A Descriptive Analysis of Notifiable Gastrointestinal Illness in the Northwest Territories, Canada, 1991-2008

Journal:	*BMJ Open*
Manuscript ID:	bmjopen-2011-000732
Article Type:	Research
Date Submitted by the Author:	10-Jan-2012

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Primary Subject Heading:	Epidemiology
Secondary Subject Heading:	Infectious diseases
Keywords:	Gastrointestinal infections < GASTROENTEROLOGY, Epidemiology < INFECTIOUS DISEASES, Quality in health care < HEALTH SERVICES ADMINISTRATION & MANAGEMENT, Public health < INFECTIOUS DISEASES

Title:

A Descriptive Analysis of Notifiable Gastrointestinal Illness in the Northwest Territories, Canada, 1991-2008

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Medical Subject Headings-Key Words:

Gastrointestinal illness, Foodborne Diseases, Minority Health, Population Surveillance

Word count: 2,909

ABSTRACT

Objectives: To describe the demographic, temporal and spatial distribution of reported enteric, food- and waterborne diseases in the Northwest Territories (NWT) from January 1991 through December 2008.

Design: Descriptive analysis of 708 reported cases of enteric, food- and waterborne diseases extracted from the Northwest Territories Communicable Disease Registry (NWT CDR).

Setting: Primary, secondary and tertiary health care centres across all 33 communities of the Northwest Territories.

Population: NWT residents of all ages with confirmed enteric, food- and waterborne diseases reported to the NWT CDR from January 1991 through December 2008.

Main Outcome Measure: Laborartory-confirmed enteric, food- and waterborne diseases.

Results: Campylobacteriosis, giardiasis and salmonellosis were the most commonly identified types of enteric illness in the territory. There was an increased risk of infection from the late summer to autumn ($p<0.01$). Higher rates of notifiable gastrointestinal illness (all 15 diseases/infections) were found in the 0 to 9 years age group and in males ($p<0.01$). Similarly, rates of giardiasis were higher in the 0 to 9 years age group and in males ($p<0.02$). A disproportionate burden of salmonellosis was found in people 60 years and older and in females ($p<0.02$). Although not significant, the incidence of campylobacteriosis was greater in the 20 to 29 years age group and in males ($p<0.07$). The health authority with the highest incidence of NGI was Yellowknife ($p<0.01$) while for campylobacteriosis and salmonellosis it was Tlicho ($p<0.01$) and for giardiasis, Sahtu region ($p<0.01$). Overall, disease rates were higher in urban areas ($p<0.01$). Contaminated eggs, poultry and untreated water were believed by health practitioners to be important sources of infection in cases of salmonellosis, campylobacteriosis and giardiasis, respectively.

Conclusion: The general patterns of these findings suggest that environmental and behavioral risk factors played key roles in infection. Further research into potential individual and community-level risk factors is warranted.

ARTICLE SUMMARY

Article Focus

- To date, there is very little baseline data on notifiable gastrointestinal illness (NGI) diseases in the Northwest Territories, where Aboriginal people constitute a majority of the population. The demographic, socio-cultural, and health conditions of northern Aboriginal people are markedly different from those of other Canadian populations.
- There is a clear need to identify demographic, geographical and temporal distributions and risk factors NGI in order to guide disease control strategie**s.**

Key Messages

- The annual average rate of NGI over the study period was 95.5 cases per 100,000 with increased risk in the 0 to 9 years age group and males.
- Reported rates of NGI declined from 1991 to 2008 however, seasonal peaks were observed in the spring and fall months.
- There was variability in the rates of NGI with higher notifications in the southern, urban areas compared to the northern, rural, remote areas of the territory suggesting the possible involvement of geographical risk factors and/or bias in the surveillance data.

Strengths and Limitations

- The study provides a historical portrait of NGI as the Northwest Territories Communicable Disease Registry (NWT CDR) broadly covered the entire territory over 18 years, therefore allowing comparisons across communities and time periods.
- Due to under-reporting, the rates of infections reported in this study are likely underestimates of the true incidence of diseases and therefore, should be interpreted as reporting rates rather than as incidence rates.
- Suspected sources of infection are infrequently confirmed by microbiological testing therefore, the results regarding 'suspected exposure' must be viewed with caution and be thought of as hypotheses.

BACKGROUND

Notifiable gastrointestinal illness (NGI) is an important global public health issue and a growing concern in northern, rural and remote populations of Canada. Many Aboriginal residents of the Northwest Territories (NWT) engage in traditional and subsistence activities (harvesting, processing, sharing and consumption of animals, fish and plants) as they have economic, dietary and socio-cultural importance.[1] Nonetheless, activities such as hunting, fishing and trapping as well as the traditional preparation, storage and consumption of wild game, seafood and untreated water can increase exposure to pathogenic agents in the environment.[2] Illness can result from the ingestion of micro-organisms in contaminated food or water, through contact with animals or other contaminated objects, and some infections can be further spread by person-to-person transmission.[3] Symptoms can include loss of appetite, abdominal cramps, diarrhea of variable severity, nausea, vomiting, and fever.[4] Estimates of the overall morbidity and identification of potential risk factors for NGI in NWT have not been previously published in the literature and hence, there is very little baseline data to inform policies and guide public health interventions in the territory. Using data elements extracted from cases of NGI in the Northwest Territories Disease Registry (NWT CDR), this study describes the demographic, temporal and spatial distribution of NGI in NWT from January 1991 through December 2008.

METHODS

Study Area

The NWT is located in northern Canada with a majority Aboriginal population (50.3%).[5] As of the 2006 Census, the population was 41,464, an increase of 11% from

2001.[5] There are 33 officially recognized communities across 1,140,835 km^2 of land; the smallest is Kakisa with 52 residents and the largest is Yellowknife with 18,700 residents.[6] The NWT population density is 0.03 people per km^2. There is a high proportion of children under 15 years of age (23.9%) and a low proportion of people over 65 years of age (4.7%).[6] The median age for both sexes is 31 years; males comprise a majority of the population (51.2%).[6]

Data Sources

Data on reported cases of enteric, food- and waterborne diseases for the period January 1991 through December 2008 were obtained from the NWT Communicable Disease Registry. Ethics approval was obtained from the University of Guelph Research Ethics Board, the Government of the Northwest Territories and the Aurora Research Institute.

The general procedures for notification remained consistent over the study period. Upon symptomatic presentation of enteric, food- and waterborne disease/infections, health practitioners send the patient's clinical specimen to the laboratory for confirmation and sero-typing. The patient's demographic information, food and water histories are collected by the health practitioner and manually-entered into the food and waterborne illness investigation form. The form is submitted to the Population Health Division of the Government of the Northwest Territories Department of Health and Social Services. Health practitioners and laboratories are required to report patients with confirmed NGI to the Population Health Division within 24 hours and this information is entered into the NWT Communicable Disease Registry.[7]

Case notification data, stripped of personal identifiers, were received for 15 diseases/infections and associated fields listed in Table 1; none of these fields was considered mandatory at the time of notification. A geographical conversion database was used to assign case-patients to their respective census subdivision (community), health and social services health authority (HSSA) as well as assign them a status of rural or urban location; cases were classified as urban if reported at a health center located in a community of at least 1,000 persons and 400 persons / sq km, others were classified as rural.[5, 6]

Data Quality Evaluation and Descriptive Analyses

Data quality evaluation involved manually checking data associated with each case for completeness and internal consistency. Missing values were replaced with "unspecified". The numbers and percentages related to "unspecified" values were calculated for each field.

Population denominators for each year were obtained from the NWT Bureau of Statistics and the mean annual age-specific rates of disease were calculated for the territory. The average annual number of cases was calculated using the total number of notifications divided by 18 years. Data manipulation and statistical analyses were conducted in SPSS version 17 (SPSS Inc., Chicago, Illinois) and choropleth maps of disease rates by health authority were created in ArcView GIS version 3.1 (ESRI, Redlands, California). Means and medians were used to describe the data; medians were used when dealing with highly skewed distributions. A least squares regression analysis was used to determine the rate of change over time. Fischer's Exact tests were used to determine statistical significance [$p<0.05$ (two-tailed)] for categorical variables. Community level risk factors for NGI are reported elsewhere.[8]

RESULTS

The percentages of missing or unspecified values for the 9 fields considered in the analysis are also shown in Table 1.

From the 708 case-patients with notified enteric, food- and waterborne diseases/infections from all years, 458 (64.7%) had bacterial infections, 240 (33.9%) had parasitic infections and 10 (1.4%) had viral (hepatitis A) infections. The three largest contributors to the total number of notifications were giardiasis with 205 cases (29.0%), salmonellosis with 202 cases (28.5%) and campylobacteriosis with 175 cases (24.7%). Too few cases were attributed to other agents (<6% each) to draw inferences, therefore, the focus of the rest of this paper is on the three most commonly notified diseases.

The annual reported incidence rates of NGI (total and cause-specific for giardiasis, salmonellosis and campylobacteriosis) are shown in Figure 1. A least squares regression analysis indicated that the incidence of NGI decreased by 3.7 (p<0.01) cases per 100,000 per year over the study period. Giardiasis and salmonellosis decreased by 1.7 (p< 0.01) and 1.2 (p<0.01) cases per 100,000 per year, respectively, but there was no significant (p<0.13) linear change in incidence of campylobacteriosis. A majority of campylobacteriosis (85.7%), giardiasis (62%), and salmonellosis (58.4%) cases were reported from health facilities in urban areas (p<0.01).

The highest rates of NGI (128.5 cases per 100,000) were observed in the 0 to 9 years age group with 56% of cases occurring in males (p<0.01). The highest rates of giardiasis (50.4 cases per 100,000) were also found in the 0 to 9 years age group with 57% of cases occurring in males (p<0.02). The highest rates of salmonellosis (46.1 cases per 100,000) were found in the 60+ years age group with 51% occurring in females (p<0.02). Although not significant (p<0.07), the highest rates of campylobacteriosis were observed in the 20 to 29 years age group for campylobacteriosis (28.2 cases per 100,000) with 53% of cases occurring in males.

Table 2 shows that the most frequently suspected vehicle for NGI was contaminated food ($p<0.01$). The probable source of giardiasis was most often attributed to untreated water whereas for campylobacteriosis and salmonellosis it was poultry and eggs, respectively ($p<0.01$).

Figure 2 show that cases of NGI ($p<0.01$) and more specifically campylobacteriosis ($p<0.01$) and salmonellosis ($p<0.04$), occurred more frequently in the late summer and early fall. Although not significant ($p<0.07$), giardiasis showed a similar trend on visual inspection of the data.

As shown in Figure 3, the highest median annual incidence of NGI (118.0 cases per 100,000) was observed in Yellowknife HSSA ($p<0.01$) whereas the lowest median annual incidence (41.0 cases per 100,000) was found in Fort Smith HSSA ($p<0.01$). The highest median annual incidence of campylobacteriosis (266.0 cases per 100,000) was found in Tlicho ($p<0.01$) whereas the lowest median annual incidence (8.0 cases per 100,000) was found in Dehcho ($p<0.01$). The highest median annual incidence of salmonellosis (35.1 cases per 100,000) was also found in Tlicho HSSA ($p<0.01$) however the lowest median annual incidence (17.0 cases per 100,000) was found in Fort Smith HSSA ($p<0.01$). The highest median annual incidence of giardiasis (38.1 cases per 100,000) was found in the Sahtu HSSA ($p<0.01$) whereas the lowest median annual incidence (14.5 cases per 100,000) was found in Beaufort Delta HSSA ($p<0.01$).

DISCUSSION

The results of this study suggest that NGI is an important health problem in NWT and that giardiasis, salmonellosis and campylobacteriosis account for the great majority (82.2%) of reported NGI in NWT. The mean annual reported rate of these three enteric diseases in NWT was 78.0 cases per 100,000, which is less than reported for Ontario (87.0 cases per 100,000) and British Columbia (145.8 cases per 100,000) based on notifiable disease data from 1991 through 2008.[9] This suggests that NWT residents may be at deceased risk of infection or alternatively, there may be a higher degree of under-reporting in the territory because of the relative paucity and distance to available health services, facilities, and qualified health professionals;[10] further investigation is required. Previous studies have shown that about 1 out of 313 (Ontario) to 350 (British Columbia) cases of acute gastrointestinal illness are captured by surveillance systems.[11, 12] Using these adjustment factors from Ontario and British Columbia, we estimate that between 182,748 and 204,282 cases of campylobacteriosis, giardiasis and salmonellosis, collectively, may have occurred in NWT over the 18 years.[4, 13, 14] Reported rates of these enteric diseases also declined over the study period, which is consistent with observed trends in southern Canada and the USA and may be attributed to effective, ongoing efforts to improve food and water quality.[15, 16]

Spatial analysis revealed that the incidence of campylobacteriosis, giardiasis and salmonellosis varied substantially between health authorities. Higher or lower-than-expected rates in health authorities could be a result of disparities in the geographical distribution of risk factors and behaviors,[17] suggesting that further studies on population-level risk factors are warranted. Overall, NGI was reported more frequently in urban than rural areas, but the underlying reasons could not be evaluated with the available data. In theory, higher reporting rates in urban areas could reflect greater propensity for person-to-person transmission; however, this is more commonly seen with organisms with human reservoirs.[18] Other possibilities include greater reliance on store-purchased foods, community water systems or other population-level risk factors. It is also possible that some infections were acquired in rural and remote areas but were reported at health facilities in urban areas. We expected exposure to these environmental or zoonotic pathogens to be more common in rural and remote areas, through contact with animals, their feces, as well as contaminated surface water and raw foods compared to urbanized areas.[19] Furthermore, higher disease rates could also be an artifact of differential reporting of cases or methods of data collection. Several studies have demonstrated that higher reporting rates in urban areas are often a function of the amount and type of available health services than the occurrence of illness itself.[20-22]

Giardiasis was the most commonly reported infection in this study, reflecting its importance as an enteric pathogen in the territory. In NWT, the mean annual reported rate of giardiasis was 27.7 cases per 100,000. This was slightly more than reported in Ontario (19.4 cases per 100,000) and similar to British Columbia (27.4 cases per 100,000).[9] Giardiasis commonly occurs through the ingestion of infective cysts found in contaminated water, food, or infected persons by the fecal-oral route. The cysts can be present in contaminated wells and water systems, particularly those sourced from surface water such as fresh water lakes and streams. Person-to-person transmission also accounts for many *Giardia* infections and is usually associated with poor hygiene and sanitation. In the Arctic, cysts of *Giardia* spp. have been found in water, sewage and fecal samples of marine mammals harvested for food.[23] Our findings of higher rates in infants and children in NWT could be related to reporting bias, poor hygiene, more frequent exposure to communal facilities or recreational water, lack of protective immunity, or a combination of factors.[24, 25] High rates in patients 30 to 39 year of age may also be at least partially attributed to contact with infected children as parents or as caregivers, and these persons are possibly more likely to seek medical care and therefore more likely to be captured by the surveillance system.[26] The higher rate of giardiasis in males is unexplained, but has also been noted in other studies.[27] In NWT, gender may act as a surrogate for true causal variables related to exposure, such as the consumption of untreated surface water or contaminated traditional foods, particularly while carrying out subsistence activities in northern areas of NWT. Consistent with previous research, the incidence of giardiasis in this study was higher in the late summer and autumn months, which may be related to greater environmental exposure during leisure and subsistence activities, potentially greater likelihood of infectious levels of cysts in water at this time of year, or exposure to contaminated recreational water that favors indirect person-to-person transmission.[28]

Salmonellosis was the second most frequently reported enteric infection in NWT. The mean annual rate for salmonellosis for NWT was 27.2 cases per 100,000 population, which is higher than Ontario (23.4 cases per 100,000) and British Columbia (20.3 cases per 100,000).[9] *Salmonella* infections are commonly acquired through consumption of contaminated food of animal origin, mainly meat, poultry, eggs and milk, but also contaminated fruit and vegetables.[29] In NWT, poultry/eggs were identified by those reporting illness as the most probable sources of this infection. Other suspected food vehicles included pork, caribou, beef, and fish/seafood; however, we do not know whether these vehicles were identified through epidemiological investigation, follow-up microbiological testing, or speculation by the health practitioner. Moreover, we do not know whether suspect foods were obtained through individual subsistence activities, community freezers, or retail locations making it difficult to hypothesize the source of microbial contamination; however, outbreaks of verotoxin-producing *Escherichia coli* O157:H7 (fourth highest notification) in NWT have been attributed to frozen minced beef and caribou obtained from grocery stores and homes.[30, 31] Higher observed rates of salmonellosis in infants and children (0 to 9 years age group) and the elderly (60 years and over age group) in this study have been noted in a previous study and may be related to lack of protective immunity or other factors mentioned for giardiasis.[32] Higher rates of disease in females are so far unexplained, but further research considering differences in food handling practices and hygiene as well as the types of foods consumed, may indicate their role in apparent gender differences.[33] Higher rates of infection in the late summer and autumn months may be attributable to environmental and social factors. These may include higher ambient temperatures, frequent travel as well as higher prevalences in food animal populations, centralized outdoor meal preparation and consumption related to large social gatherings.[34, 35]

Campylobacteriosis was the third most frequently reported infection in NWT. The mean annual incidence of campylobacteriosis in NWT was 23.5 cases per 100,000 population, which is lower than Ontario (44.2 cases per 100,000) and British Columbia (55.2 cases per 100,000).[9] Campylobacteriosis commonly occurs through the poor handling of raw poultry, and consumption of undercooked poultry, unpasteurized milk and contaminated drinking water. *Campylobacter* is also common in migratory birds and the consumption of fresh water from surface contaminated with bird feces could be a seasonal driver of this disease in the North.[36] In NWT, the predominant mode of transmission was believed to be foodborne; poultry, eggs, pork, caribou, beef, and fish/seafood from unspecified sources, were once again identified as probable exposures for infection. Incidence rates were highest in adults 20 to 49 years of age. The relatively higher rates in young males noted in other studies have been thought to reflect poor hygiene and food handling practices.[37] As with other studies on campylobacteriosis, disease occurred more frequently in the late summer and autumn months.[38] Traditionally, in northern communities, hunting activities and the collection of plants, berries, and bird’s eggs as well as the consumption of surface water occur more frequently during this time period.[39] The reason for the apparently lower incidence in NWT compared to southern Canada is unknown. *Campylobacter* are more susceptible to freezing than other bacteria, therefore it is tempting to speculate that the colder northern climate may play a role in reducing exposure in food and water.

This study demonstrates the usefulness of surveillance data to guide epidemiological research and public health practice in Northern communities. Of the nine reporting fields in the NWT Communicable Disease Registry, eight had less than 5% of data missing. To maximize the usefulness of the data, however, it is important to improve the completeness and hence, the quality of reported data for some fields. The field 'suspected exposure', unknown (missing) for 73.5% of the records, is a source of potential bias. Exposure information is frequently ascertained through an interview or questionnaire, thus, it is difficult to assess the extent to which recall or reporting bias has occurred and there are obvious limitations on the quality of exposure data obtained in this fashion. In addition, suspected sources are infrequently confirmed by microbiological testing, therefore, the results regarding the 'suspected exposure' must be viewed with considerable caution.

In summary, the results of the study indicate that giardiasis, salmonellosis and campylobacteriosis were the most important enteric diseases in NWT from 1991 through 2008, and the incidence declined in later years of the study period. There was increased risk of NGI in the late summer and early fall, in infants and children, males and urban residents. The geographical distribution of case-patients varied by disease suggesting that environmental and behavioral risk factors played key roles in infection and may provide opportunities for prevention. For future study, multivariable regression and spatial analyses at the community level are necessary for valid risk factor identification as well as for implementing specific and geographically-appropriate risk reduction and control strategies. It is anticipated that this information will guide future research as well as the allocation of resources for prevention, promotion and control initiatives.

