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A descriptive analysis of notifiable gastrointestinal illness in the Northwest Territories, Canada, 1991–2008

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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 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 0–9-year age group and in men ($p<0.01$). Similarly, rates of giardiasis were higher in the 0–9-year age group and in men ($p<0.02$). A disproportionate burden of salmonellosis was found in people aged 60 years and older and in women ($p<0.02$). Although not significant, the incidence of campylobacteriosis was greater in the 20–29-years age group and in men ($p<0.07$). 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.

Conclusions: The general patterns of these findings suggest that environmental and behavioural 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 are very little baseline data on Notifiable Gastrointestinal Illness (NGI) 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 0–9-year age group and men.
- Reported rates of NGI declined from 1991 to 2008; however, seasonal peaks were observed in late summer and autumn.
- There was variability in the rates of NGI with higher notifications in the southern urban areas compared with 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 of this study

- The study provides a historical portrait of NGI as the 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 40-60% of NWT residents living in remote and/or isolated communities rely on country foods 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 with meats eaten in Southern Canada. Seal and whale are good sources 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 microorganisms 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, diarrhoea 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 are 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 recognised 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 square kilometre. 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; men 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, foodborne 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 (GNWT) 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 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 serotyping. The patient's demographic information, food and water histories are collected by the health practitioner and manually entered into the foodborne and waterborne illness investigation form. The paper form is submitted to the Population Health Division of the GNWT Department of Health and Social Services (DHSS). Health practitioners and laboratories are required to report patients with confirmed NGI to the Population Health Division within 24 h. 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 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 were 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 centre located in a community of at least 1000 persons and 400 persons people per square kilometre, and 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 V.17 (SPSS Inc.), and choropleth maps of disease rates by health authority were created in ArcView GIS V.3.1 (ESRI). 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 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

Table 1 Notifiable gastrointestinal illness (NGI) and associated per cent missing or unspecified values, by field and disease, Northwest Territories, Canada, 1991–2008

Disease/agent (number of reported cases 1991–2008)	Notifiable disease report form fields—per cent missing values							
	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
Escherichia 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 five cases due to clostridium and five cases due to bacillus. Infections from these agents are not notifiable unless they are from food poisoning.

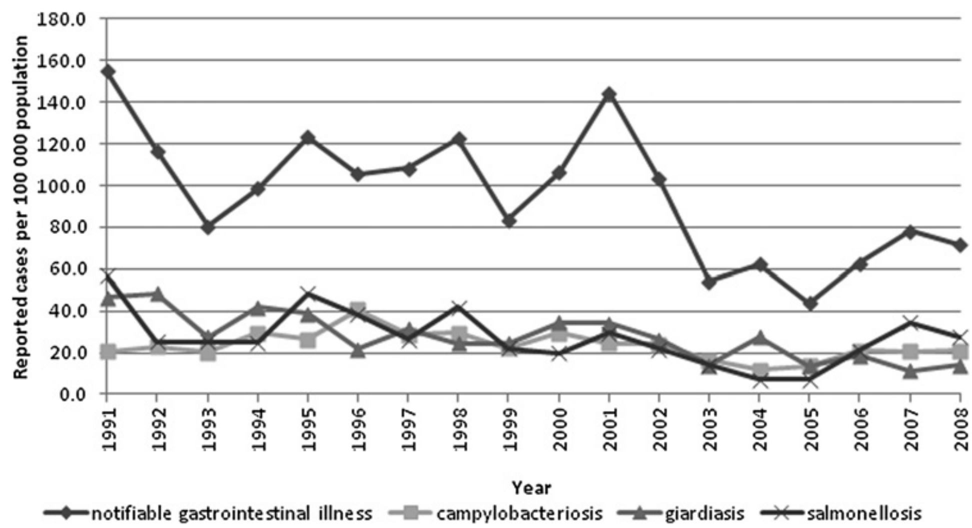

Figure 1 Annual incidence rates of notifiable gastrointestinal illness (total and cause specific for giardiasis, salmonellosis and campylobacteriosis), Northwest Territories, Canada, 1991–2008.

