Overall	Children	Adults	Elderly
Log Pop Density	Unadjusted	2.56 (2.05, 3.20)***	1.74 (1.24, 2.46)**	2.27 (1.83, 2.81)***	2.45 (1.93, 3.11)***	5.22 (3.37, 8.09)***	4.33 (3.13, 6.00)***	5.97 (3.87, 9.21)***	3.26 (2.49, 4.25)***
	Adjusted	1.74 (1.23, 2.45)**	1.54 (0.92, 2.60)	1.67 (1.20, 2.33)**	1.76 (1.19, 2.59)**	2.59 (1.18, 5.89)*	1.93 (1.15, 3.24)*	1.95 (0.92, 4.10)	2.00 (1.36, 2.94)***
Dependency ratio	Unadjusted	1.02 (0.99, 1.04)	1.03 (0.98, 1.08)	1.00 (0.98, 1.02)	1.01 (0.99, 1.04)	1.07 (1.03, 1.11)**	1.06 (1.03, 1.10)***	1.07 (1.03, 1.10)***	1.04 (1.02, 1.07)**
	Adjusted	1.00 (0.97, 1.03)	1.04 (0.99, 1.09)	0.98 (0.95, 1.01)	1.00 (0.97, 1.04)	1.00 (0.94, 1.07)	1.02 (0.97, 1.07)	0.99 (0.93, 1.05)	1.03 (1.00, 1.07)
Household Size	Unadjusted	2.61 (1.06, 6.41)*	1.23 (0.18, 8.53)	1.60 (0.63, 4.06)	2.78 (0.99, 7.83)	4.42 (1.18, 16.56)*	4.25 (1.48, 12.23)**	3.89 (1.20, 12.69)*	0.69 (0.29, 1.68)
	Adjusted	6.25 (1.87, 20.89)**	1.81 (0.21, 15.59)	3.64 (1.10, 12.09)*	10.52 (2.51, 44.11)**	0.76 (0.10, 5.94)	2.81 (0.61, 13.01)	0.82 (0.12, 5.41)	0.74 (0.22, 2.50)
Reported HIV	Unadjusted	5.81 (3.57, 9.44)***	2.15 (0.76, 6.09)	7.14 (4.06, 12.55)***	4.81 (2.66, 8.69)***	23.52 (7.10, 77.86)***	12.59 (6.46, 24.53)***	26.54 (9.33, 75.50)***	7.62 (4.54, 12.81)***
	Adjusted	1.73 (0.88, 3.40)	0.92 (0.23, 3.69)	3.22 (1.57, 6.61)**	1.29 (0.57, 2.92)	0.61 (0.10, 3.82)	1.07 (0.38, 3.06)	0.64 (0.13, 3.23)	1.61 (0.77, 3.33)
Log Per Capita Income	Unadjusted	2.36 (1.10, 5.08)*	1.84 (0.38, 8.82)	2.05 (0.93, 4.52)	2.31 (1.00, 5.36)*	4.06 (1.10, 15.00)*	6.30 (2.18, 18.19)**	3.57 (1.14, 11.20)*	3.28 (1.50, 7.19)**
	Adjusted	1.69 (0.59, 4.86)	1.75 (0.38, 8.15)	1.89 (0.67, 5.30)	2.17 (0.72, 6.54)	0.80 (0.11, 6.02)	5.24 (0.97, 28.22)	0.80 (0.12, 5.36)	4.34 (1.38, 13.67)*
Majority private water (N = 98)									
Log Pop Density	Unadjusted	2.42 (1.34, 4.38)**	a	1.91 (1.02, 3.58)*	2.74 (1.15, 6.56)*	3.39 (1.96, 5.78)***	3.87 (2.25, 6.67)***	3.89 (2.25, 6.73)***	2.38 (1.13, 5.00)*
	Adjusted	17.32 (1.13, 265)*		17.03 (0.89, 325)	3.96 (0.12, 134)	11.90 (2.64, 53.69)**	22.63 (3.25, 158)**	5.75 (1.23, 26.86)*	12.26 (0.60, 252)
Dependency ratio	Unadjusted	1.03 (0.96, 1.10)		1.00 (0.91, 1.09)	1.07 (0.98, 1.17)	1.02 (0.97, 1.09)	1.03 (0.97, 1.09)	1.03 (0.98, 1.10)	1.07 (0.98, 1.16)
	Adjusted	0.97 (0.88, 1.08)		0.92 (0.82, 1.04)	1.06 (0.93, 1.21)	0.97 (0.89, 1.05)	0.93 (0.85, 1.02)	0.97 (0.89, 1.05)	1.02 (0.91, 1.14)
Household Size	Unadjusted	6.98 (0.70, 70.00)		2.27 (0.18, 28.05)	85.4 (1.85, 3949)*	17.28 (2.60, 114.8)**	15.67 (2.49, 96.68)**	44.82 (5.96, 336.9)***	0.79 (0.06, 11.17)
	Adjusted	0.61 (0.02, 20.05)		0.18 (0.003, 9.16)	17.40 (0.12, 2567)	1.45 (0.07, 28.59)	0.54 (0.03, 10.16)	4.80 (0.27, 84.05)	0.02 (0.001, 1.74)
Reported HIV	Unadjusted	3.47 (1.07, 11.30)*		4.41 (1.20, 16.16)*	3.26 (0.70, 15.20)	3.05 (0.80, 11.46)	4.73 (1.42, 15.78)*	3.68 (1.11, 12.24)*	3.85 (0.95, 15.53)
	Adjusted	0.34 (0.04, 2.55)		0.77 (0.11, 5.71)	0.53 (0.04, 7.76)	0.59 (0.05, 7.74)	1.01 (0.10, 9.99)	0.63 (0.06, 6.10)	0.77 (0.05, 10.87)
Log Per Capita Income	Unadjusted	0.76 (0.11, 5.23)		0.44 (0.04, 4.80)	1.46 (0.12, 17.47)	2.35 (0.48, 11.48)	5.85 (1.19, 28.86)*	3.14 (0.89, 14.30)	4.97 (0.84, 38.54)
	Adjusted	0.16 (0.01, 2.28)		0.11 (0.002, 4.59)	0.17 (0.01, 4.27)	1.20 (0.11, 13.27)	5.35 (0.49, 58.03)	1.79 (0.18, 17.86)	9.89 (0.49, 199)
Septic Tank Density	Unadjusted	0.99 (0.92, 1.07)		1.01 (0.94, 1.10)	0.91 (0.78, 1.06)	0.96 (0.91, 1.02)	0.95 (0.89, 1.01)	0.94 (0.89, 1.00)*	1.00 (0.92, 1.10)
	Adjusted	1.05 (0.95, 1.16)		1.05 (0.94, 1.17)	0.99 (0.80, 1.22)	1.02 (0.94, 1.10)	1.00 (0.92, 1.08)	1.01 (0.94, 1.09)	1.03 (0.90, 1.17)

* p < 0.05

p < 0.01

p < 0.001

Adjusted for presence of water advisory and population size

^aNo cases of cryptosporidiosis in children were reported in towns with predominantly public water supplies.