COMPETING INTERESTS

None

ACKNOWLEDGMENTS

The authors gratefully acknowledge the Government of the Northwest Territories Health and Social Services Department and Bureau of Statistics for providing the data to complete this study. This work was supported by Nasivvik Centre for Inuit Health and Changing Environments.

CONTRIBUTORSHIP

APA contributed to the manuscript through study design and planning, data collection, analysis and interpretation of results, drafting of manuscript and response to editorial comments and preparation of final manuscript for submission. JW, VLE, CF, RRS and SAM contributed to the manuscript through study design and planning, consultation on study progress, troubleshooting, data analysis and interpretation of results, reviewing and commenting on manuscript drafts. MS contributed to the manuscript through data collection, interpretation of results and reviewing and commenting on manuscript drafts.

DATA SHARING

The dataset may be requested from Population Health, Department of Health and Social Services, Government of the Northwest Territories (www.hlthss.gov.nt.ca).

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Table 1. Notifiable gastrointestinal illnesses (NGI) and associated percent missing or unspecified values, by field and disease, Northwest Territories, Canada, 1991-2008.

	Notifiable Disease Report Form Fields - Percent Missing Values							
Disease / Agent (number of reported cases 1991-2008)	**Age**	**Gender**	**Community**	**Health Unit**	**Report Date**	**Etiologic Agent**	**Subtype**	**Suspected exposure**
Amoebiasis (n=10)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	60.0
Botulism (n=8)	0.0	0.0	0.0	0.0	0.0	0.0	12.5	25.0
Brucellosis (n=3)	0.0	0.0	0.0	33.3	0.0	0.0	66.7	66.7
Campylobacteriosis (n=175)	0.0	0.0	2.3	0.6	0.0	0.0	0.0	79.4
Cryptosporidiosis (n=18)	0.0	0.0	11.1	0.0	0.0	0.0	0.0	100.0
E. coli (VTEC) (n=40)	0.0	0.0	12.5	0.0	0.0	0.0	0.0	62.5
Food Poisoning (n=10)	0.0	0.0	0.0	0.0	0.0	0.0	100.0	10.0
Giardiasis	0.0	0.0	3.9	0.0	0.0	0.0	0.0	73.7

(n=205)								
Hepatitis A (n=10)	0.0	0.0	10.0	0.0	0.0	0.0	0.0	90.0
Listeriosis (n=1)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0
Salmonellosis (n=202)	0.0	0.0	0.0	4.5	0.0	0.0	0.0	70.8
Shigellosis (n=12)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	83.3
Tapeworm (n=7)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	57.1
Tularemia (n=1)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0
Yersiniosis (n=6)	0.0	0.0	16.7	0.0	0.0	0.0	0.0	100.0
Total NGI Cases (n=708)	**0.0**	**0.0**	**2.6**	**0.1**	**0.0**	**0.0**	**1.8**	**73.2**

Table 2. Percentage distribution of reported suspected sources of infection for notifiable gastrointestinal illness, campylobacteriosis, giardiasis and salmonellosis, Northwest Territories, Canada, 1991-2008.

	Percent of cases attributed to suspected exposure			
Suspected Exposure (%)	**NGI**	**Campylobacteriosis**	**Giardiasis**	**Salmonellosis**
Beef	6.8	2.8	3.7	3.4
Caribou	6.3	2.8	5.6	5.1
Fish/Seafood	3.2	11.1	0.0	1.7
Muktuk (Whale)	1.6	0.0	0.0	0.0
Pork	4.7	2.8	0.0	13.6
Poultry/eggs	18.9	38.9	1.9	33.9
Seal	0.5	0.0	0.0	0.0

Foodborne unknown	28.4	41.7	5.6	37.3
Untreated water	27.9	0.0	81.5	0.0
Waterborne unknown	0.5	0.0	1.9	5.1
Perinatal transmission	0.5	0.0	0.0	0.0
Person-to-person	0.5	0.0	0.0	0.0

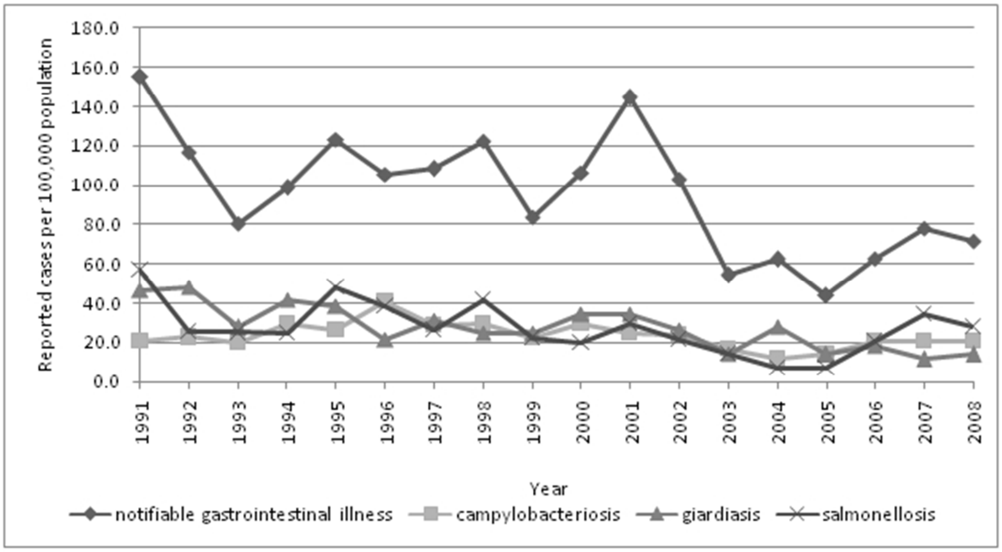

Figure 1. Annual incidence rates of notifiable gastrointestinal illness (total and cause-specific for giardiasis, salmonellosis and campylobacteriosis). Northwest, Territories, Canada, 1991-2008.
166x93mm (96 x 96 DPI)

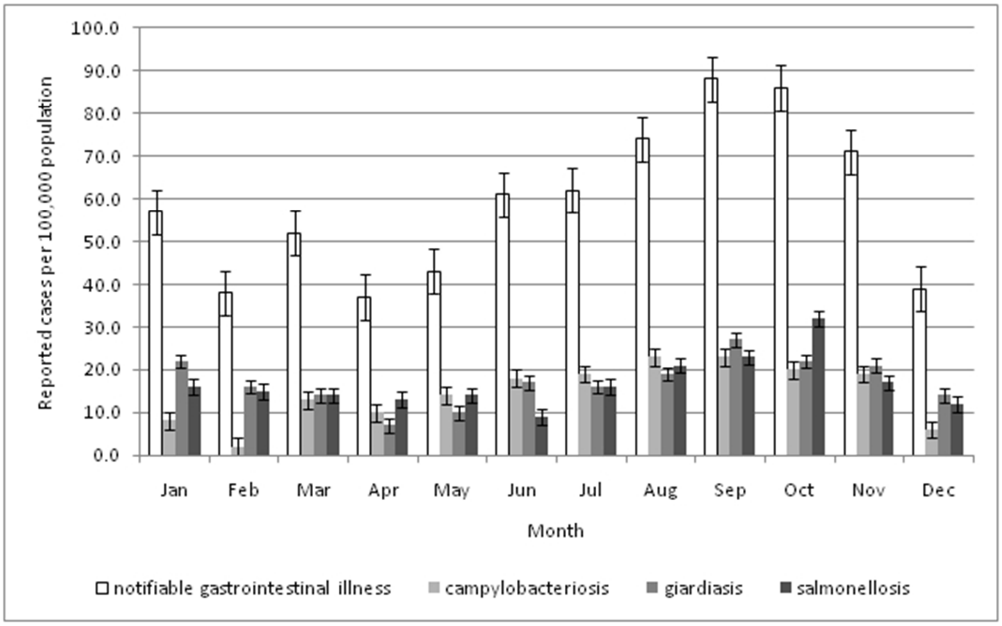

Figure 2. Incidence of notifiable gastrointestinal illness (total and cause-specific for giardiasis, salmonellosis and campylobacteriosis) by month, Northwest Territories, Canada, 1991-2008.
166x103mm (96 x 96 DPI)

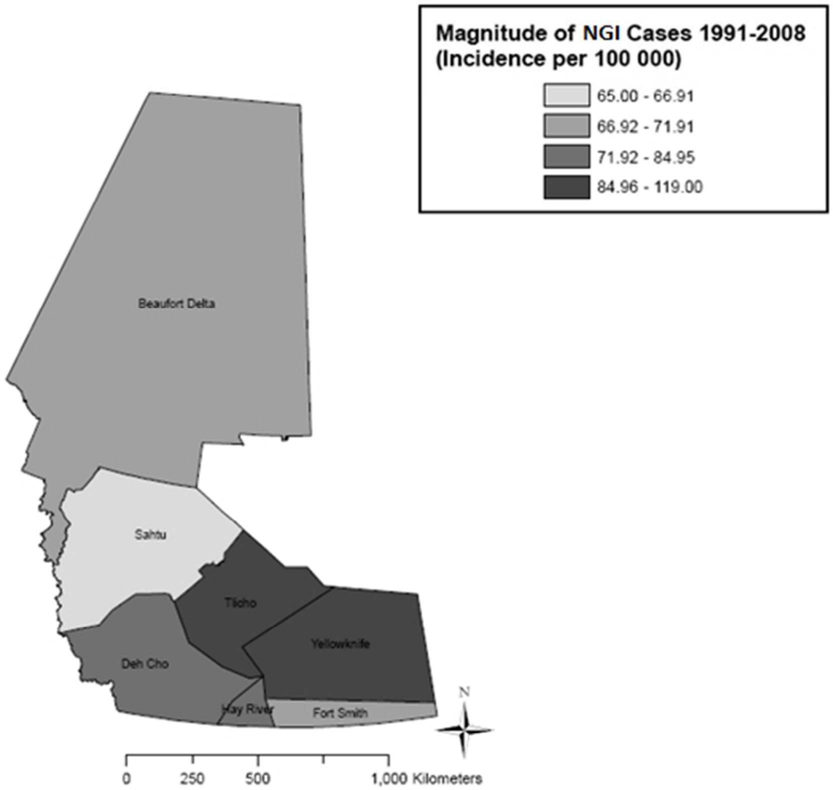

Figure 3. Map of incidence rates per 100,000 population by health authority for reported cases of notifiable gastrointestinal illness (NGI). Northwest Territories. 1991-2008.
166x141mm (96 x 96 DPI)

STROBE 2007 (v4) checklist of items to be included in reports of observational studies in epidemiology*
Checklist for cohort, case-control, and cross-sectional studies (combined)

Section/Topic	Item #	Recommendation	Reported on page #
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	2
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	2
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	5
Objectives	3	State specific objectives, including any pre-specified hypotheses	5
Methods			
Study design	4	Present key elements of study design early in the paper	7
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	5,6
Participants	6	(*a*) *Cohort study*—Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up *Case-control study*—Give the eligibility criteria, and the sources and methods of case ascertainment and control selection. Give the rationale for the choice of cases and controls *Cross-sectional study*—Give the eligibility criteria, and the sources and methods of selection of participants	N/A
		(*b*) *Cohort study*—For matched studies, give matching criteria and number of exposed and unexposed *Case-control study*—For matched studies, give matching criteria and the number of controls per case	N/A
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	6,7
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	*6,7*
Bias	9	Describe any efforts to address potential sources of bias	10,14
Study size	10	Explain how the study size was arrived at	N/A
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	7
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	7
		(*b*) Describe any methods used to examine subgroups and interactions	7
		(*c*) Explain how missing data were addressed	7
		(*d*) *Cohort study*—If applicable, explain how loss to follow-up was addressed *Case-control study*—If applicable, explain how matching of cases and controls was addressed	N/A

		Cross-sectional study—If applicable, describe analytical methods taking account of sampling strategy	
		(*e*) Describe any sensitivity analyses	N/A
Results			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	8,21
		(b) Give reasons for non-participation at each stage	N/A
		(c) Consider use of a flow diagram	N/A
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	8,9
		(b) Indicate number of participants with missing data for each variable of interest	7,21
		(c) *Cohort study*—Summarise follow-up time (eg, average and total amount)	N/A
Outcome data	15*	*Cohort study*—Report numbers of outcome events or summary measures over time	N/A
		Case-control study—Report numbers in each exposure category, or summary measures of exposure	N/A
		Cross-sectional study—Report numbers of outcome events or summary measures	N/A
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	N/A
		(*b*) Report category boundaries when continuous variables were categorized	N/A
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	N/A
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	N/A
Discussion			
Key results	18	Summarise key results with reference to study objectives	9,10,14
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	10,14
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	9,10,14
Generalisability	21	Discuss the generalisability (external validity) of the study results	10
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	15

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.

A Descriptive Analysis of Notifiable Gastrointestinal Illness in the Northwest Territories, Canada, 1991-2008

Journal:	*BMJ Open*
Manuscript ID:	bmjopen-2011-000732.R1
Article Type:	Research
Date Submitted by the Author:	02-Apr-2012
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Primary Subject Heading:	Epidemiology
Secondary Subject Heading:	Infectious diseases
Keywords:	Gastrointestinal infections < GASTROENTEROLOGY, Epidemiology < INFECTIOUS DISEASES, Quality in health care < HEALTH SERVICES ADMINISTRATION & MANAGEMENT, Public health < INFECTIOUS DISEASES

Title:

A Descriptive Analysis of Notifiable Gastrointestinal Illness in the Northwest Territories, Canada, 1991-2008

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Medical Subject Headings-Key Words:

Gastrointestinal illness, Foodborne Diseases, Minority Health, Population Surveillance

Word count: 4448

ABSTRACT

Objectives: To describe the major characteristics of reported Notifiable Gastrointestinal Illness (NGI) data in the Northwest Territories (NWT) from January 1991 through December 2008.

Design: Descriptive analysis of 708 reported cases of NGI extracted from the Northwest Territories Communicable Disease Registry (NWT CDR).

Setting: Primary, secondary and tertiary health care centres across all 33 communities of NWT.

Population: NWT residents of all ages with confirmed NGI reported to the NWT CDR from January 1991 through December 2008.

Main Outcome Measure: Laborartory-confirmed NGI, with a particular emphasis on campylobacteriosis, giardiasis, and salmonellosis.

Results: Campylobacteriosis, giardiasis and salmonellosis were the most commonly identified types of NGI in the territory. Seasonal peaks for all three diseases were observed in late summer to autumn ($p<0.01$). Higher rates of NGI (all 15 diseases/infections) were found in the 0 to 9 years age group and in males ($p<0.01$). Similarly, rates of giardiasis were higher in the 0 to 9 years age group and in males ($p<0.02$). A disproportionate burden of salmonellosis was found in people 60 years and older and in females ($p<0.02$). Although not significant, the incidence of campylobacteriosis was greater in the 20 to 29 years age group and in males ($p<0.07$). The health authority with the highest incidence of NGI was Yellowknife ($p<0.01$) while for salmonellosis and campylobacteriosis it was Tlicho ($p<0.01$) and for giardiasis, the Sahtu region ($p<0.01$). Overall, disease rates were higher in urban areas ($p<0.01$).

Comment [TA1]:
Reviewer 2: In the abstract you indicate higher increased risk in late summer/fall but in key messages (and paper) you indicate seasonal peaks in spring and fall months. Please clarify and ensure consistent messaging.

APA: It is seasonal peaks. Please see corrections in lines 33-34.

Contaminated eggs, poultry and untreated water were believed by health practitioners to be important sources of infection in cases of salmonellosis, campylobacteriosis and giardiasis, respectively.

Conclusion: The general patterns of these findings suggest that environmental and behavioral risk factors played key roles in infection. Further research into potential individual and community-level risk factors is warranted.

ARTICLE SUMMARY

Article Focus

- To date, there is very little baseline data on notifiable gastrointestinal illness (NGI) diseases in the Northwest Territories (NWT), where Aboriginal people constitute a majority of the population. The demographic, socio-cultural, and health conditions of northern Aboriginal people are markedly different from those of other Canadian populations.

- There is a clear need to identify the major characteristics of reported NGI in order to generate hypotheses, guide future studies, and help public health officials target resources, interventions or increased surveillance to areas of greatest need in NWT.

Comment [TA2]:
Reviewer 1: The authors aim to describe demographical characteristics, temporal and spatial distribution and risk factors of reported enteric, food- and waterborne diseases. However, this very simple descriptive analysis is not sufficient to address the research questions. The reviewer would suggest to add futher spatial and temporal analyses based on the available data.

APA: I agree with you. This article does not fully address the research question; therefore, I have revised my research question as well as the objectives (please see lines 22-23, 55-57 and 117-122) so that it accurately reflects the contents of the paper. The aim of this paper was to provide an overview of the major characteristics of NGI over the 18 years. I have done a very technical paper on spatial, temporal and spatio-temporal analysis but I have submitted it to the International Journal of Health Geographics. However, I have added to the results (Please see Table 2, Figures 5,6 and 7) and expanded on the discussion (Please see lines 234-257, 266-270, 348-364, and 374-400) to strengthen the interpretation and conclusions (also suggested by Reviewer 2).

Key Messages

- The annual average rate of NGI over the study period was 95.5 cases per 100,000 with increased risk in the 0 to 9 years age group and males.

- Reported rates of NGI declined from 1991 to 2008 however, seasonal peaks were observed in the spring and fall months.

- There was variability in the rates of NGI with higher notifications in the southern, urban areas compared to the northern, rural/remote areas of the territory suggesting the possible involvement of geographical risk factors and/or bias in the surveillance data.

Strengths and Limitations

- The study provides a historical portrait of NGI as the Northwest Territories Communicable Disease Registry (NWT CDR) broadly covered the entire territory over 18 years, therefore allowing comparisons across communities and time periods.

- Due to under-reporting, the rates of infections reported in this study are likely underestimates of the true incidence of diseases and therefore, should be interpreted as reporting rates rather than as incidence rates.

- Suspected sources of infection are infrequently confirmed by microbiological testing therefore, the results regarding 'suspected exposure' must be viewed with caution and be thought of as hypotheses.

BACKGROUND

Notifiable gastrointestinal illness (NGI) is an important global public health issue and a growing concern in the Northwest Territories, where Aboriginal people constitute a majority of the population.[1]. The Aboriginal population of NWT maintains strong ties to the environment, continually adapting and learning to use available resources to provide food and other necessities, sustain livelihoods, and reinforce social relations.[2] Foods obtained by harvesting, hunting, fishing and trapping are referred to as traditional or country foods. About 40 to 60% of NWT residents living in small communities rely on country food for most (at least 75%) of their meat and fish.[3] This percentage has remained nearly the same for the past 10 years.[3]

Comment [TA3]: Reviewer 2: In the first few sentences you lead into the fact that the population of the NWT (specifically Aboriginal) may engage in tradition activities but the way they are currently described does not appear unique. Is it possible to provide more specific examples of the harvesting, processing, consumption, economic, dietary issues that this population faces?

APA: Please see lines 79-106.