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

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 shows 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

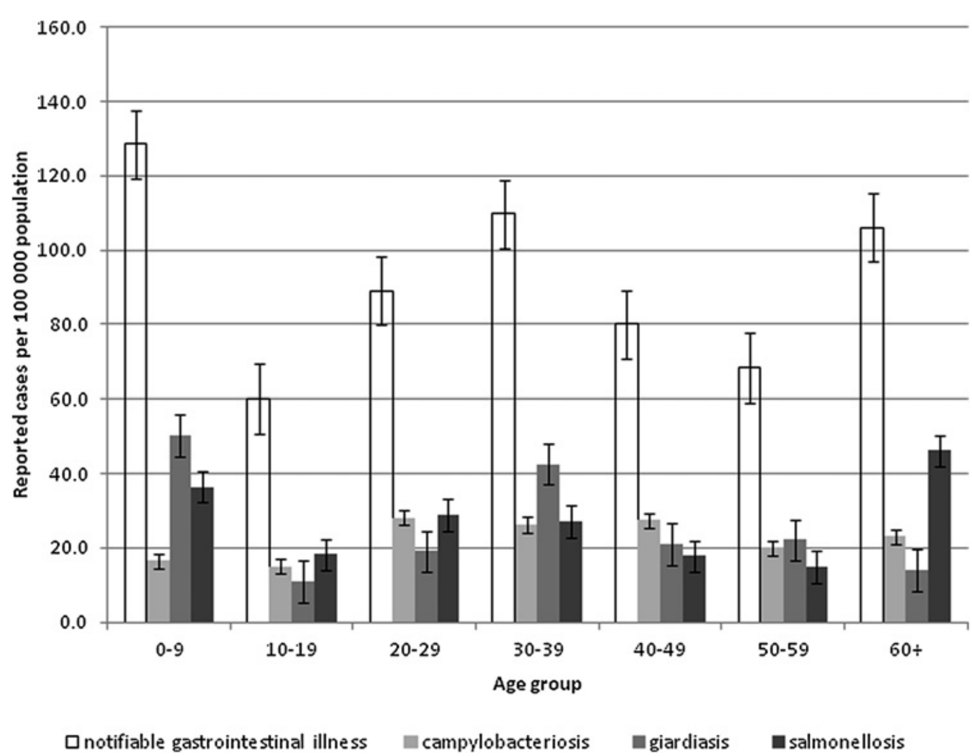

Figure 2 Incidence of notifiable gastrointestinal illness (total and cause specific for giardiasis, salmonellosis and campylobacteriosis) by age group, Northwest Territories, Canada, 1991–2008.

Table 2 Percentage distribution of reported suspected sources of infection for notifiable gastrointestinal illness (NGI), campylobacteriosis, giardiasis and salmonellosis, Northwest Territories, Canada, 1991–2008

	Per cent 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

($p<0.07$), 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 HSSA ($p<0.01$), 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 with some southern areas as of Canada, NWT residents may be at decreased 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