Country foods in NWT vary by geographic area, season, climate and availability and include items such as Caribou, Moose, Ducks, Geese, Seals, Hare, Grouse, Ptarmigan, Lake Trout, Char, Inconnu, White Fish, Pike, and Burbot.[4, 5] Due to the harsh climate, animal products are the staple, and fresh vegetables and fruits provide additional nutrients when available. During the short summers, items such as blueberries, cranberries, blackberries and cloudberries are gathered, both for eating fresh and for drying or freezing to eat during the winter.[4] The consumption of untreated water from lakes, creeks, and rivers in the summer or from melted ice or snow in winter and spring is also common practice during subsistence activities.[6]

A well-balanced diet is primarily achieved by consuming muscle meat and other parts of the animals (raw or with minimal processing) such as the stomach, liver and fat which contain iron, calcium and a range of vitamins.[7] Common Traditional meats are also an excellent source of protein and lower in fat compared to meats eaten in southern Canada. Seal and whale are a good source of omega-3 fatty acids which help reduce the risk of chronic conditions such as cardiovascular disease.[7] Although the traditional diet is nutritious, it is also very high in calories. High caloric intake is an adaptation feature that enables the northern residents to keep warm through the long, frigid winters.[5]

Sharing food is a key element of the Aboriginal culture in NWT. Traditionally, when hunters return with fresh game or fish, it is distributed according to social rules [2]. Meals are communal and fresh, uncooked animal-derived foods are first given out to people who are feeling cold or hungry, then to the community, and the remaining portion is shared within the household. The distribution of raw meats can occur several times in a week.[2]

Activities such as hunting, fishing and trapping as well as the traditional preparation, storage and consumption of wild game, seafood and untreated water can increase exposure to pathogenic agents in the environment.[8] Illness can result from the ingestion of micro-organisms in contaminated food or water, through contact with animals or other contaminated objects, and some infections can be further spread by person-to-person transmission.[9] Symptoms can include loss of appetite, abdominal cramps, diarrhea of variable severity, nausea, vomiting, and fever.[10] Estimates of the overall morbidity and identification of potential risk factors for NGI in NWT have not been previously published in the literature and hence, there is very little baseline data to inform policies and guide public health interventions in the territory. Using data elements extracted from cases of NGI in the Northwest Territories Disease Registry (NWT CDR), this study provides a descriptive analysis of reported NGI in NWT from January 1991 through December 2008. At the time of writing, the surveillance system for NGI was going through a review process and the human resources structure was in a phase of organizational change; therefore, the findings of this study should be considered with respect to the surveillance system in place during the study period. This study can also provide a baseline against which the performance of the new process can be measured.

METHODS

Study Area

The NWT is located in northern Canada with a majority Aboriginal population (50.3%).[11] As of the 2006 Census, the population was 41,464, an increase of 11% from 2001.[3] There are 33 officially recognized communities across 1,140,835 km^2 of land; the smallest is Kakisa with 52 residents and the largest is Yellowknife with 18,700 residents.[12] The NWT population density is 0.03 people per km^2. There is a high proportion of children under 15 years of age (23.9%) and a low proportion of people over 65 years of age (4.7%).[12] The median age for both sexes is 31 years; males comprise a majority of the population (51.2%).[12]

Data Sources

Data on reported cases of NGI for the period January 1991 through December 2008 were obtained from the NWT Communicable Disease Registry. Reported NGI is an umbrella term for fifteen enteric, food- and waterborne conditions that were reportable under the NWT Public Health Act during the study period: amoebiasis, botulism, brucellosis, campylobacteriosis, cryptosporidiosis, infection with *Escherichia coli*, food poisoning, giardiasis, hepatitis A, listeriosis, salmonellosis, shigellosis, tapeworm, tularemia, and yersiniosis. Ethics approval was obtained from the University of Guelph Research Ethics Board, the Government of the Northwest Territories, and the Aurora Research Institute.

Comment [TA4]: Throughout the paper you switch between "notifiable gastrointestinal illness (NGI) and "cases of enteric, food- and waterborne diseases". I recommend you select one of these terms and use it consistently throughout the manuscript. If they are 2 distinct terms then they should be clearly defined previously to using the terms.

APA: I have selected NGI and clearly defined it in lines 135-139.

Comment [TA5]:
Reviewer 2: The diseases are listed in the tables but it might be easier for the reader to have them presented/listed in the first paragraph of the data sources as a reference point.

APA: Please see lines 135-139.

The NWT Communicable Disease Manual provides guidelines to assist public health practitioners with decision making about specific situations, and to support consistency of territorial public health practice;[13] therefore the general procedures for notification remained consistent over the study period. Upon symptomatic presentation of NGI as described in the Manual, health practitioners send the patient's clinical specimen to the laboratory for confirmation and sero-typing. The patient's demographic information, food and water histories are collected by the health practitioner and manually-entered into the food and waterborne illness investigation form. The paper form is submitted to the Population Health Division of the Government of the Northwest Territories Department of Health and Social Services. Health practitioners and laboratories are required to report patients with confirmed NGI to the Population Health Division within 24 hours. Once the paper form is received, disease registry officers at the territorial level collate, verify, enter, and disseminate illness investigation data electronically through the Integrated Public Health Information System (i-PHIS) for inclusion into the NWT CDR and the National Notifiable Disease database at the Public Health Agency of Canada.[13]

Case notification data, stripped of personal identifiers, were received for 15 diseases/infections and associated fields listed in Table 1; none of these fields was considered mandatory at the time of notification. A geographical conversion database was used to assign case-patients to their respective census subdivision (community), health and social services health authority (HSSA) as well as assign them a status of rural or urban location; cases were classified as urban if reported at a health center located in a community of at least 1,000 persons and 400 persons / sq km, others were classified as rural.[3, 12]

Comment [TA6]: Reviewer 2: In the procedures for notification: what is the definition of symptomatic presentation? Is there a standard practice? Is it a number of symptoms, a single symptom? Does the practitioner have discretion on what is sent for testing or are their standard guidelines? If there are guidelines for testing please state; if there are not then the procedures may be consistent but the variation from practitioner to practitioner may be significant which may warrant further discussion.

APA: Please see lines 142-145.

Comment [TA7]: Reviewer 2: Is the illness investigation form entered into the disease registry or is this information maintained only on paper forms and required you to re-enter or extract it from another system?

APA: Please see lines 152-156.

Data Quality Evaluation and Descriptive Analyses

Data quality evaluation involved manually checking data associated with each case for completeness and internal consistency. Missing values were replaced with "unspecified". The numbers and percentages related to "unspecified" values were calculated for each field.

Population denominators for each year were obtained from the NWT Bureau of Statistics and the mean annual age-specific rates of disease were calculated for the territory. The average annual number of cases was calculated using the total number of notifications divided by 18 years. Data manipulation and statistical analyses were conducted in SPSS version 17 (SPSS Inc., Chicago, Illinois) and choropleth maps of disease rates by health authority were created in ArcView GIS version 3.1 (ESRI, Redlands, California). Means and medians were used to describe the data; medians were used when dealing with highly skewed distributions. A least squares regression analysis was used to determine the rate of change over time. Fischer's Exact tests were used to determine statistical significance [$p<0.05$ (two-tailed)] for categorical variables. Community level risk factors for NGI are reported elsewhere.[14]

RESULTS

The percentages of missing or unspecified values for the 9 fields considered in the analysis are also shown in Table 1.

From the 708 case-patients with NGI from all years, 458 (64.7%) had bacterial infections, 240 (33.9%) had parasitic infections and 10 (1.4%) had viral (hepatitis A) infections. The three largest contributors to the total number of notifications were giardiasis with 205 cases (29.0%), salmonellosis with 202 cases (28.5%) and campylobacteriosis with 175 cases (24.7%). Too few

Comment [TA8]:
Reviewer 2: What were the cases of illness for "food poisoning"? Typically a term like this would suggest that no known agent was identified but it is not missing data according to Table 1. If the pathogen is known is there a reason why they were not included under the appropriate pathogen for analysis vs. a general category?

APA: Food poisoning includes 5 cases of clostridium and 5 cases of bacillus. Infections from these agents are not notifiable in NWT unless they are from food poisoning. I have added a footnote in Table 1.

cases were attributed to other agents (<6% each) to draw inferences, therefore, the focus of the rest of this paper is on the three most commonly notified diseases.

The annual reported incidence rates of NGI (total and cause-specific for giardiasis, salmonellosis and campylobacteriosis) are shown in Figure 1. A least squares regression analysis indicated that the incidence of NGI decreased by 3.7 ($p<0.01$) cases per 100,000 per year over the study period. Giardiasis and salmonellosis decreased by 1.7 ($p< 0.01$) and 1.2 ($p<0.01$) cases per 100,000 per year, respectively, but there was no significant ($p<0.13$) linear change in incidence of campylobacteriosis. A majority of campylobacteriosis (85.7%), giardiasis (62%), and salmonellosis (58.4%) cases were reported from health facilities in urban areas ($p<0.01$).

Comment [TA9]: Reviewer 2: .In the incidence over time graph there is a large spike in NGI in 2001 and incidence drops after that and remains low. I expected a comment on this in the discussion. Was there a change that lead to this decrease?

APA: Please see lines 259-261

The average annual incidence of NGI (total and cause-specific for giardiasis, salmonellosis and campylobacteriosis) by age-group are shown in Figure 2. The highest rates of NGI (128.5 cases per 100,000) were observed in the 0 to 9 years age group with 56% of cases occurring in males ($p<0.01$). The highest rates of giardiasis (50.4 cases per 100,000) were also found in the 0 to 9 years age group with 57% of cases occurring in males ($p<0.02$). The highest rates of salmonellosis (46.1 cases per 100,000) were found in the 60+ years age group with 51% occurring in females ($p<0.02$). Although not significant ($p<0.07$), the highest rates of campylobacteriosis were observed in the 20 to 29 years age group for campylobacteriosis (28.2 cases per 100,000) with 53% of cases occurring in males.

Comment [TA10]: Reviewer 2: .You state the highest rates for each disease by age group but do not present the incidence in the other age ranges. It is hard to assess how much higher the rates were for the age groups you have specified. Is there a way to provide an indication of the magnitude?

APA: Please see Figure 2

Table 2 shows that the most frequently suspected vehicle for NGI was contaminated food ($p<0.01$). The probable source of giardiasis was most often attributed to untreated water whereas for campylobacteriosis and salmonellosis it was poultry and eggs, respectively ($p<0.01$).

Figure 3 show that cases of NGI (p<0.01) and more specifically campylobacteriosis (p<0.01) and salmonellosis (p<0.04), occurred more frequently in the late summer and early fall. Although not significant (p<0.07), giardiasis showed a similar trend on visual inspection of the data.

As shown in Figure 4, the highest median annual incidence of NGI (118.0 cases per 100,000) was observed in Yellowknife HSSA (p<0.01) whereas the lowest median annual incidence (41.0 cases per 100,000) was found in Fort Smith HSSA (p<0.01). Figure 5 shows that the highest median annual incidence of campylobacteriosis (265.5 cases per 100,000) was found in Tlicho (p<0.01) whereas the lowest median annual incidence (0.0 cases per 100,000) was found in Beaufort Delta, Dehcho, Fort Smith, and Sahtu HSSAs (p<0.01). Figure 6 shows the highest median annual incidence of salmonellosis (35.0 cases per 100,000) was also found in Tlicho HSSA (p<0.01) however the lowest median annual incidence (0.0 cases per 100,000) was found in Fort Smith, Hay River, and Sahtu HSSAs (p<0.01). Figure 7 shows highest median annual incidence of giardiasis (38.0 cases per 100,000) was found in the Sahtu HSSA (p<0.01) whereas the lowest median annual incidence (0.0 cases per 100,000) was found in Tlicho HSSA (p<0.01).

Comment [TA11]:
Reviewer 2: For the description of incidence by geography I wonder if there is an easier way to present this data to help inform the reader. I naturally wanted to determine if there were any that were consistently high or low and ended up making a table for myself. You have shown NGI in Figure 3, did you consider visually representing the other diseases?

APA: I think you were referring to Figure 4. The other disease are represented in Figures 5, 6, and 7.

DISCUSSION

The results of this study suggest that NGI is an important health problem in NWT and that giardiasis, salmonellosis and campylobacteriosis account for the great majority (82.2%) of reported NGI in NWT. The mean annual reported rate of these three enteric diseases in NWT was 78.0 cases per 100,000, which is less than reported for Ontario (87.0 cases per 100,000) and British Columbia (145.8 cases per 100,000) based on notifiable disease data from 1991 through

Comment [TA12]:
Reviewer 2: .Is there a reason why you compared this data to ON and BC?

APA: I was interested in making a north-south comparison. Please see lines 228-230.

2008.[9] This may suggest that compared to some southern areas as of Canada, NWT residents may be at deceased risk of infection or alternatively, there may be a higher degree of under-reporting in the territory;[15, 16] further investigation is required. Previous studies have shown that about 1 out of 313 (Ontario) to 350 (British Columbia) cases of acute gastrointestinal illness are captured by surveillance systems.[17, 18] Using these adjustment factors from Ontario and British Columbia, we estimate that between 182,748 and 204,282 cases of campylobacteriosis, giardiasis and salmonellosis, collectively, may have occurred in NWT over the 18 years.[10, 11, 19] Several explanations for under-reporting have been proposed, such as cases not presenting to medical facilities, health workers not submitting clinical samples to laboratories, laboratory test sensitivity issues, absence or delay of reporting from local to territorial health authorities. Patients may not seek medical attention because symptoms are mild and self-limiting, they may be too ill to travel, or they may prefer to seek treatment from local healers.[19] These tendencies are exacerbated in rural/remote communities of NWT due to the relative paucity of available health services, facilities, and health professionals. Increased distances to health facilities and transportation problems further aggravate other barriers to accessing the health systems in rural/remote settings in northern communities.[15, 16] There are no data addressing possible geographical reporting biases in NWT; therefore, research to characterize and quantify reporting bias in the NWT CDR is needed. Reduction of under-reporting and differential reporting (if it does exist) would require increased awareness of community health practitioners about the potential usefulness of surveillance data and therefore, the need to improve their quality.

In NWT, seasonal peaks over the study period may have been attributed to social environmental factors such as higher ambient temperatures, frequent travel for subsistence activities, centralized outdoor meal preparation as well as the consumption of country foods and

Comment [TA13]:
Reviewer 2: Ideally I would like for more of the discussion to focus on what your findings mean for this unique population. For Salmonella, Giardia and Campylobacter you spend time discussing each pathogen and findings separately but it reads somewhat repetitive at times and it would be interesting for the readers to also have comment on the impacts and specific risks or consideration for the population of the NWT.

APA: I tried to rephrase a little so that it wouldn't sound repetitive. I have added to the discussion. Please see:
-Lines 235-258
-Lines 267-271
-Lines 349-365
-Lines 375-401

surface water.[4, 6, 20-23] Therefore, control strategies, such as regular, coordinated public education and communication about known risk factors of the disease (e.g., drinking contaminated water, safe food preparation) would therefore need to be targeted during these seasons. Such public health programs need to take into account the wide geographic distribution of these communities, their cultural diversity and the number of languages used [24]. Community-oriented media such as local television and radio, have proven to be successful methods of reaching rural/remote populations by providing a forum for which health issues can be identified and discussed thus, increasing general awareness.[25-27]

Fluctuations in rates of NGI over the 18 years are likely to be explained, at least in part, by random variation due to small number of cases. The peaks in 1995 and 2001 also coincide with known outbreaks of salmonellosis and cryptosporidiosis, respectively.[28] The incidence of NGI however, declined over the last few years of the study period (since 2002), which is consistent with observed trends in southern Canada and the USA. The decline may attributed to effective, ongoing efforts to improve food and water quality or an artifact of diagnostic procedures, reporting practices or changes in population demographics.[29, 30] The extent to which these factors may have contributed to a decrease in incidence is unknown but it is an important topic for future research. This trend however, is not consistent with the theory of temperature-driven increases of enteric disease related to climate change;[31-32] unless the decline would have been steeper without it. The use of statistical techniques to correlate NGI data with weather events and climate variables would allow the impact of these factors on human health to be examined and better understood in a northern context.

Spatial analysis revealed that the incidence of campylobacteriosis, giardiasis and salmonellosis varied substantially between health authorities. Higher or lower-than-expected rates in health authorities could be a result of disparities in the geographical distribution of risk factors and behaviors,[33] suggesting that further studies on population-level risk factors are warranted. Overall, NGI was reported more frequently in urban than rural areas, but the underlying reasons could not be evaluated with the available data. In theory, higher reporting rates in urban areas could reflect greater propensity for person-to-person transmission; however, this is more commonly seen with organisms with human reservoirs.[34] Other possibilities include greater accessibility, affordability and/or reliance on store-purchased foods, restaurant meals, and foreign travel as well as other population-level risk factors such as community water systems.[35] It is also possible that some infections were acquired in rural/remote areas of NWT but were reported at health facilities in urban areas.[36] We expected exposure to these environmental or zoonotic pathogens to be more common in rural/remote areas, through contact with animals, their feces, as well as contaminated surface water and raw foods compared to urbanized areas.[37] Furthermore, higher disease rates could also be an artifact of differential reporting of cases or methods of data collection that vary by area or practitioners. Several studies have demonstrated that higher reporting rates in urban areas are often a function of the amount and type of available health services, rather than the occurrence of illness itself.[38-40]

Comment [TA14]: Reviewer 2: Some studies in other jurisdictions have also identified higher rates of enteric illness in urban settings. Some hypothesis of this has been due to travel related illness. Did you explore either of these or would the inclusion of travel have any impact on your findings?

APA: Please see lines 276-283

Comment [TA15]: Reviewer 2: On page 11 you state that higher disease rates could be an artefact of differential reporting or data collection. In the methods you state the procedure was consistent over time. Are you suggesting changes between areas/practitioners vs. time please clarify?

APA: Please see lines 286-287.

Giardiasis was the most commonly reported infection in this study, reflecting its importance as an enteric pathogen in the territory. Giardiasis commonly occurs through the ingestion of infective cysts found in contaminated water, food, or infected persons by the fecal-oral route. The cysts can be present in contaminated wells and water systems, particularly those sourced from surface water such as fresh water lakes and streams. Person-to-person transmission also accounts for many *Giardia* infections and is usually associated with poor hygiene and sanitation. In the Arctic, cysts of *Giardia* spp. have been found in water, sewage and fecal samples of marine mammals harvested for food.[23] Our findings of higher rates in infants and children in NWT could be related to reporting bias, poor hygiene, more frequent exposure to communal facilities or recreational water, lack of protective immunity, or a combination of factors.[41, 42] High rates in patients 30 to 39 year of age may also be at least partially attributed to contact with infected children as parents or as caregivers, and these persons are possibly more likely to seek medical care and therefore more likely to be captured by the surveillance system.[43] The higher rate of giardiasis in males is unexplained, but has also been noted in other studies.[44] In NWT, gender may act as a surrogate for true causal variables related to exposure, such as the consumption of untreated surface water or contaminated traditional foods, particularly while carrying out subsistence activities in northern areas of NWT. Consistent with previous research, the incidence of giardiasis in this study was higher in the late summer and autumn months, which may be related to greater environmental exposure during leisure and subsistence activities, potentially greater likelihood of infectious levels of cysts in water at this time of year, or exposure to contaminated recreational water that favors indirect person-to-person transmission.[45]

Comment [TA16]:
Reviewer 2: On page 13 you note lack of protective immunity related to age differences. Could you include a reference for this or expand on this further?

APA: I am referring to protection induced by natural exposure. Please see reference 41.

Salmonellosis, the second most frequently reported enteric infection, is commonly acquired through consumption of contaminated food of animal origin, mainly meat, poultry, eggs and milk, but also contaminated fruit and vegetables.[36] In NWT, poultry/eggs were identified by those reporting illness as the most probable sources of this infection. Other suspected food vehicles included pork, caribou, beef, and fish/seafood; however, we do not know whether these vehicles were identified through epidemiological investigation, follow-up microbiological testing, or speculation by the health practitioner. Moreover, we do not know whether suspect foods were obtained through individual subsistence activities, community freezers, or retail locations making it difficult to hypothesize the source of microbial contamination; however, outbreaks of verotoxin-producing *Escherichia coli* O157:H7 (fourth highest notification) in NWT have been attributed to frozen minced beef and caribou obtained from grocery stores and homes.[46, 47] Higher observed rates of salmonellosis in infants and children (0 to 9 years age group) and the elderly (60 years and over age group) in this study have been noted in a previous study and may be related to lack of protective immunity or other factors mentioned for giardiasis.[41, 48, 49] Higher rates of disease in females are so far unexplained, but further research considering differences in food handling practices and hygiene as well as the types of foods consumed, may indicate their role in apparent gender differences.[50] Higher rates of infection in the late summer and autumn months may be attributable to environmental and social factors. These may include higher ambient temperatures, frequent travel as well as higher prevalences in food animal populations, centralized outdoor meal preparation and consumption related to large social gatherings.[20, 51]

Campylobacteriosis, the third most frequently reported infection, commonly occurs through the poor handling of raw poultry, and consumption of undercooked poultry, unpasteurized milk and contaminated drinking water. *Campylobacter* is also common in migratory birds and the consumption of fresh water from surface contaminated with bird feces could be a seasonal driver of this disease in the North.[52] In NWT, the predominant mode of transmission was believed to be foodborne; poultry, eggs, pork, caribou, beef, and fish/seafood from unspecified sources, were once again identified as probable exposures for infection. Incidence rates were highest in adults 20 to 49 years of age. The relatively higher rates in young males noted in other studies have been thought to reflect poor hygiene and food handling practices.[53] As with other studies on campylobacteriosis, disease occurred more frequently in the late summer and autumn months.[54] Traditionally, in northern communities, hunting activities and the collection of plants, berries, and bird's eggs as well as the consumption of surface water occur more frequently during this time period.[4]. *Campylobacter* however, are more susceptible to freezing than other bacteria, therefore it is tempting to speculate that the colder northern climate may play a role in reducing exposure in food and water.

Cryptosporidium infections in humans may be from either human or animal origin, and no attempts were made to differentiate among strains in this study. The apparent low incidence of pathogens such as *Cryptosporidium* (2.4 cases per 100,000) in NWT may be due to the lack of exposure to agricultural animals in the North.[55] Domestic livestock, including beef and dairy cattle as well as sheep are often perceived to be the leading environmental source of waterborne pathogens,[56] although contamination from human sewage also occurs. Animals shed oocysts through manure contributing to the *Cryptosporidium* load of drinking water sources [57]. Several studies have shown that concentrations of *Cryptosporidium* are significantly higher in agricultural rather than non-agricultural watersheds.[58, 59] The role of wildlife as a source of *Cryptosporidium* is less clear in published literature. A study conducted over a 4-year period in northern Alaska found that the prevalence of *Cryptospordium* spp. in fecal samples of marine mammals from subsistence hunts was highest in Ringed Seals (22.6%) followed by Right Whales (24.5%) and Bowhead Whales (5.1%).[60] A study in Nunavik (Quebec, Canada) also found a prevalence of 9% in fecal samples of Ringed Seals.[61] These studies suggest that some animals used in traditional foods may be reservoirs for the disease in the north. In this study, Caribou, Muktuk, and Seal were also suspected sources of infection for 8.4% of NGI cases; therefore, further evaluations of environmental risk factors in NWT are warranted.

This study demonstrates the usefulness of surveillance data to guide epidemiological research and public health practice in Northern communities. Of the nine reporting fields in the NWT Communicable Disease Registry, eight had less than 5% of data missing; however, the field ‘suspected exposure’, unknown (missing) for 73.5% of the records, is a source of potential bias. Exposure information is frequently ascertained through an interview or questionnaire, thus, it is difficult to assess the extent to which recall or reporting bias has occurred and there are obvious limitations on the quality of exposure data obtained in this fashion. In addition, suspected sources are infrequently confirmed by microbiological testing, therefore, the results regarding the ‘suspected exposure’ must be viewed with considerable caution and can be thought of as hypotheses. For the data to be useful, particularly for risk factor identification, it is essential that the completeness of fields and hence, quality be improved. From 1991 to 2008, there were no mandatory fields enforced by the GNWT. Due to the contextual challenges of conducting surveillance in northern, rural/remote communities, the NWT CDR is based around the minimum data set concept, where the focus is on collecting the most essential data fields; however, these fields must be standardized and sufficiently detailed to support the delivery, planning and monitoring of public health initiatives. Although issues related to data quality are not unique to surveillance systems serving northern, rural/remote areas, they may be exacerbated when the systems serve sparse populations and have inadequate infrastructure, human and financial resources.[62] The implementation of electronic-based platforms for reporting have been shown to improve data quality and completeness in low-resource settings.[63,64]

Comment [TA17]: Reviewer 2: You state the limitation related to suspected source. Do you have any recommendations on how this data could be improved or should this data be used for analysis?

APA: Please see lines 375-385.

Published knowledge on surveillance in rural/remote areas is sparse; as a result, very little has been recommended in terms of cohesive and effective approaches to enhance surveillance in these communities. The gap in the literature suggests that the development of a comprehensive

Comment [TA18]: Reviewer 2: Do you have any other recommendations (more specific) about how this data could be improved or used? Did this analysis lead to any changes in surveillance in the NWT? Was this data used for any further programs or shared with the community?

APA: Please see lines 386-407.

public health surveillance system for rural/remote communities, which takes into account local realities and needs, is a priority area for research; however, this will require a collaborative effort from stakeholders, partners and knowledge-users of the system. Suggestions for moving forward include a collaborative design of suitable data elements, data collection protocols, data quality assurance, research and evaluation training, and procedures for confidential data entry and transfer. The existing literature recommends several strategies to augment insufficient data from traditional health surveillance. Andresen et al. (2004) suggest methodological approaches such as aggregation, spatial smoothing, small area estimation and exact statistics.[65] Sentinel surveillance, population-based sample surveys, community-based observations, and syndromic surveillance can also be used as surrogates for more widespread surveillance.[65,66] The capacity to generate high quality surveillance data in northern, rural/remote populations, such as those in NWT, may exist if innovative, informal and population-specific approaches are considered and applied to public health surveillance.

In 2011, the Department of Health and Social Services (DHSS), GNWT, introduced a new electronic tool to improve surveillance for NGI. The application, called DHSS Tools, is a restricted-access site which includes a case reporting module (environmental health - food and waterborne illness investigation) that can be used by community public health officers, disease consultants, epidemiologists and environmental health officers to ensure better communication, follow-up, decision-making, and completeness of information.

In summary, the results of the study indicate that giardiasis, salmonellosis and campylobacteriosis were the most important enteric diseases in NWT from 1991 through 2008, and the incidence declined in later years of the study period. There was increased risk of NGI in the late summer and early fall, in infants and children, males and urban residents. The geographical distribution of case-patients varied by disease suggesting that environmental and behavioral risk factors played key roles in infection and may provide opportunities for prevention. For future study, multivariable regression and spatial analyses at the community level are necessary for valid risk factor identification as well as for implementing specific and geographically-appropriate risk reduction and control strategies. It is anticipated that this information will guide future research as well as the allocation of resources for prevention, promotion and control initiatives.

COMPETING INTERESTS

None

ACKNOWLEDGMENTS

The authors gratefully acknowledge the Government of the Northwest Territories Health and Social Services Department and Bureau of Statistics for providing the data to complete this study. This work was supported by Nasivvik Centre for Inuit Health and Changing Environments.

CONTRIBUTORSHIP

APA contributed to the manuscript through study design and planning, data collection, analysis and interpretation of results, drafting of manuscript and response to editorial comments and preparation of final manuscript for submission. JW, VLE, CF, RRS and SAM contributed to the manuscript through study design and planning, consultation on study progress, troubleshooting, data analysis and interpretation of results, reviewing and commenting on manuscript drafts. MS contributed to the manuscript through data collection, interpretation of results and reviewing and commenting on manuscript drafts.

DATA SHARING

The dataset may be requested from Population Health, Department of Health and Social Services, Government of the Northwest Territories (www.hlthss.gov.nt.ca).

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Table 1. Notifiable gastrointestinal illnesses (NGI) and associated percent missing or unspecified values, by field and disease, Northwest Territories, Canada, 1991-2008.

	Notifiable Disease Report Form Fields - Percent Missing Values							
Disease / Agent (number of reported cases 1991-2008)	**Age**	**Gender**	**Community**	**Health Unit**	**Report Date**	**Etiologic Agent**	**Subtype**	**Suspected exposure**
Amoebiasis (n=10)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	60.0
Botulism (n=8)	0.0	0.0	0.0	0.0	0.0	0.0	12.5	25.0
Brucellosis (n=3)	0.0	0.0	0.0	33.3	0.0	0.0	66.7	66.7
Campylobacteriosis (n=175)	0.0	0.0	2.3	0.6	0.0	0.0	0.0	79.4
Cryptosporidiosis (n=18)	0.0	0.0	11.1	0.0	0.0	0.0	0.0	100.0
E. coli (VTEC) (n=40)	0.0	0.0	12.5	0.0	0.0	0.0	0.0	62.5

Food Poisoning[*] (n=10)	0.0	0.0	0.0	0.0	0.0	0.0	100.0	10.0
Giardiasis (n=205)	0.0	0.0	3.9	0.0	0.0	0.0	0.0	73.7
Hepatitis A (n=10)	0.0	0.0	10.0	0.0	0.0	0.0	0.0	90.0
Listeriosis (n=1)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0
Salmonellosis (n=202)	0.0	0.0	0.0	4.5	0.0	0.0	0.0	70.8
Shigellosis (n=12)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	83.3
Tapeworm (n=7)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	57.1
Tularemia (n=1)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0
Yersiniosis (n=6)	0.0	0.0	16.7	0.0	0.0	0.0	0.0	100.0
Total NGI Cases (n=708)	**0.0**	**0.0**	**2.6**	**0.1**	**0.0**	**0.0**	**1.8**	**73.2**

[*] Includes 5 cases due to clostridium and 5 cases due to bacillus. Infections from these agents are not notifiable unless they are from food poisoning.

Table 2. Percentage distribution of reported suspected sources of infection for notifiable gastrointestinal illness, campylobacteriosis, giardiasis and salmonellosis, Northwest Territories, Canada, 1991-2008.

	Percent of cases attributed to suspected exposure			
Suspected Exposure (%)	**NGI**	**Campylobacteriosis**	**Giardiasis**	**Salmonellosis**
Beef	6.8	2.8	3.7	3.4
Caribou	6.3	2.8	5.6	5.1
Fish/Seafood	3.2	11.1	0.0	1.7
Muktuk (Whale)	1.6	0.0	0.0	0.0
Pork	4.7	2.8	0.0	13.6
Poultry/eggs	18.9	38.9	1.9	33.9
Seal	0.5	0.0	0.0	0.0

Foodborne unknown	28.4	41.7	5.6	37.3
Untreated water	27.9	0.0	81.5	0.0
Waterborne unknown	0.5	0.0	1.9	5.1
Perinatal transmission	0.5	0.0	0.0	0.0
Person-to-person	0.5	0.0	0.0	0.0

FIGURES

Figure 1: Annual incidence rates of notifiable gastrointestinal illness (total and cause-specific for giardiasis, salmonellosis and campylobacteriosis). Northwest, Territories, Canada, 1991 to 2008.

Figure 2: Incidence of notifiable gastrointestinal illness (total and cause-specific for giardiasis, salmonellosis and campylobacteriosis) by age-group, Northwest Territories, Canada, 1991 to 2008.

Figure 3: Incidence of notifiable gastrointestinal illness (total and cause-specific for giardiasis, salmonellosis and campylobacteriosis) by month, Northwest Territories, Canada, 1991 to 2008.

Figure 4: Map of incidence rates per 100,000 population for reported cases of notifiable gastrointestinal illness (NGI). Northwest Territories. 1991 to 2008.

Figure 5: Map of incidence rates per 100,000 population for reported cases of campylobacteriosis. Northwest Territories. 1991 to 2008.

Figure 6: Map of incidence rates per 100,000 population for reported cases of salmonellosis. Northwest Territories. 1991 to 2008.

Figure 7: Map of incidence rates per 100,000 population for reported cases of giardiasis. Northwest Territories. 1991 to 2008.

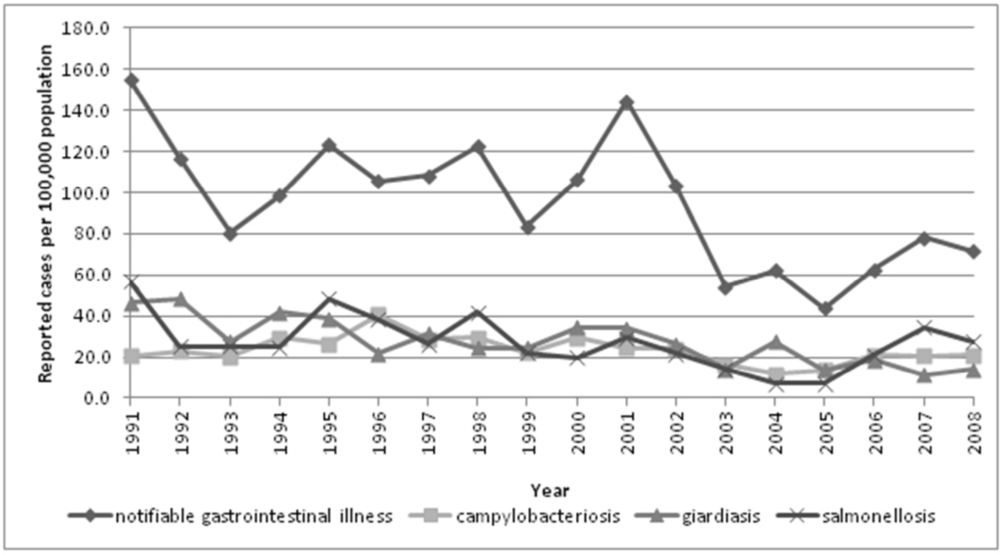

Figure 1 Annual incidence rates of notifiable gastrointestinal illness (total and cause-specific for giardiasis, salmonellosis and campylobacteriosis). Northwest, Territories, Canada, 1991 to 2008
166x92mm (96 x 96 DPI)

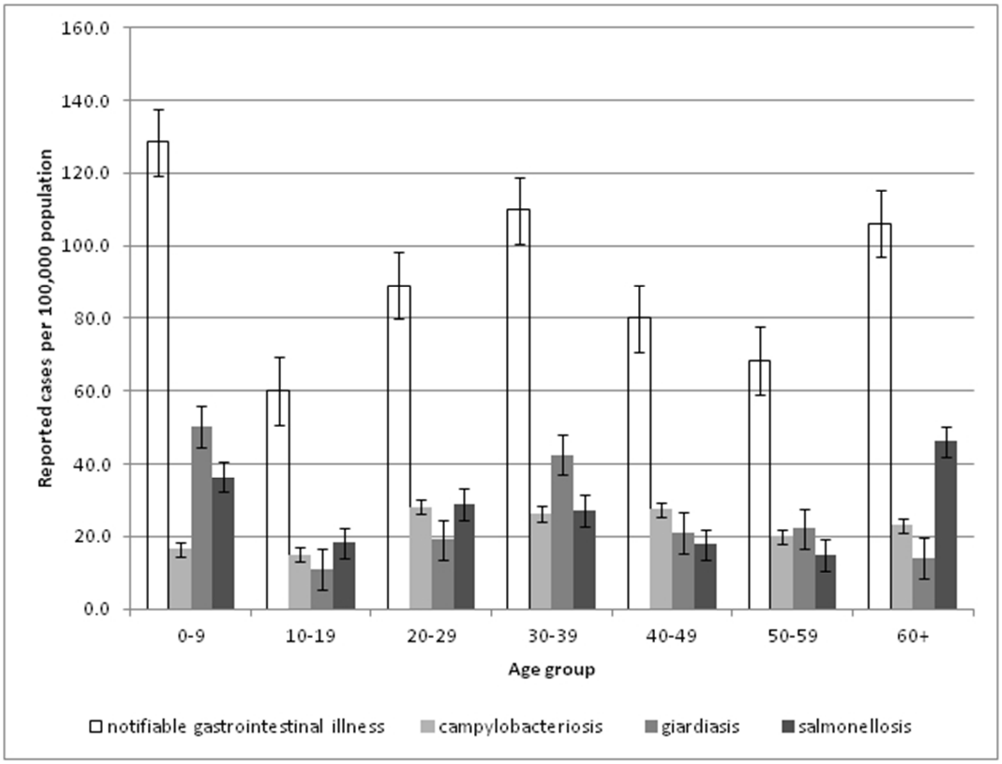

Figure 2 Incidence of notifiable gastrointestinal illness (total and cause-specific for giardiasis, salmonellosis and campylobacteriosis) by age-group, Northwest Territories, Canada, 1991 to 2008
166x127mm (96 x 96 DPI)

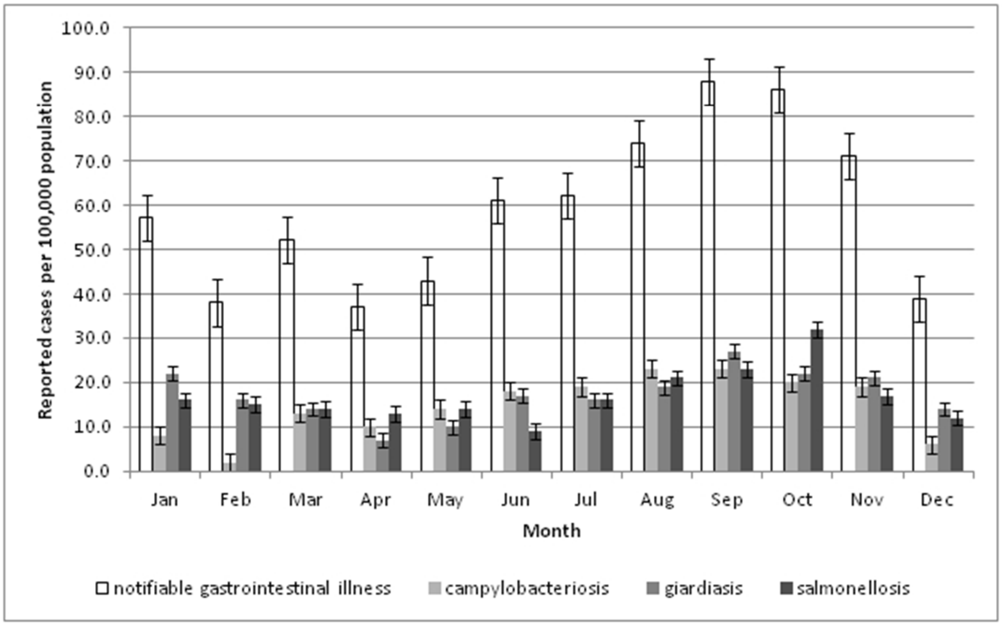

Figure 3 Incidence of notifiable gastrointestinal illness (total and cause-specific for giardiasis, salmonellosis and campylobacteriosis) by month, Northwest Territories, Canada, 1991 to 2008
166x103mm (96 x 96 DPI)