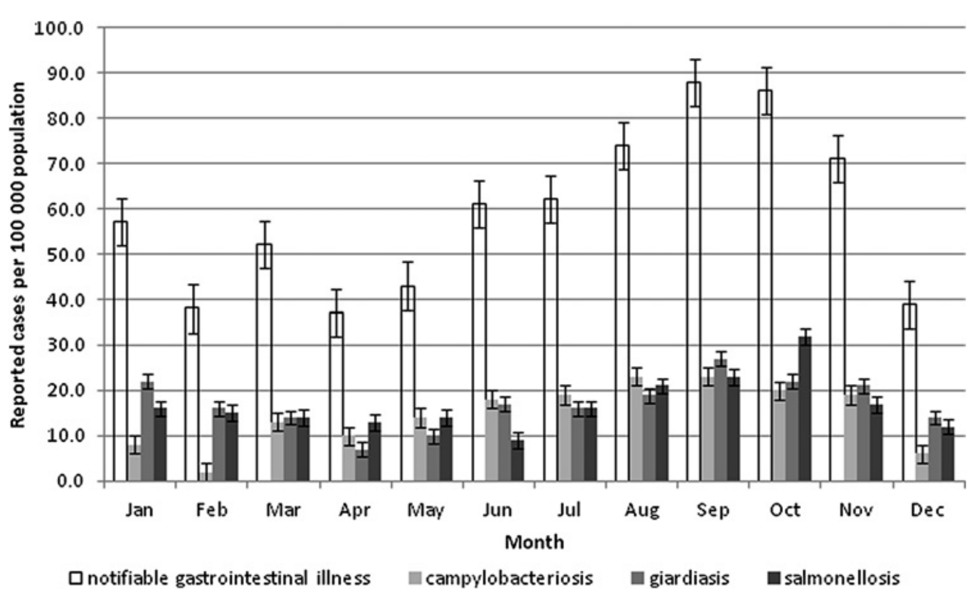

Figure 3 Incidence of notifiable gastrointestinal illness (total and cause specific for giardiasis, salmonellosis and campylobacteriosis) by month, Northwest Territories, Canada, 1991–2008.

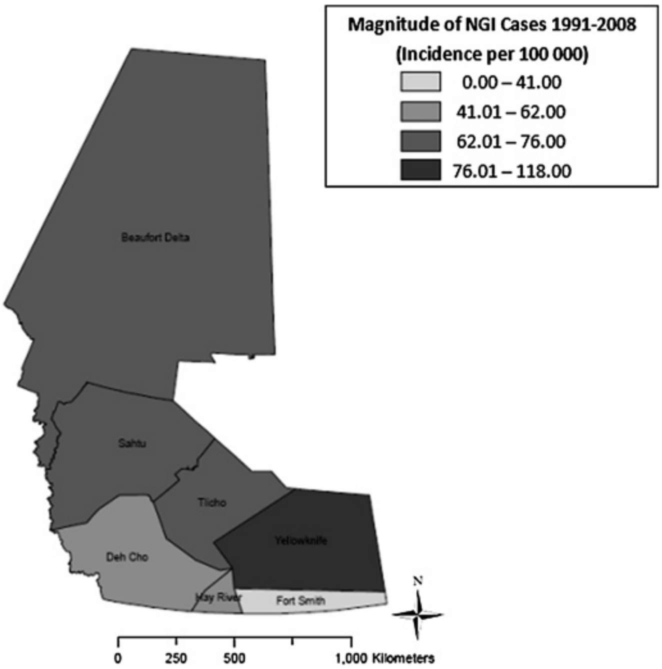

Figure 4 Map of incidence rates per 100 000 population for reported cases of notifiable gastrointestinal illness (NGI), Northwest Territories, Canada, 1991–2008.

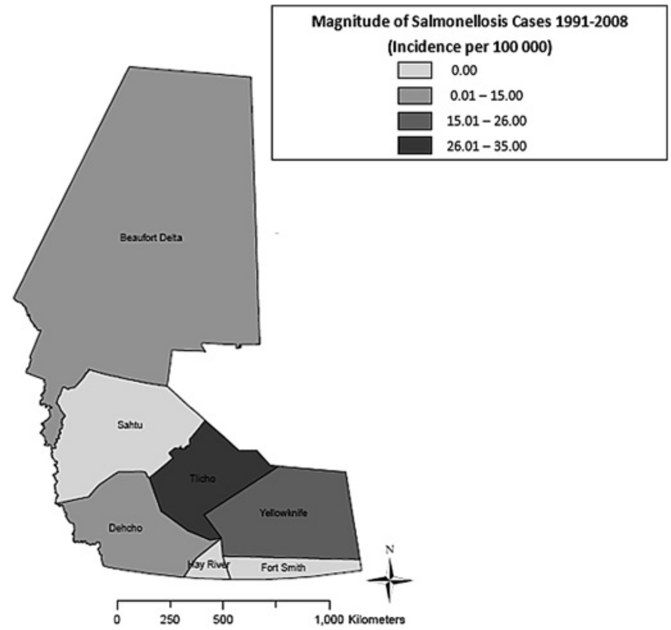

Figure 6 Map of incidence rates per 100 000 population for reported cases of salmonellosis, Northwest Territories, Canada, 1991–2008.