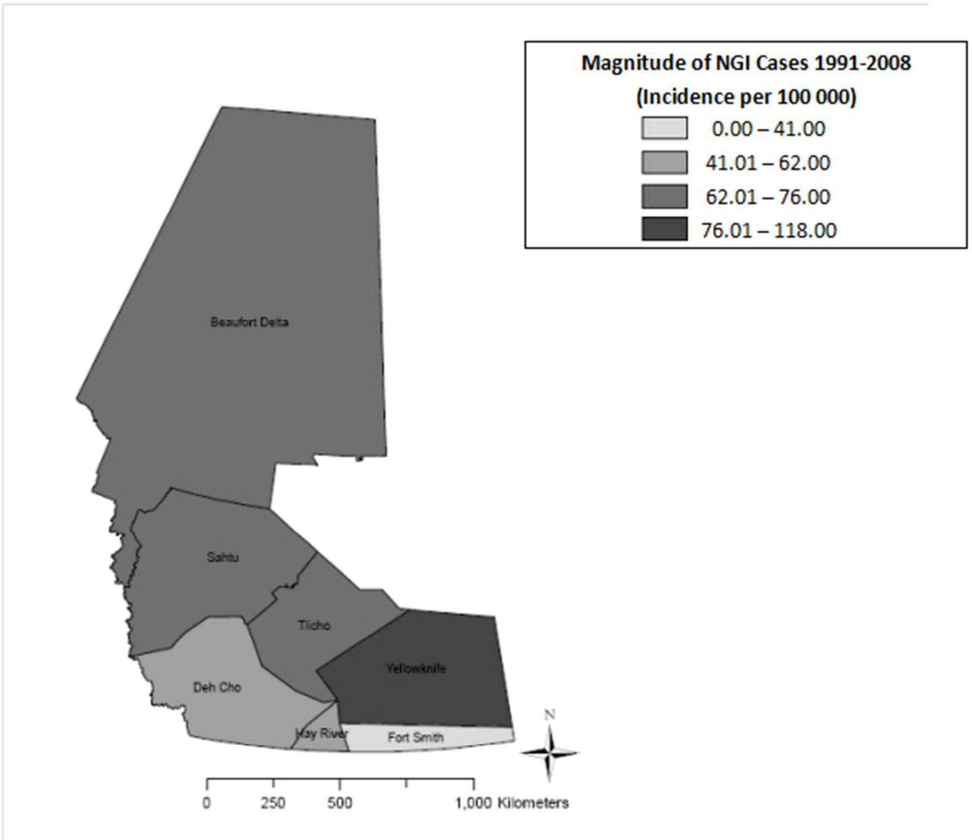

Figure 4 Map of incidence rates per 100,000 population for reported cases of notifiable gastrointestinal illness (NGI). Northwest Territories. 1991 to 2008
163x139mm (96 x 96 DPI)

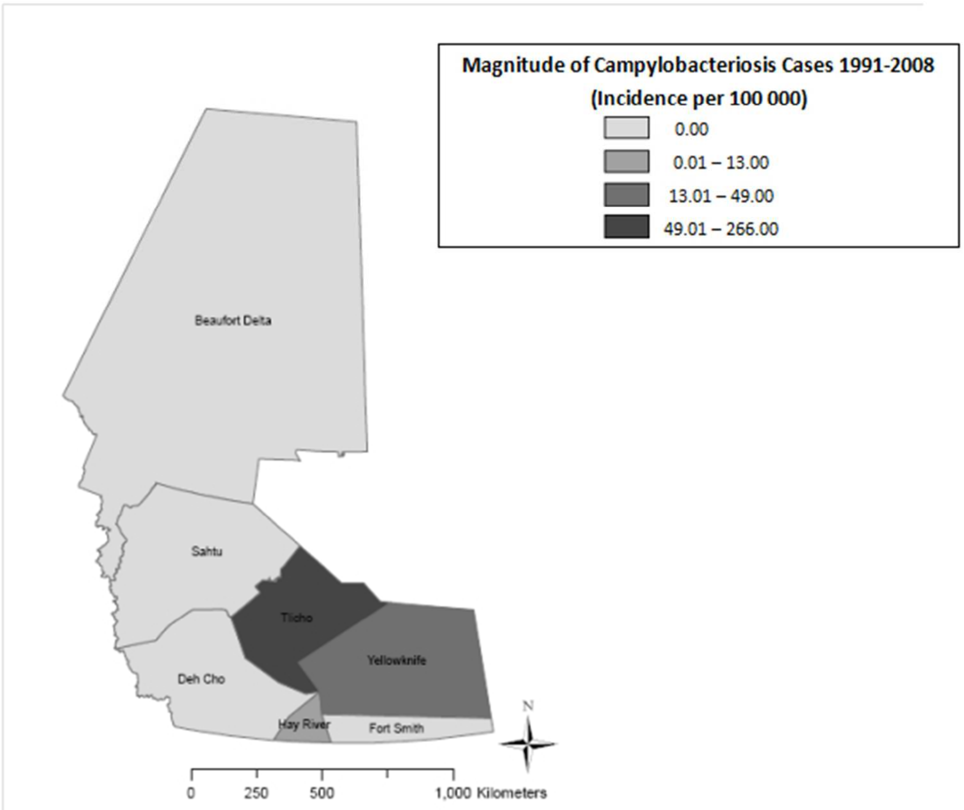

Figure 5 Map of incidence rates per 100,000 population for reported cases of campylobacteriosis. Northwest Territories. 1991 to 2008
166x137mm (96 x 96 DPI)

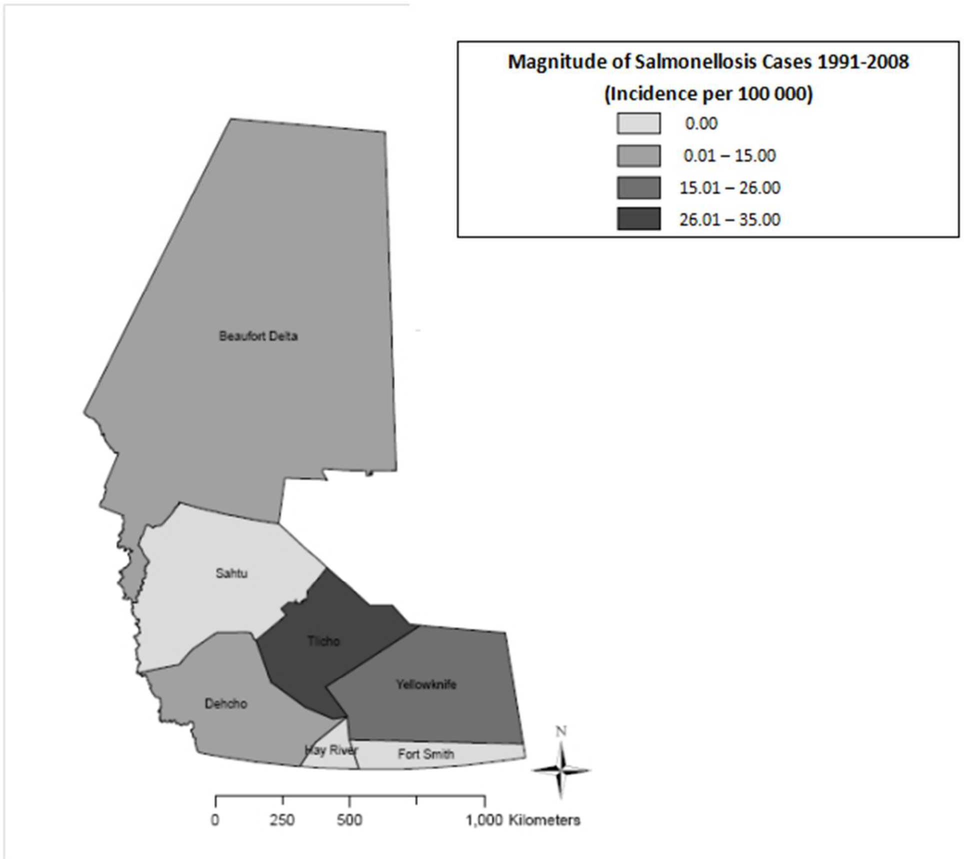

Figure 6 Map of incidence rates per 100,000 population for reported cases of salmonellosis. Northwest Territories. 1991 to 2008
172x150mm (96 x 96 DPI)

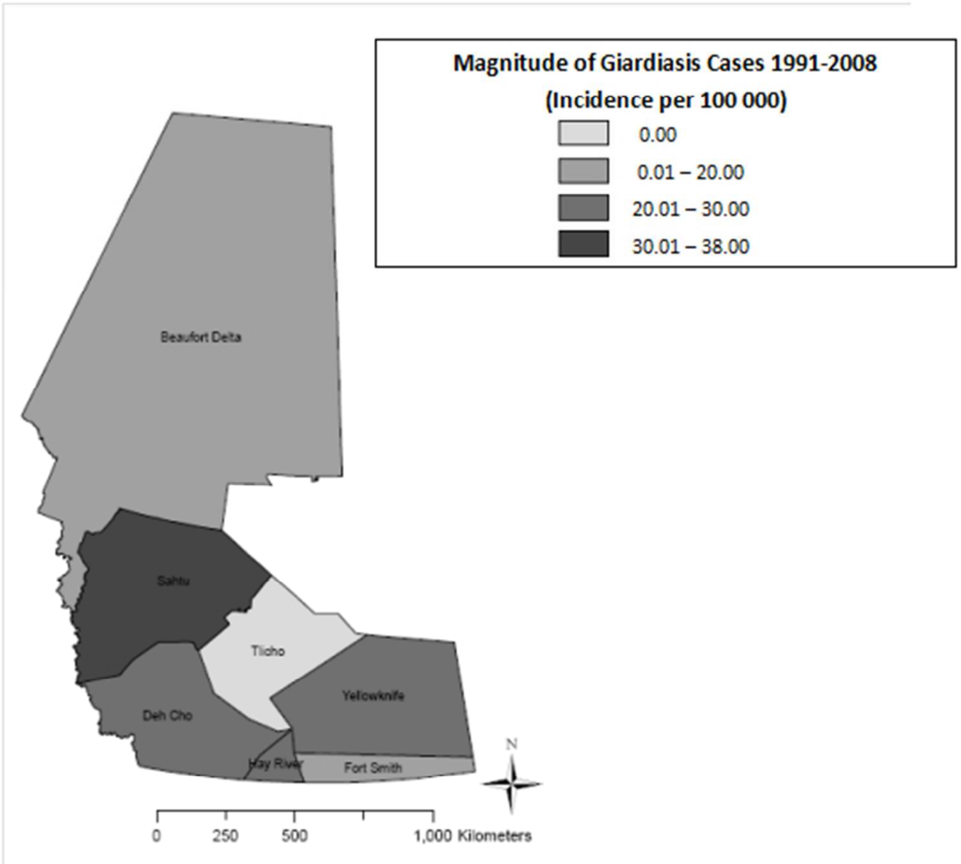

Figure 7 Map of incidence rates per 100,000 population for reported cases of giardiasis. Northwest Territories. 1991 to 2008
149x130mm (96 x 96 DPI)

STROBE 2007 (v4) checklist of items to be included in reports of observational studies in epidemiology*

Checklist for cohort, case-control, and cross-sectional studies (combined)

Section/Topic	Item #	Recommendation	Reported on page #
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	2
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	2, 3
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	5-7
Objectives	3	State specific objectives, including any pre-specified hypotheses	6
Methods			
Study design	4	Present key elements of study design early in the paper	9
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	7
Participants	6	(*a*) *Cohort study*—Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up *Case-control study*—Give the eligibility criteria, and the sources and methods of case ascertainment and control selection. Give the rationale for the choice of cases and controls *Cross-sectional study*—Give the eligibility criteria, and the sources and methods of selection of participants	N/A
		(*b*) *Cohort study*—For matched studies, give matching criteria and number of exposed and unexposed *Case-control study*—For matched studies, give matching criteria and the number of controls per case	N/A
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	7-8
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	*7-8*
Bias	9	Describe any efforts to address potential sources of bias	18
Study size	10	Explain how the study size was arrived at	N/A
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	8-9
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	8-9
		(*b*) Describe any methods used to examine subgroups and interactions	8-9
		(*c*) Explain how missing data were addressed	8-9
		(*d*) *Cohort study*—If applicable, explain how loss to follow-up was addressed *Case-control study*—If applicable, explain how matching of cases and controls was addressed	N/A

		Cross-sectional study—If applicable, describe analytical methods taking account of sampling strategy	
		(*e*) Describe any sensitivity analyses	N/A
Results			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	9,30-31
		(b) Give reasons for non-participation at each stage	N/A
		(c) Consider use of a flow diagram	N/A
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	7-9,32
		(b) Indicate number of participants with missing data for each variable of interest	9,21
		(c) *Cohort study*—Summarise follow-up time (eg, average and total amount)	N/A
Outcome data	15*	*Cohort study*—Report numbers of outcome events or summary measures over time	N/A
		Case-control study—Report numbers in each exposure category, or summary measures of exposure	N/A
		Cross-sectional study—Report numbers of outcome events or summary measures	N/A
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	N/A
		(*b*) Report category boundaries when continuous variables were categorized	N/A
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	N/A
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	N/A
Discussion			
Key results	18	Summarise key results with reference to study objectives	11-17
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	18
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	18-20
Generalisability	21	Discuss the generalisability (external validity) of the study results	12
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	20

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.

A Descriptive Analysis of Notifiable Gastrointestinal Illness in the Northwest Territories, Canada, 1991-2008

Journal:	*BMJ Open*
Manuscript ID:	bmjopen-2011-000732.R2
Article Type:	Research
Date Submitted by the Author:	25-May-2012

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Primary Subject Heading:	Epidemiology
Secondary Subject Heading:	Infectious diseases, Gastroenterology and hepatology
Keywords:	Gastrointestinal infections < GASTROENTEROLOGY, Epidemiology < INFECTIOUS DISEASES, Quality in health care < HEALTH SERVICES ADMINISTRATION & MANAGEMENT, Public health < INFECTIOUS DISEASES

Title:

A Descriptive Analysis of Notifiable Gastrointestinal Illness in the Northwest Territories, Canada, 1991-2008

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Medical Subject Headings-Key Words:

Gastrointestinal illness, Foodborne Diseases, Minority Health, Population Surveillance

Word count: 4566

ABSTRACT

Objectives: To describe the major characteristics of reported Notifiable Gastrointestinal Illness (NGI) data in the Northwest Territories (NWT) from January 1991 through December 2008.

Design: Descriptive analysis of 708 reported cases of NGI extracted from the Northwest Territories Communicable Disease Registry (NWT CDR).

Setting: Primary, secondary and tertiary health care centers across all 33 communities of the NWT.

Population: NWT residents of all ages with confirmed NGI reported to the NWT CDR from January 1991 through December 2008.

Main Outcome Measure: Laboratory-confirmed NGI, with a particular emphasis on campylobacteriosis, giardiasis, and salmonellosis.

Results: Campylobacteriosis, giardiasis and salmonellosis were the most commonly identified types of NGI in the territory. Seasonal peaks for all three diseases were observed in late summer to autumn ($p<0.01$). Higher rates of NGI (all 15 diseases/infections) were found in the 0 to 9 years age group and in males ($p<0.01$). Similarly, rates of giardiasis were higher in the 0 to 9 years age group and in males ($p<0.02$). A disproportionate burden of salmonellosis was found in people 60 years and older and in females ($p<0.02$). Although not significant, the incidence of campylobacteriosis was greater in the 20 to 29 years age group and in males ($p<0.07$). The health authority with the highest incidence of NGI was Yellowknife ($p<0.01$) while for salmonellosis and campylobacteriosis it was Tlicho ($p<0.01$) and for giardiasis, the Sahtu region ($p<0.01$). Overall, disease rates were higher in urban areas ($p<0.01$).

Contaminated eggs, poultry and untreated water were believed by health practitioners to be important sources of infection in cases of salmonellosis, campylobacteriosis and giardiasis, respectively.

Conclusion: The general patterns of these findings suggest that environmental and behavioral risk factors played key roles in infection. Further research into potential individual and community-level risk factors is warranted.

ARTICLE SUMMARY

Article Focus

- To date, there is very little baseline data on notifiable gastrointestinal illness (NGI) diseases in the Northwest Territories (NWT), where Aboriginal people constitute a majority of the population. The demographic, socio-cultural, and health conditions of northern Aboriginal people are markedly different from those of other Canadian populations.

- There is a clear need to identify the major characteristics of reported NGI in order to generate hypotheses, guide future studies, and help public health officials target resources, interventions or increased surveillance to areas of greatest need in the NWT.

Key Messages

- The annual average rate of NGI over the study period was 95.5 cases per 100,000 with increased risk in the 0 to 9 years age group and males.

- Reported rates of NGI declined from 1991 to 2008 however, seasonal peaks were observed in late summer and autumn.

Comment [TA1]: Reviewer 1: My earlier comment about seasonal peaks has not been fully addressed in lines 33-34 and 206-209 the authors indicate late summer and autumn peaks but in lines 61-62 they note spring and fall peaks. I believe lines 61 and 62 should be edited for consistency and accuracy.

APA: I apologize - I have corrected lines 61-62.

- There was variability in the rates of NGI with higher notifications in the southern, urban areas compared to the northern, rural/remote areas of the territory suggesting the possible involvement of geographical risk factors and/or bias in the surveillance data.

Strengths and Limitations

- The study provides a historical portrait of NGI as the Northwest Territories Communicable Disease Registry (NWT CDR) broadly covered the entire territory over 18 years, therefore allowing comparisons across communities and time periods.

- Due to under-reporting, the rates of infections reported in this study are likely underestimates of the true incidence of diseases and therefore, should be interpreted as reporting rates rather than as incidence rates.

- Suspected sources of infection are infrequently confirmed by microbiological testing therefore, the results regarding 'suspected exposure' must be viewed with caution and be thought of as hypotheses.

BACKGROUND

Notifiable gastrointestinal illness (NGI) is an important global public health issue and a growing concern in the Northwest Territories (NWT), where Aboriginal people constitute a majority of the population.[1]. The Aboriginal population of the NWT maintains strong ties to the environment, continually adapting and learning to use available resources to provide food and other necessities, sustain livelihoods, and reinforce social relations.[2] Foods obtained by harvesting, hunting, fishing and trapping are referred to as traditional or country foods. About 40 to 60% of NWT residents living in remote and/or isolated communities rely on country food for 75% or more of their meat and fish consumption.[3]

Country foods in the NWT vary by geographic area, season, climate and availability and include items such as caribou, moose, ducks, geese, seals, hare, grouse, ptarmigan, lake trout, char, inconnu, white fish, pike, and burbot.[4, 5] Due to the harsh climate, animal products are the staple, and fresh vegetables and fruits provide additional nutrients when available. During the short summers, items such as blueberries, cranberries, blackberries and cloudberries are gathered, both for eating fresh and for drying or freezing to eat during the winter.[4] The consumption of untreated water from lakes, creeks, and rivers in the summer or from melted ice or snow in winter and spring is also common practice during subsistence activities.[6]

A well-balanced diet is primarily achieved by consuming muscle meat and other parts of the animals (raw or with minimal processing) such as the stomach, liver and fat which contain iron, calcium and a range of vitamins.[7] Common traditional meats are also an excellent source of protein and are lower in fat compared to meats eaten in Southern Canada. Seal and whale are a good source of omega-3 fatty acids which help reduce the risk of chronic conditions such as cardiovascular disease.[7] Although the traditional diet is nutritious, it is also very high in calories. High caloric intake is an adaptation feature that enables residents of the North to keep warm through the long, frigid winters.[5]

Sharing food is a key element of the Aboriginal culture in the NWT. Traditionally, when hunters return to communities with fresh game or fish, it is distributed according to social rules or convention.[2] Meals are communal and fresh, uncooked animal-derived foods are first given out to people who are cold or hungry, then to the rest of the community, and finally, the remaining portion is shared within the household. The distribution and consumption of raw meats can occur several times in a week.[2]

Activities such as hunting, fishing and trapping as well as the traditional preparation, storage and consumption of wild game, seafood and untreated water can increase exposure to pathogenic agents in the environment.[8] Illness can result from the ingestion of micro-organisms in contaminated food or water, through contact with animals or other contaminated objects, and some infections can be further spread by person-to-person transmission.[9] Symptoms can include loss of appetite, abdominal cramps, diarrhea of variable severity, nausea, vomiting, and fever.[10] Estimates of the overall morbidity and identification of potential risk factors for NGI in the NWT have not been previously published in the literature and hence, there is very little baseline data to inform policies and guide public health interventions in the territory. Using data elements extracted from cases of NGI in the Northwest Territories Communicable Disease Registry (NWT CDR), this study provides a descriptive analysis of reported NGI in the NWT from January 1991 through December 2008.