about one 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

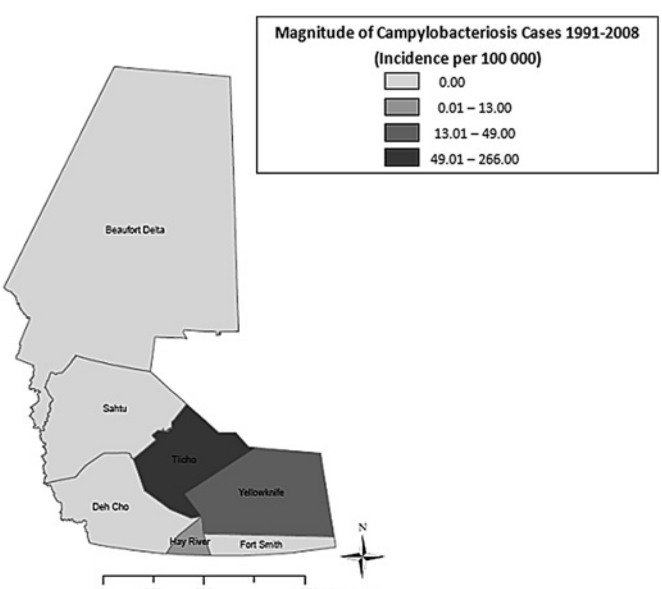

Figure 5 Map of incidence rates per 100 000 population for reported cases of campylobacteriosis, Northwest Territories, Canada, 1991–2008.

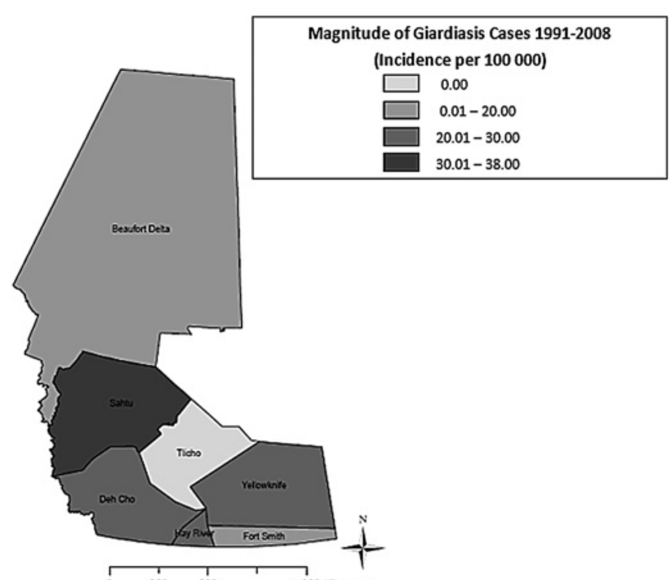

Figure 7 Map of incidence rates per 100 000 population for reported cases of giardiasis, Northwest Territories, Canada, 1991–2008.

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 characterise 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, centralised outdoor meal preparation as well as the consumption of country foods and surface water.[4 6 20–23] Control strategies, such as regular, coordinated public education and communication about known risk factors of the disease (eg, drinking contaminated water, safe food preparation), would therefore need to be targeted during these seasons. Such public health programmes 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 a 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 be attributed to effective ongoing efforts to improve food and water quality or an artefact 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 the predicted temperature-driven increase of enteric disease in the North.[31] Since the 1940s (when record collection began), the average annual temperature in the NWT has increased by 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 rates in health authorities could be a result of disparities in the geographical distribution of risk factors and behaviours,[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 with urbanised areas.[37] Furthermore, higher disease rates could also be an artefact 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 the 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 30–39 years 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 men 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 favours indirect person-to-person transmission.[45]

Salmonellosis, the second most frequently reported enteric infection, is commonly acquired from consuming 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 *E 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 (0–9-year age group) and the elderly (60+-year 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 women 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, centralised 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, unpasteurised 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 20–29 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 <5% of data missing; however, the field 'suspected exposure', unknown (missing) for 73.2% 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 standardised 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 has 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*[65] suggest methodological approaches such as aggregation, spatial smoothing, small area estimation and exact statistics. 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 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—foodborne 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, men and urban residents. The geographical distribution of case–patients varied by disease, suggesting that environmental and behavioural 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.

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Contributors AP-A contributed to the manuscript through study design and planning, data collection, analysis and interpretation of results, drafting the manuscript and response to editorial comments and preparation of the final manuscript for submission. JW, VLE, CF, RR-S 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.

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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 *Cross-sectional study*—If applicable, describe analytical methods taking account of sampling strategy	N/A
		(*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.