METHODS

Study Area

The NWT is located in Northern Canada with a majority Aboriginal population (50.3%).[11] As of the 2006 Census, the population was 41,464, an increase of 11% from 2001.[3] There are 33 officially recognized communities across 1,140,835 km^2 of land; the smallest is Kakisa with 52 residents and the largest is Yellowknife with 18,700 residents.[12] The NWT population density is 0.03 people per km^2. There is a high proportion of children under 15 years of age (23.9%) and a low proportion of people over 65 years of age (4.7%).[12] The median age for both sexes is 31 years; males comprise a majority of the population (51.2%).[12]

Data Sources

Data on reported cases of NGI for the period January 1991 through December 2008 were obtained from the NWT CDR. Reported NGI is an umbrella term for 15 enteric, food- and waterborne conditions that were reportable under the NWT Public Health Act during the study period: amoebiasis, botulism, brucellosis, campylobacteriosis, cryptosporidiosis, infection with *Escherichia coli*, food poisoning, giardiasis, hepatitis A, listeriosis, salmonellosis, shigellosis, tapeworm, tularemia, and yersiniosis. Ethics approval was obtained from the University of Guelph Research Ethics Board, the Government of the Northwest Territories, and the Aurora Research Institute.

The NWT Communicable Disease Manual provides guidelines to assist public health practitioners with decision making about specific situations, and to support consistency of territorial public health practice;[13] therefore the general procedures for notification remained

Comment [TA2]: Reviewer 1: Line 142-is there a referene (even online) for the NWT CD Manual?

APA: Please see reference 13

consistent over the study period. Upon symptomatic presentation of NGI as described in the Manual, health practitioners send the patient's clinical specimen to the laboratory for confirmation and sero-typing. The patient's demographic information, food and water histories are collected by the health practitioner and manually-entered into the food and waterborne illness investigation form. The paper form is submitted to the Population Health Division of the Government of the Northwest Territories Department of Health and Social Services. Health practitioners and laboratories are required to report patients with confirmed NGI to the Population Health Division within 24 hours. Once the paper form is received, disease registry officers at the territorial level collate, verify, enter, and disseminate illness investigation data electronically through the Integrated Public Health Information System (i-PHIS) for inclusion into the NWT CDR and the National Notifiable Disease database at the Public Health Agency of Canada.[13]

Comment [TA3]: Reviewer 1: Line 155 and throughout-I could not find a definition of NWT CDR. Please inidicate what the acronymn is and my apologies if it is noted earlier and I missed it.

APA: Please see line 24 in abstract, line 67 in key messages and line 117 in background.

Case notification data, stripped of personal identifiers, were received for 15 diseases/infections and associated fields listed in Table 1; none of these fields was considered mandatory at the time of notification. A geographical conversion database was used to assign case-patients to their respective census subdivision (community), Health and Social Services Authority (HSSA) as well as assign them a status of rural or urban location; cases were classified as urban if reported at a health center located in a community of at least 1,000 persons and 400 persons / sq km, others were classified as rural.[3, 12]

Data Quality Evaluation and Descriptive Analyses

Data quality evaluation involved manually checking data associated with each case for completeness and internal consistency. Missing values were replaced with the term "unspecified". The numbers and percentages related to "unspecified" values were calculated for each field.

Population denominators for each year were obtained from the NWT Bureau of Statistics and the mean annual age-specific rates of disease were calculated for the territory. The average annual number of cases was calculated using the total number of notifications divided by 18 years. Data manipulation and statistical analyses were conducted in SPSS version 17 (SPSS Inc., Chicago, Illinois) and choropleth maps of disease rates by health authority were created in ArcView GIS version 3.1 (ESRI, Redlands, California). Means and medians were used to describe the data; medians were used when dealing with highly skewed distributions. A least squares regression analysis was used to determine the rate of change over time. Fischer's Exact tests were used to determine statistical significance [$p<0.05$ (two-tailed)] for categorical variables. Community level risk factors for NGI are reported elsewhere.[14]

RESULTS

The percentages of missing or unspecified values for the nine fields considered in the analysis are also shown in Table 1.

From the 708 case-patients with NGI from all years, 458 (64.7%) had bacterial infections, 240 (33.9%) had parasitic infections and 10 (1.4%) had viral (hepatitis A) infections. The three largest contributors to the total number of notifications were giardiasis with 205 cases (29.0%), salmonellosis with 202 cases (28.5%) and campylobacteriosis with 175 cases (24.7%). Too few cases were attributed to other agents (<6% each) to draw inferences, therefore, the focus of the rest of this paper was on the three most commonly notified diseases.

The annual reported incidence rates of NGI (total and cause-specific for giardiasis, salmonellosis and campylobacteriosis) are shown in Figure 1. A least squares regression analysis indicated that the incidence of NGI decreased by 3.7 ($p<0.01$) cases per 100,000 per year over the study period. Giardiasis and salmonellosis decreased by 1.7 ($p< 0.01$) and 1.2 ($p<0.01$) cases per 100,000 per year, respectively, but there was no significant ($p<0.13$) linear change in incidence of campylobacteriosis. A majority of campylobacteriosis (85.7%), giardiasis (62%), and salmonellosis (58.4%) cases were reported from health facilities in urban areas ($p<0.01$).

The average annual incidence of NGI (total and cause-specific for giardiasis, salmonellosis and campylobacteriosis) by age-group are shown in Figure 2. The highest rates of NGI (128.5 cases per 100,000) were observed in the 0 to 9 years age group with 56% of cases occurring in males ($p<0.01$). The highest rates of giardiasis (50.4 cases per 100,000) were also found in the 0 to 9 years age group with 57% of cases occurring in males ($p<0.02$). The highest rates of salmonellosis (46.1 cases per 100,000) were found in the 60+ years age group with 51% occurring in females ($p<0.02$). Although not significant ($p<0.07$), the highest rates of campylobacteriosis were observed in the 20 to 29 years age group for campylobacteriosis (28.2 cases per 100,000) with 53% of cases occurring in males.

Table 2 shows that the most frequently suspected vehicle for NGI was contaminated food ($p<0.01$). The probable source of giardiasis was most often attributed to untreated water whereas for campylobacteriosis and salmonellosis it was poultry and eggs, respectively ($p<0.01$).

Figure 3 show that cases of NGI ($p<0.01$) and more specifically campylobacteriosis ($p<0.01$) and salmonellosis ($p<0.04$), occurred more frequently in the late summer and early fall.

Although not significant (p<0.07), giardiasis showed a similar trend on visual inspection of the data.

As shown in Figure 4, the highest median annual incidence of NGI (118.0 cases per 100,000) was observed in Yellowknife HSSA (p<0.01) whereas the lowest median annual incidence (41.0 cases per 100,000) was found in Fort Smith HSSA (p<0.01). Figure 5 shows that the highest median annual incidence of campylobacteriosis (265.5 cases per 100,000) was found in Tlicho (p<0.01) whereas the lowest median annual incidence (0.0 cases per 100,000) was found in Beaufort Delta, Dehcho, Fort Smith, and Sahtu HSSAs (p<0.01). Figure 6 shows the highest median annual incidence of salmonellosis (35.0 cases per 100,000) was also found in Tlicho HSSA (p<0.01) however the lowest median annual incidence (0.0 cases per 100,000) was found in Fort Smith, Hay River, and Sahtu HSSAs (p<0.01). Figure 7 shows highest median annual incidence of giardiasis (38.0 cases per 100,000) was found in the Sahtu HSSA (p<0.01) whereas the lowest median annual incidence (0.0 cases per 100,000) was found in Tlicho HSSA (p<0.01).

DISCUSSION

The results of this study suggest that NGI is an important health problem in the NWT and that giardiasis, salmonellosis and campylobacteriosis account for the great majority (82.2%) of reported NGI in the territory. The mean annual reported rate of these three enteric diseases in the NWT was 78.0 cases per 100,000, which is less than reported for Ontario (87.0 cases per 100,000) and British Columbia (145.8 cases per 100,000) based on notifiable disease data from 1991 through 2008.[9] This may suggest that compared to some southern areas as of Canada, NWT residents may be at deceased risk of infection or alternatively, there may be a higher degree of under-reporting in the territory;[15, 16] further investigation is required. Previous studies have shown that about one out of 313 (Ontario) to 350 (British Columbia) cases of acute gastrointestinal illness are captured by surveillance systems.[17, 18] Using these adjustment factors from Ontario and British Columbia, we estimate that between 182,748 and 204,282 cases of campylobacteriosis, giardiasis and salmonellosis, collectively, may have occurred in the NWT over the 18 years.[10, 11, 19] Several explanations for under-reporting have been proposed, such as cases not presenting to medical facilities, health workers not submitting clinical samples to laboratories, laboratory test sensitivity issues, absence or delay of reporting from local to territorial health authorities. Patients may not seek medical attention because symptoms are mild and self-limiting, they may be too ill to travel, or they may prefer to seek treatment from local healers.[19] These tendencies are exacerbated in rural/remote communities of the NWT due to the relative paucity of available health services, facilities, and health professionals. Increased distances to health facilities and transportation problems further aggravate other barriers to accessing the health systems in rural/remote settings in northern communities.[15, 16] There are no data addressing possible geographical reporting biases in the NWT; therefore, research to characterize and quantify reporting bias in the NWT CDR is needed. Reduction of under-reporting and differential reporting (if it does exist) would require increased awareness of community health practitioners about the potential usefulness of surveillance data and therefore, the need to improve their quality.

In the NWT, seasonal peaks over the study period may have been attributed to social environmental factors such as higher ambient temperatures, frequent travel for subsistence activities, centralized outdoor meal preparation as well as the consumption of country foods and surface water.[4, 6, 20-23] Therefore, control strategies, such as regular, coordinated public education and communication about known risk factors of the disease (e.g., drinking contaminated water, safe food preparation) would therefore need to be targeted during these seasons. Such public health programs need to take into account the wide geographic distribution of these communities, their cultural diversity and the number of languages used.[24] Community-oriented media such as local television and radio, have proven to be successful methods of reaching rural/remote populations by providing a forum for which health issues can be identified and discussed thus, increasing general awareness.[25-27]

Fluctuations in rates of NGI over the 18 years are likely to be explained, at least in part, by random variation due to small number of cases. The peaks in 1995 and 2001 also coincide with known outbreaks of salmonellosis and cryptosporidiosis, respectively.[28] The incidence of NGI however, declined over the last few years of the study period (since 2002), which is consistent with observed trends in Southern Canada and the USA. The decline may attributed to effective, ongoing efforts to improve food and water quality or an artifact of diagnostic procedures, reporting practices or changes in population demographics.[29, 30] The extent to which these factors may have contributed to a decrease in incidence is unknown but it is an important topic for future research. The statistically significant decreasing trend of NGI incidence however, is inconsistent with predicted temperature-driven increase of enteric disease in the North.[31] Since the 1940's (when record collection began), the average annual temperature in NWT has been increasing about 2°C and scientists predict that temperatures will continue to warm due to climate change.[32] The potential impact of warmer temperature on the incidence of NGI in the NWT should be further explored.

Spatial analysis revealed that the incidence of campylobacteriosis, giardiasis and salmonellosis varied substantially between health authorities. Higher or lower-than-expected

Comment [U4]: Reviewer 1: Lines 267-271. I think the note about pursuing further study around temperature change and GI illness is intereting but these sentences are unclear. Do you have a reference that indicates that temeprature has increased in NWT over this time period? Would it be more appropriate to reword that these factors should be explored?

APA: I have rephrased for clarity in lines 265-270.

rates in health authorities could be a result of disparities in the geographical distribution of risk factors and behaviors,[33] suggesting that further studies on population-level risk factors are warranted. Overall, NGI was reported more frequently in urban than rural areas, but the underlying reasons could not be evaluated with the available data. In theory, higher reporting rates in urban areas could reflect greater propensity for person-to-person transmission; however, this is more commonly seen with organisms with human reservoirs.[34] Other possibilities include greater accessibility, affordability and/or reliance on store-purchased foods, restaurant meals, and foreign travel as well as other population-level risk factors such as community water systems.[35] It is also possible that some infections were acquired in rural/remote areas of the NWT but were reported at health facilities in urban areas.[36] We expected exposure to these environmental or zoonotic pathogens to be more common in rural/remote areas, through contact with animals, their feces, as well as contaminated surface water and raw foods compared to urbanized areas.[37] Furthermore, higher disease rates could also be an artifact of differential reporting of cases or methods of data collection that vary by area or practitioners. Several studies have demonstrated that higher reporting rates in urban areas are often a function of the amount and type of available health services, rather than the occurrence of illness itself.[38-40]

Giardiasis was the most commonly reported infection in this study, reflecting its importance as an enteric pathogen in the territory. Giardiasis commonly occurs through the ingestion of infective cysts found in contaminated water, food, or infected persons by the fecal-oral route. The cysts can be present in contaminated wells and water systems, particularly those sourced from surface water such as fresh water lakes and streams. Person-to-person transmission also accounts for many *Giardia* infections and is usually associated with poor hygiene and sanitation. In the Arctic, cysts of *Giardia* spp. have been found in water, sewage and fecal samples of marine mammals harvested for food.[23] Our findings of higher rates in infants and children in NWT could be related to reporting bias, poor hygiene, more frequent exposure to communal facilities or recreational water, lack of protective immunity, or a combination of factors.[41, 42] High rates in patients 30 to 39 year of age may also be at least partially attributed to contact with infected children as parents or as caregivers, and these persons are possibly more likely to seek medical care and therefore more likely to be captured by the surveillance system.[43] The higher rate of giardiasis in males is unexplained, but has also been noted in other studies.[44] In the NWT, gender may act as a surrogate for true causal variables related to exposure, such as the consumption of untreated surface water or contaminated traditional foods, particularly while carrying out subsistence activities in northern areas of the NWT. Consistent with previous research, the incidence of giardiasis in this study was higher in the late summer and autumn months, which may be related to greater environmental exposure during leisure and subsistence activities, potentially greater likelihood of infectious levels of cysts in water at this time of year, or exposure to contaminated recreational water that favors indirect person-to-person transmission.[45]

Salmonellosis, the second most frequently reported enteric infection, is commonly acquired through consumption of contaminated food of animal origin, mainly meat, poultry, eggs and milk, but also contaminated fruit and vegetables.[36] In the NWT, poultry/eggs were identified by those reporting illness as the most probable sources of this infection. Other suspected food vehicles included pork, caribou, beef, and fish/seafood; however, we do not know whether these vehicles were identified through epidemiological investigation, follow-up microbiological testing, or speculation by the health practitioner. Moreover, we do not know whether suspect foods were obtained through individual subsistence activities, community freezers, or retail locations making it difficult to hypothesize the source of microbial contamination; however, outbreaks of verotoxin-producing *Escherichia coli* O157:H7 (fourth highest notification) in the NWT have been attributed to frozen minced beef and caribou obtained from grocery stores and homes.[46, 47] Higher observed rates of salmonellosis in infants and children (0 to 9 years age group) and the elderly (60+ years age group) in this study have been noted in a previous study and may be related to lack of protective immunity or other factors mentioned for giardiasis.[41, 48, 49] Higher rates of disease in females are so far unexplained, but further research considering differences in food handling practices and hygiene as well as the types of foods consumed, may indicate their role in apparent gender differences.[50] Higher rates of infection in the late summer and autumn months may be attributable to environmental and social factors. These may include higher ambient temperatures, frequent travel as well as higher prevalence in food animal populations, centralized outdoor meal preparation and consumption related to large social gatherings.[20, 51]

Campylobacteriosis, the third most frequently reported infection, commonly occurs through the poor handling of raw poultry, and consumption of undercooked poultry, unpasteurized milk and contaminated drinking water. *Campylobacter* is also common in migratory birds and the consumption of fresh water from surface contaminated with bird feces could be a seasonal driver of this disease in the North.[52] In the NWT, the predominant mode of transmission was believed to be foodborne; poultry, eggs, pork, caribou, beef, and fish/seafood from unspecified sources, were once again identified as probable exposures for infection. Incidence rates were highest in adults 20 to 49 years of age. The relatively higher rates in young males noted in other studies have been thought to reflect poor hygiene and food handling practices.[53] As with other studies on campylobacteriosis, disease occurred more frequently in the late summer and autumn months.[54] Traditionally, in northern communities, hunting activities and the collection of plants, berries, and bird's eggs as well as the consumption of surface water occur more frequently during this time period.[4]. *Campylobacter* however, are more susceptible to freezing than other bacteria, therefore it is tempting to speculate that the colder northern climate may play a role in reducing exposure in food and water.

Cryptosporidium infections in humans may be from either human or animal origin, and no attempts were made to differentiate among strains in this study. The apparent low incidence of pathogens such as *Cryptosporidium* (2.4 cases per 100,000) in the NWT may be due to the lack of exposure to agricultural animals in the North.[55] Domestic livestock, including beef and dairy cattle as well as sheep are often perceived to be the leading environmental source of waterborne pathogens,[56] although contamination from human sewage also occurs. Animals shed oocysts through manure contributing to the *Cryptosporidium* load of drinking water sources [57]. Several studies have shown that concentrations of *Cryptosporidium* are significantly higher in agricultural rather than non-agricultural watersheds.[58, 59] The role of wildlife as a source of *Cryptosporidium* is less clear in published literature. A study conducted over a 4-year period in Northern Alaska found that the prevalence of *Cryptospordium* spp. in fecal samples of marine mammals from subsistence hunts was highest in ringed seals (22.6%) followed by right whales (24.5%) and bowhead whales (5.1%).[60] A study in Nunavik (Quebec, Canada) also found a prevalence of 9% in fecal samples of ringed seals.[61] These studies suggest that some animals used in traditional foods may be reservoirs for the disease in the north. In this study, caribou, muktuk, and seal were also suspected sources of infection for 8.4% of NGI cases; therefore, further evaluations of environmental risk factors in the NWT are warranted.

This study demonstrates the usefulness of surveillance data to guide epidemiological research and public health practice in northern communities. Of the nine reporting fields in the NWT CDR, eight had less than 5% of data missing; however, the field 'suspected exposure', unknown (missing) for 73.5% of the records, is a source of potential bias. Exposure information is frequently ascertained through an interview or questionnaire, thus, it is difficult to assess the extent to which recall or reporting bias has occurred and there are obvious limitations on the quality of exposure data obtained in this fashion. In addition, suspected sources are infrequently confirmed by microbiological testing, therefore, the results regarding the 'suspected exposure' must be viewed with considerable caution and can be thought of as hypotheses. For the data to be useful, particularly for risk factor identification, it is essential that the completeness of fields and hence, quality be improved. From 1991 to 2008, there were no mandatory fields enforced by the GNWT. Due to the contextual challenges of conducting surveillance in northern, rural/remote communities, the NWT CDR is based around the minimum data set concept, where the focus is on collecting the most essential data fields; however, these fields must be standardized and sufficiently detailed to support the delivery, planning and monitoring of public health initiatives. Although issues related to data quality are not unique to surveillance systems serving northern, rural/remote areas, they may be exacerbated when the systems serve sparse populations and have inadequate infrastructure, human and financial resources.[62] The implementation of electronic-based platforms for reporting have been shown to improve data quality and completeness in low-resource settings.[63,64]

Published knowledge on surveillance in rural/remote areas is sparse; as a result, very little has been recommended in terms of cohesive and effective approaches to enhance surveillance in these communities. The gap in the literature suggests that the development of a comprehensive public health surveillance system for rural/remote communities, which takes into account local realities and needs, is a priority area for research; however, this will require a collaborative effort from stakeholders, partners and knowledge-users of the system. Suggestions for moving forward include a collaborative design of suitable data elements, data collection protocols, data quality assurance, research and evaluation training, and procedures for confidential data entry and transfer. The existing literature recommends several strategies to augment insufficient data from traditional health surveillance. Andresen et al. (2004) suggest methodological approaches such as aggregation, spatial smoothing, small area estimation and exact statistics.[65] Sentinel surveillance, population-based sample surveys, community-based observations, and syndromic surveillance can also be used as surrogates for more widespread surveillance.[65,66] The capacity to generate high quality surveillance data in northern, rural/remote populations, such as those in the NWT, may exist if innovative, informal and population-specific approaches are considered and applied to public health surveillance.

In 2011, the Department of Health and Social Services (DHSS), GNWT, introduced a new electronic tool to improve surveillance for NGI. The application, called DHSS Tools, is a restricted-access site which includes a case reporting module (environmental health - food and waterborne illness investigation) that can be used by community public health officers, disease consultants, epidemiologists and environmental health officers to ensure better communication, follow-up, decision-making, and completeness of information.

In summary, the results of the study indicate that giardiasis, salmonellosis and campylobacteriosis were the most important enteric diseases in the NWT from 1991 through 2008, and the incidence declined in later years of the study period. There was increased risk of NGI in the late summer and early fall, in infants and children, males and urban residents. The geographical distribution of case-patients varied by disease suggesting that environmental and behavioral risk factors played key roles in infection and may provide opportunities for prevention. For future study, multivariable regression and spatial analyses at the community level are necessary for valid risk factor identification as well as for implementing specific and geographically-appropriate risk reduction and control strategies. It is anticipated that this information will guide future research as well as the allocation of resources for prevention, promotion and control initiatives.

COMPETING INTERESTS

None

ACKNOWLEDGMENTS

The authors gratefully acknowledge the Government of the Northwest Territories Department of Health and Social Services and Bureau of Statistics for providing the data to complete this study. This work was supported by Nasivvik Centre for Inuit Health and Changing Environments.

CONTRIBUTORSHIP

APA contributed to the manuscript through study design and planning, data collection, analysis and interpretation of results, drafting of manuscript and response to editorial comments and preparation of final manuscript for submission. JW, VLE, CF, RRS and SAM contributed to the manuscript through study design and planning, consultation on study progress, troubleshooting, data analysis and interpretation of results, reviewing and commenting on manuscript drafts. MS contributed to the manuscript through data collection, interpretation of results and reviewing and commenting on manuscript drafts.

DATA SHARING

The dataset may be requested from Population Health, Department of Health and Social Services, Government of the Northwest Territories (www.hlthss.gov.nt.ca).

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Table 1. Notifiable gastrointestinal illnesses (NGI) and associated percent missing or unspecified values, by field and disease, Northwest Territories, Canada, 1991-2008.

	Notifiable Disease Report Form Fields - Percent Missing Values							
Disease / Agent (number of reported cases 1991-2008)	**Age**	**Gender**	**Community**	**Health Unit**	**Report Date**	**Etiologic Agent**	**Subtype**	**Suspected exposure**
Amoebiasis (n=10)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	60.0
Botulism (n=8)	0.0	0.0	0.0	0.0	0.0	0.0	12.5	25.0
Brucellosis (n=3)	0.0	0.0	0.0	33.3	0.0	0.0	66.7	66.7
Campylobacteriosis (n=175)	0.0	0.0	2.3	0.6	0.0	0.0	0.0	79.4
Cryptosporidiosis (n=18)	0.0	0.0	11.1	0.0	0.0	0.0	0.0	100.0
E. coli (VTEC) (n=40)	0.0	0.0	12.5	0.0	0.0	0.0	0.0	62.5

Food Poisoning* **(n=10)**	0.0	0.0	0.0	0.0	0.0	0.0	100.0	10.0
Giardiasis (n=205)	0.0	0.0	3.9	0.0	0.0	0.0	0.0	73.7
Hepatitis A (n=10)	0.0	0.0	10.0	0.0	0.0	0.0	0.0	90.0
Listeriosis (n=1)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0
Salmonellosis (n=202)	0.0	0.0	0.0	4.5	0.0	0.0	0.0	70.8
Shigellosis (n=12)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	83.3
Tapeworm (n=7)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	57.1
Tularemia (n=1)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0
Yersiniosis (n=6)	0.0	0.0	16.7	0.0	0.0	0.0	0.0	100.0
Total NGI Cases (n=708)	**0.0**	**0.0**	**2.6**	**0.1**	**0.0**	**0.0**	**1.8**	**73.2**

* Includes 5 cases due to clostridium and 5 cases due to bacillus. Infections from these agents are not notifiable unless they are from food poisoning.

Table 2. Percentage distribution of reported suspected sources of infection for notifiable gastrointestinal illness, campylobacteriosis, giardiasis and salmonellosis, Northwest Territories, Canada, 1991-2008.

	Percent of cases attributed to suspected exposure			
Suspected Exposure (%)	**NGI**	**Campylobacteriosis**	**Giardiasis**	**Salmonellosis**
Beef	6.8	2.8	3.7	3.4
Caribou	6.3	2.8	5.6	5.1
Fish/Seafood	3.2	11.1	0.0	1.7
Muktuk (Whale)	1.6	0.0	0.0	0.0
Pork	4.7	2.8	0.0	13.6
Poultry/eggs	18.9	38.9	1.9	33.9
Seal	0.5	0.0	0.0	0.0

Foodborne unknown	28.4	41.7	5.6	37.3
Untreated water	27.9	0.0	81.5	0.0
Waterborne unknown	0.5	0.0	1.9	5.1
Perinatal transmission	0.5	0.0	0.0	0.0
Person-to-person	0.5	0.0	0.0	0.0

FIGURES

Figure 1: Annual incidence rates of notifiable gastrointestinal illness (total and cause-specific for giardiasis, salmonellosis and campylobacteriosis). Northwest, Territories, Canada, 1991 to 2008.

Figure 2: Incidence of notifiable gastrointestinal illness (total and cause-specific for giardiasis, salmonellosis and campylobacteriosis) by age-group, Northwest Territories, Canada, 1991 to 2008.

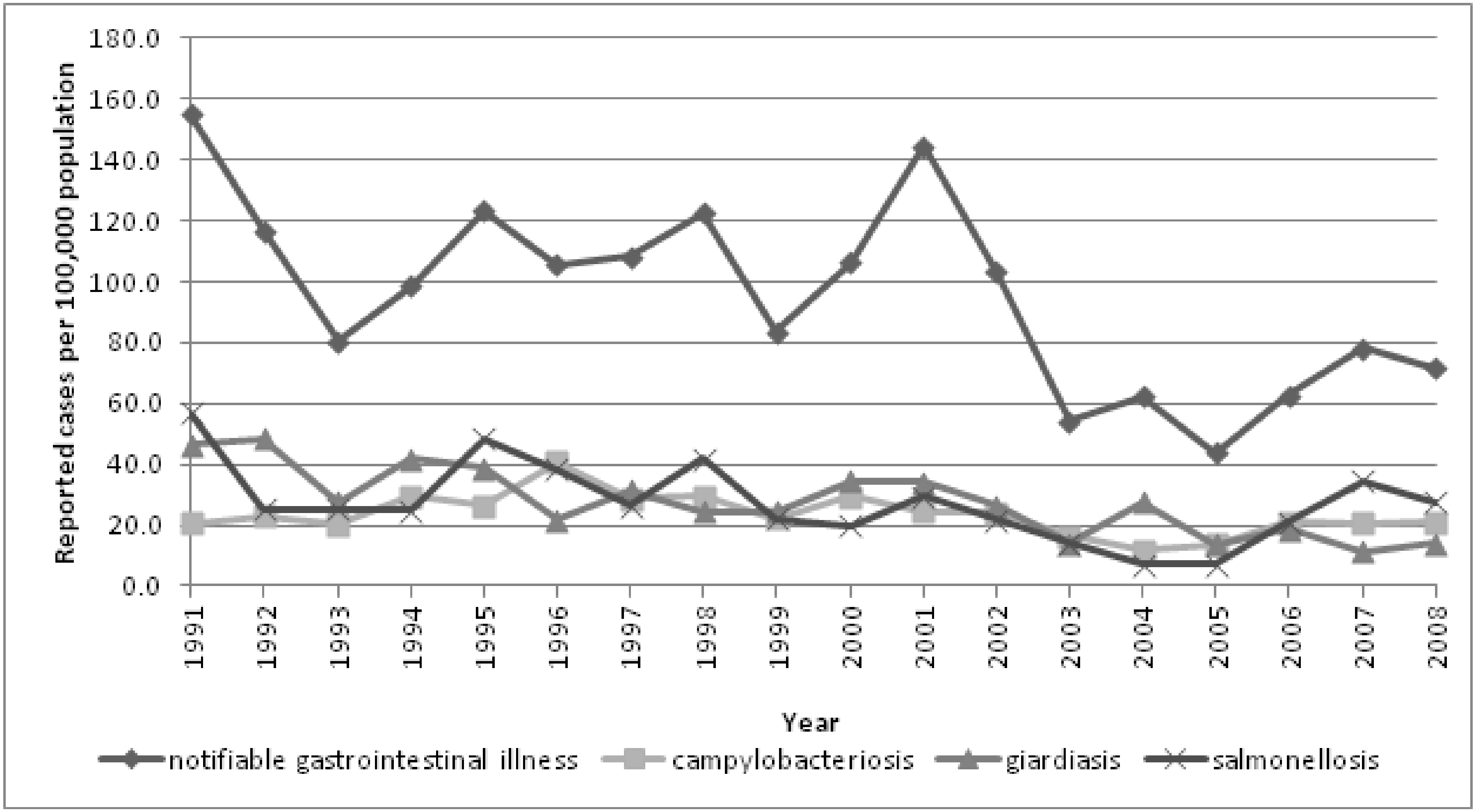
Figure 3: Incidence of notifiable gastrointestinal illness (total and cause-specific for giardiasis, salmonellosis and campylobacteriosis) by month, Northwest Territories, Canada, 1991 to 2008.

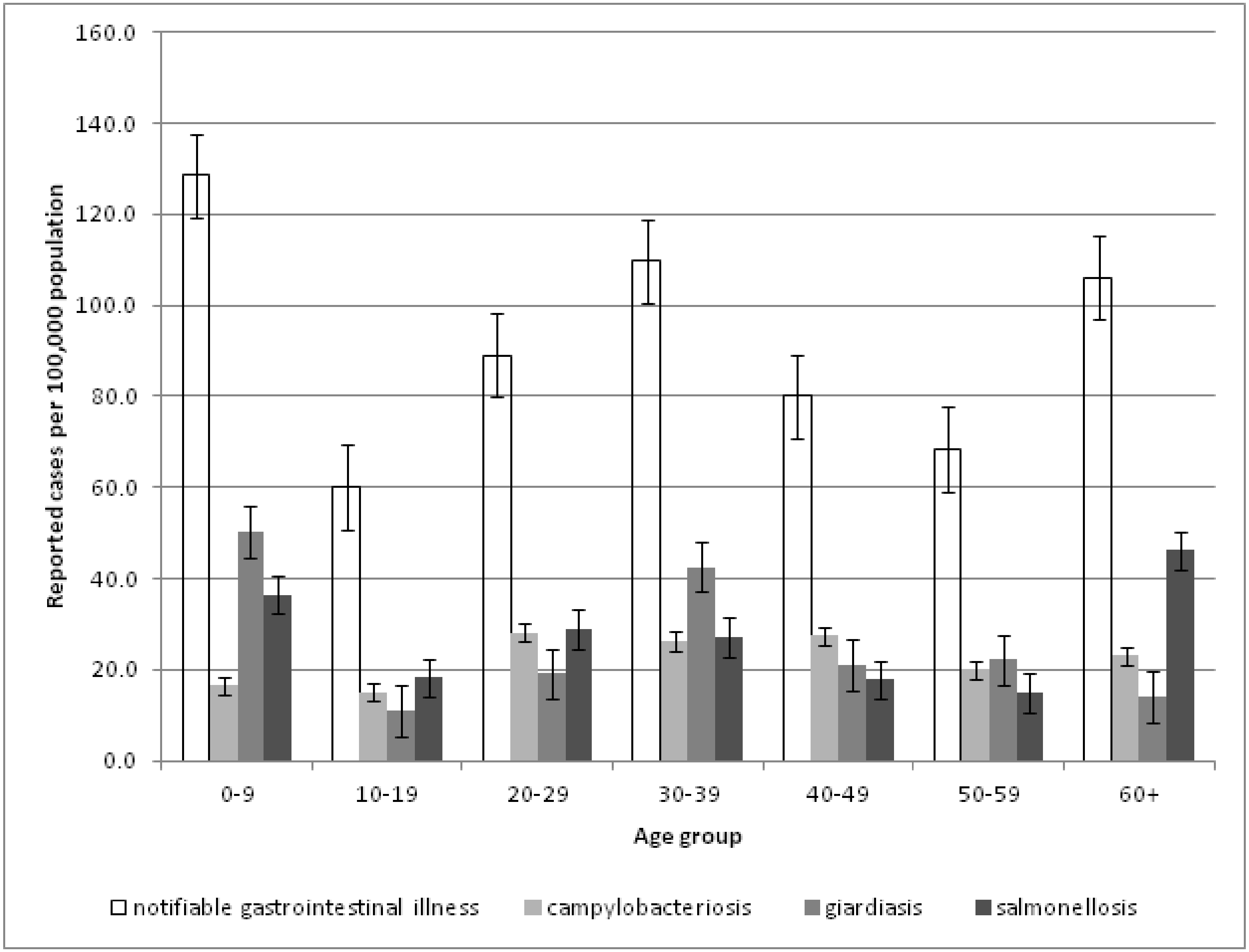
Figure 4: Map of incidence rates per 100,000 population for reported cases of notifiable gastrointestinal illness (NGI). Northwest Territories. 1991 to 2008.

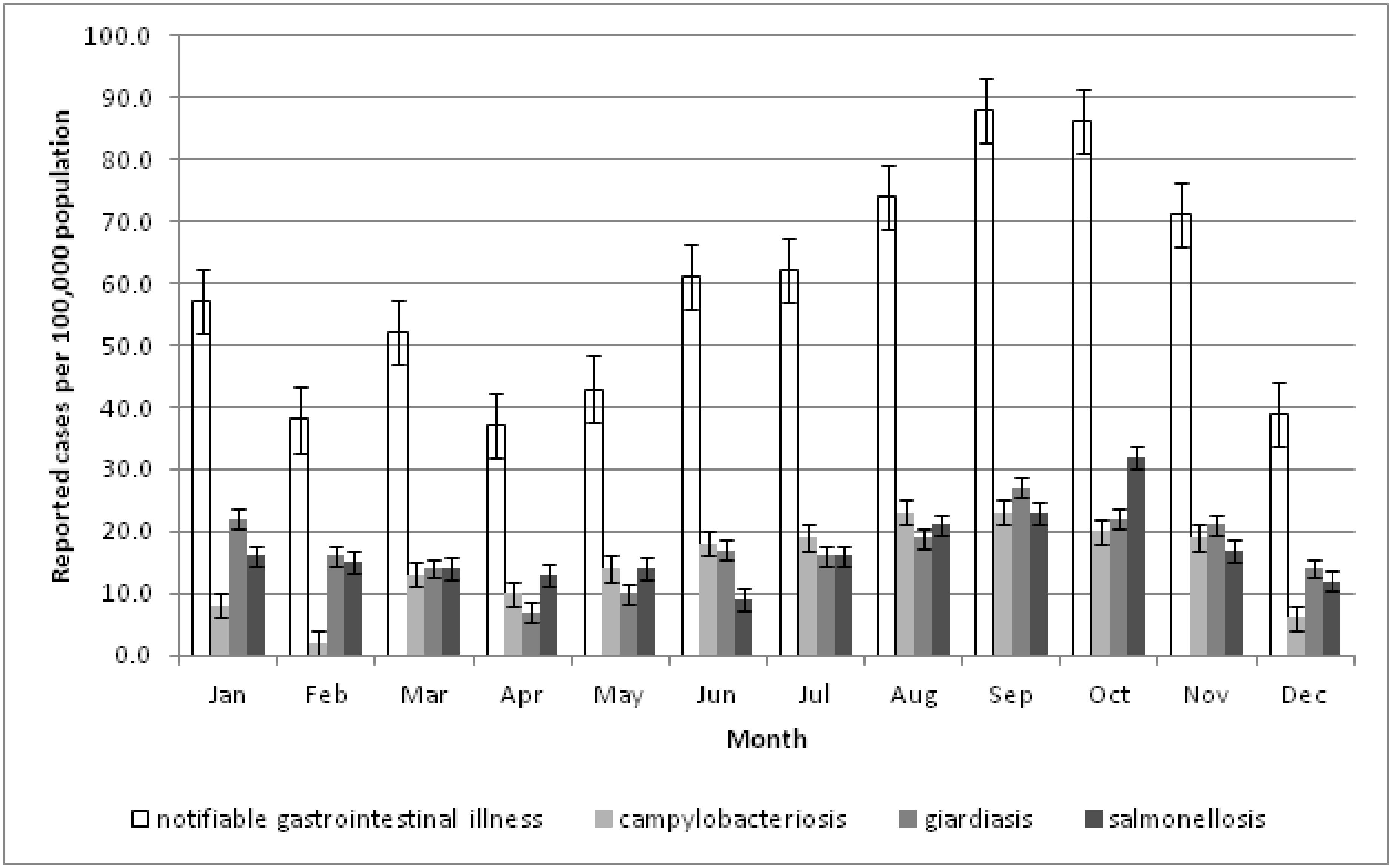
Figure 5: Map of incidence rates per 100,000 population for reported cases of campylobacteriosis. Northwest Territories. 1991 to 2008.

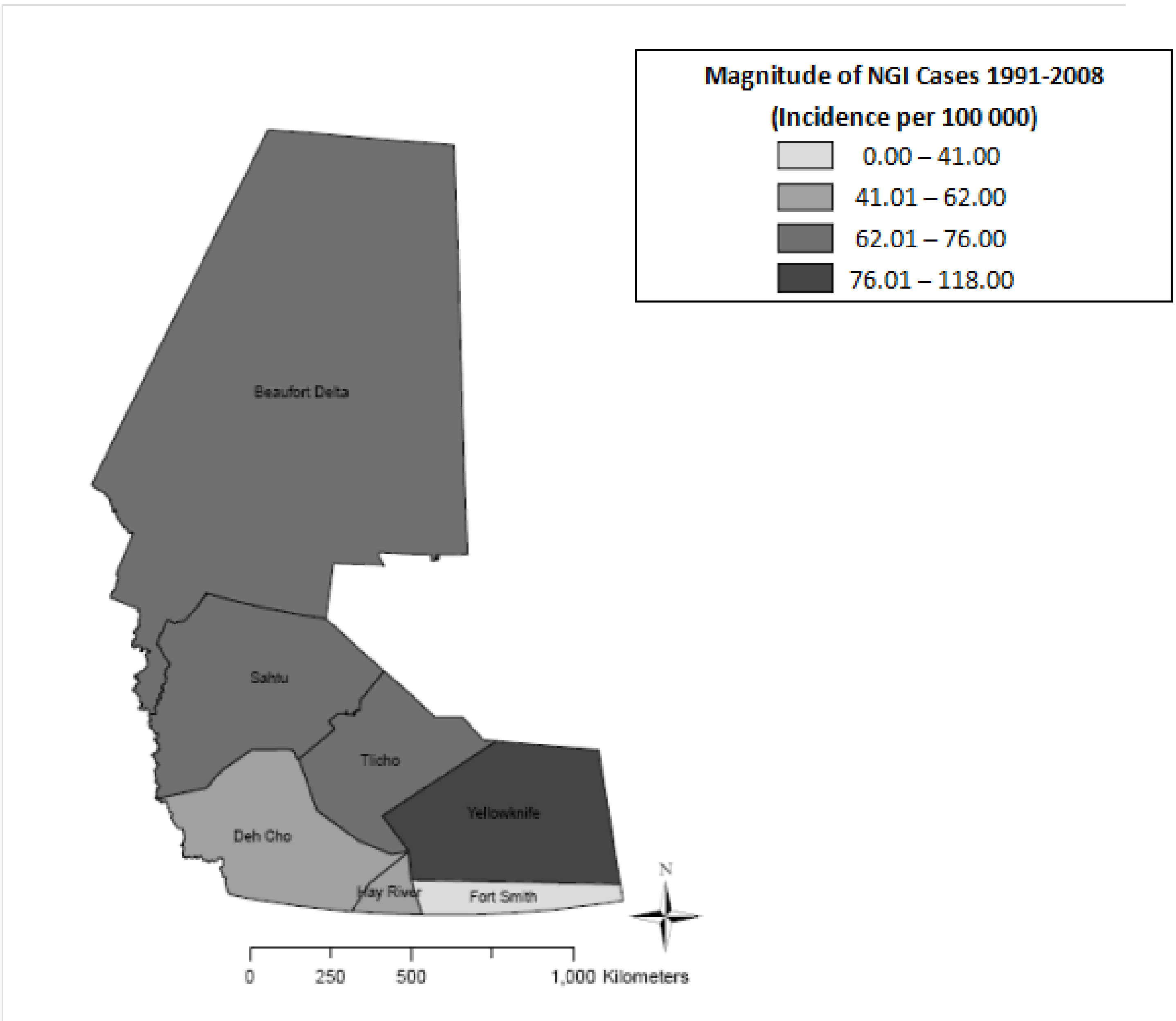
Figure 6: Map of incidence rates per 100,000 population for reported cases of salmonellosis. Northwest Territories. 1991 to 2008.

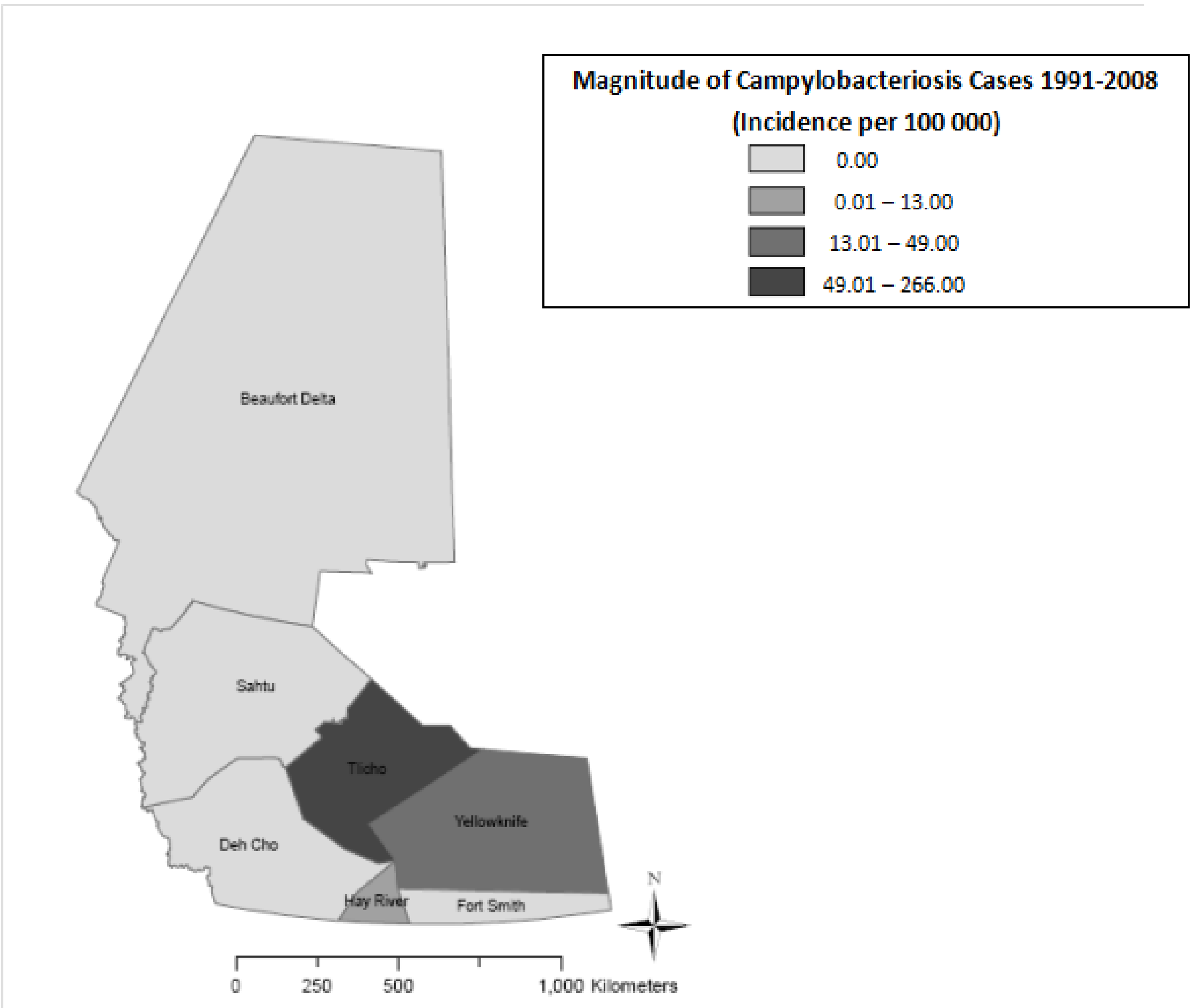
Figure 7: Map of incidence rates per 100,000 population for reported cases of giardiasis. Northwest Territories. 1991 to 2008.

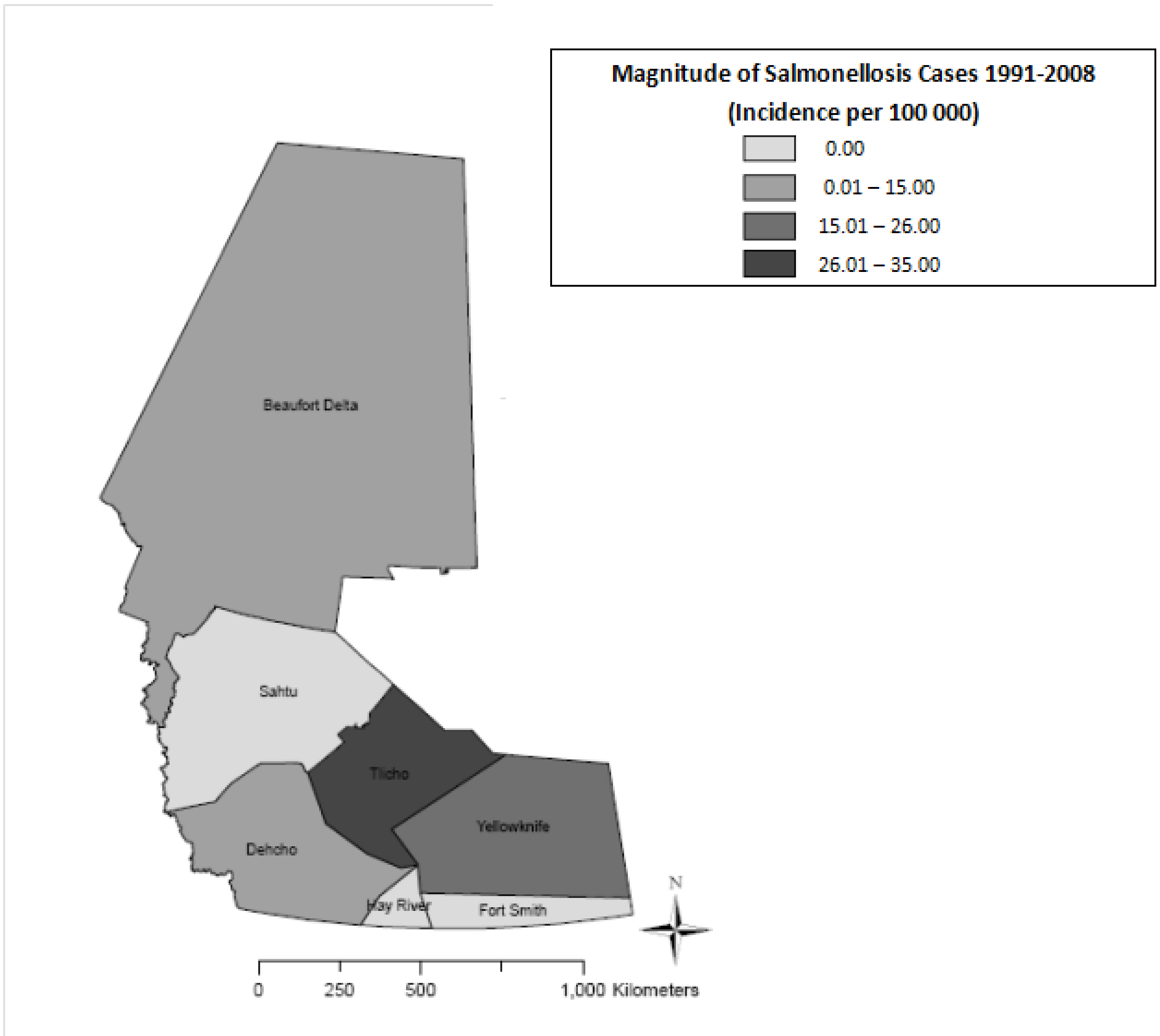

Reported cases per 100,000 population
180.0
160.0
140.0
120.0
100.0
80.0
60.0
40.0
20.0
0.0
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
Year
notifiable gastrointestinal illness
campylobacteriosis
giardiasis
salmonellosis

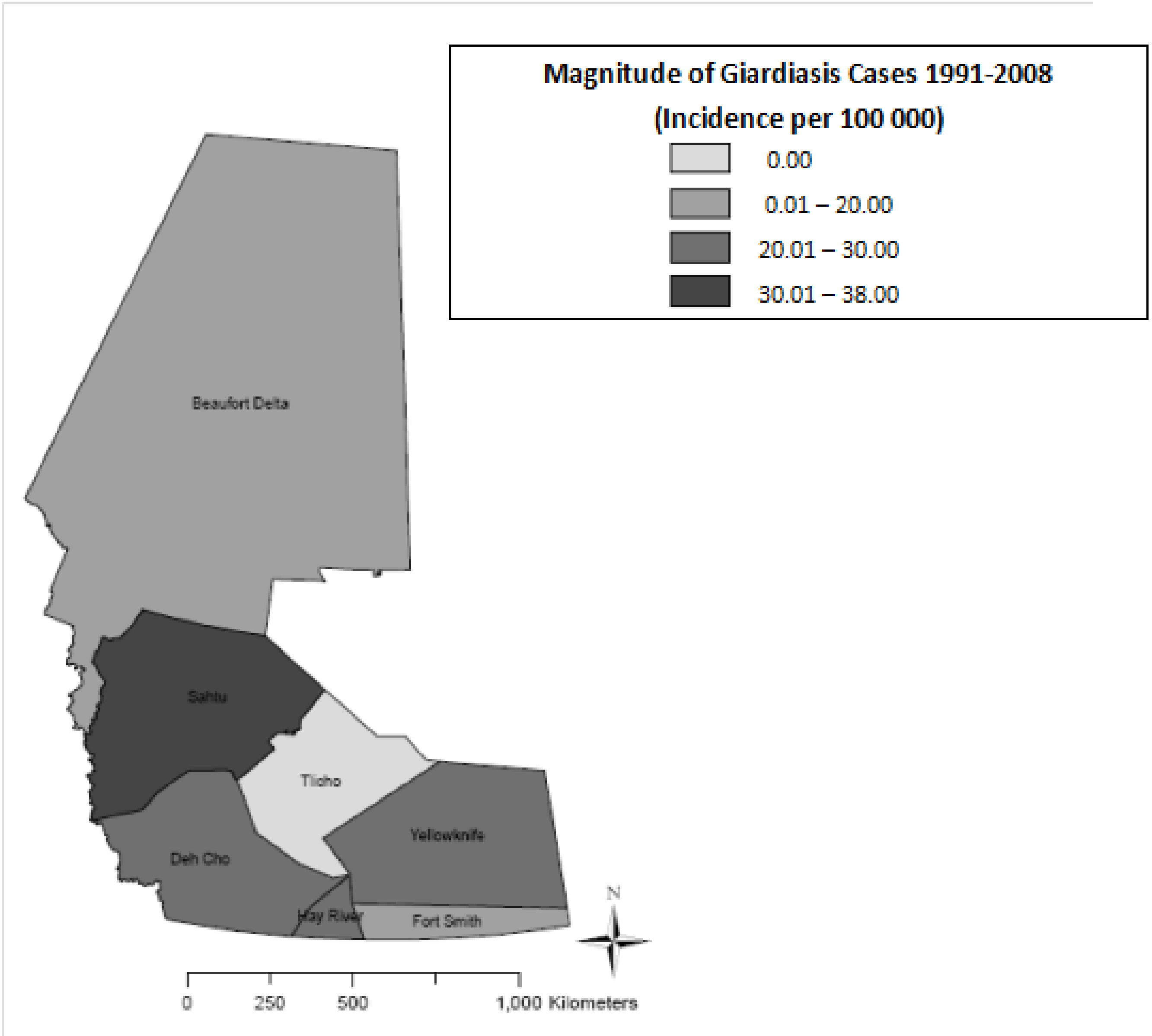

160.0
140.0
120.0
100.0
80.0
60.0
40.0
20.0
0.0
Reported cases per 100,000 population
0-9
10-19
20-29
30-39
40-49
50-59
60+
Age group
notifiable gastrointestinal illness
campylobacteriosis
giardiasis
salmonellosis


Reported cases per 100,000 population
100.0
90.0
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0.0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Month
notifiable gastrointestinal illness
campylobacteriosis
giardiasis
salmonellosis


Magnitude of NGI Cases 1991-2008
(Incidence per 100 000)
0.00 – 41.00
41.01 – 62.00
62.01 – 76.00
76.01 – 118.00
Beaufort Delta
Sahtu
Tlicho
Yellowknife
Deh Cho
Hay River
Fort Smith
N
0
250
500
1,000 Kilometers


Magnitude of Campylobacteriosis Cases 1991-2008
(Incidence per 100 000)
0.00
0.01 – 13.00
13.01 – 49.00
49.01 – 266.00
Beaufort Delta
Sahtu
Tlicho
Yellowknife
Deh Cho
Hay River
Fort Smith
N
0
250
500
1,000 Kilometers


Magnitude of Salmonellosis Cases 1991-2008
(Incidence per 100 000)
0.00
0.01 – 15.00
15.01 – 26.00
26.01 – 35.00
Beaufort Delta
Sahtu
Tlicho
Dehcho
Yellowknife
Hay River
Fort Smith
N
0
250
500
1,000 Kilometers


Magnitude of Giardiasis Cases 1991-2008
(Incidence per 100 000)
0.00
0.01 – 20.00
20.01 – 30.00
30.01 – 38.00
Beaufort Delta
Sahtu
Tlicho
Yellowknife
Deh Cho
Hay River
Fort Smith
N
0
250
500
1,000 Kilometers

STROBE 2007 (v4) checklist of items to be included in reports of observational studies in epidemiology*

Checklist for cohort, case-control, and cross-sectional studies (combined)

Section/Topic	Item #	Recommendation	Reported on page #
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	2
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	2, 3
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	5-6
Objectives	3	State specific objectives, including any pre-specified hypotheses	6
Methods			
Study design	4	Present key elements of study design early in the paper	8-9
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	7
Participants	6	(*a*) *Cohort study*—Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up *Case-control study*—Give the eligibility criteria, and the sources and methods of case ascertainment and control selection. Give the rationale for the choice of cases and controls *Cross-sectional study*—Give the eligibility criteria, and the sources and methods of selection of participants	N/A
		(*b*) *Cohort study*—For matched studies, give matching criteria and number of exposed and unexposed *Case-control study*—For matched studies, give matching criteria and the number of controls per case	N/A
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	7-9
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	*7-9*
Bias	9	Describe any efforts to address potential sources of bias	18
Study size	10	Explain how the study size was arrived at	N/A
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	7-9
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	7-9
		(*b*) Describe any methods used to examine subgroups and interactions	7-9
		(*c*) Explain how missing data were addressed	7-9
		(*d*) *Cohort study*—If applicable, explain how loss to follow-up was addressed *Case-control study*—If applicable, explain how matching of cases and controls was addressed	N/A

		Cross-sectional study—If applicable, describe analytical methods taking account of sampling strategy	
		(*e*) Describe any sensitivity analyses	N/A
Results			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	9,30-31
		(b) Give reasons for non-participation at each stage	N/A
		(c) Consider use of a flow diagram	N/A
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	7-9,32
		(b) Indicate number of participants with missing data for each variable of interest	9,21
		(c) *Cohort study*—Summarise follow-up time (eg, average and total amount)	N/A
Outcome data	15*	*Cohort study*—Report numbers of outcome events or summary measures over time	N/A
		Case-control study—Report numbers in each exposure category, or summary measures of exposure	N/A
		Cross-sectional study—Report numbers of outcome events or summary measures	N/A
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	N/A
		(*b*) Report category boundaries when continuous variables were categorized	N/A
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	N/A
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	N/A
Discussion			
Key results	18	Summarise key results with reference to study objectives	11-17
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	18
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	18-20
Generalisability	21	Discuss the generalisability (external validity) of the study results	12
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	20

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.
Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.