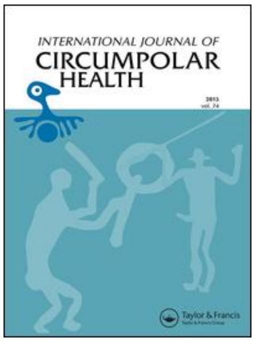

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POTENTIAL IMPACTS OF CLIMATE CHANGE ON INFECTIOUS DISEASES IN THE ARCTIC

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ABSTRACT

Climate change could cause changes in the incidence of infectious diseases in Arctic regions. Higher ambient temperatures in the Arctic may result in an increase in some temperature sensitive foodborne diseases such as gastroenteritis, paralytic shellfish poisoning and botulism. An increase in mean temperature may also influence the incidence of infectious diseases of animals that are spread to humans (zoonoses) by changing the population and range of animal hosts and insect vectors. An increase in flooding events may result in outbreaks of waterborne infection, such as *Giardia lamblia* or *Cryptospordium parvum*. A change in rodent and fox populations may result in an increase in rabies or echinococcosis. Temperature and humidity influence the distribution and density of many arthropod vectors which in turn may influence the incidence and northern range of vectorborne diseases such as West Nile virus. Recommendations include: the strenghtening of public health systems, disease surveillance coordinated with climate monitoring, and research into the detection, prevention, control and treatment of temperature-sensitive infectious diseases.
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Keywords: climate change, infections, diseases, Arctic

INTRODUCTION

Climate and weather are two of the most important factors in the emergence of infectious disease in humans (1). Climate refers to the average state over a longer time period and strongly influences weather patterns. Weather refers to the day-to-day state of the environment (temperature precipitation, humidity and wind). Climate change is likely to have a significant impact on the occurrence of infectious diseases world wide, by affecting population size and range of hosts and pathogens, the length of transmission season, and the timing and persistence of outbreaks (2).

Climate and weather influences the transport and dissemination of infectious agents that cause food and waterborne diseases through increased precipitation and runoff and the effects of temperature on pathogen survival and replication. Food and waterborne diseases are caused by pathogens often spread through drinking water or recreational water contaminated with human waste, seafood contaminated with toxins or waste water, or fresh produce processed or irrigated with contaminated water (3). Extreme weather events such as floods, droughts, and storms directly affect human health and often serve as catalysts for outbreaks of infectious diseases (4). In general, warmer ambient temperatures and increased precipitation will favor extensions of the geographical range and season of infectious disease vectors such as insects and rodents. This in turn leads to an expansion of the opportunity for transmission for many vector borne diseases, such as malaria, dengue fever, yellow fever and forms of viral encephalitis (5).

The health impacts of climate change and extreme weather events are likely to vary from place to place due to regional differences in the rate of climate change as well as variations in health status, public health response and adaptive capacity and preparedness of different populations. Those living in small isolated communities that are underdeveloped and have limited public health infrastructure may be particularly susceptible to increase risk of infections associated with climate change (6). Because the average Arctic temperatures have increased at almost twice the rate of the rest of the world in the past two decades, Arctic regions may serve as a critical sentinel for detecting the influence of climate change on infectious disease epidemiology. Increased ambient temperatures may led to northward spread of infectious diseases from temperate regions as well as southward spread of infections that are most common in the Arctic and sub-Arctic. In this paper, we review specific infectious diseases that may be influenced by climate change in the Arctic.

Foodborne infectious diseases

Halophilic *Vibro* species occurs naturally in marine or coastal environments and can be found in fish and shellfish, and can cause gastroenteritis following ingestion of raw or inadequately cooked fish or shell fish (7). Outbreaks are related to water temperatures of greater than 15°C. In July of 2004 an outbreak of *V. parahaemolyticus* -related gastroenteritis was reported among cruise ship passengers that consume raw farmed oysters in the Prince William Sound area of Alaska (approximately 60° N, Figure 1). The July-August water temperature of the oyster farm has increased 0.21°C per year since 1997; 2004 was the first summer on record that the mean water temperature exceeded 15°C the threshold temperature for the harvest of implicated oysters during the outbreak. (8). Prior to 2004, the most northerly reported outbreak of *V. parahaemolyticus* gastroenteritis occurred in northern British Columbia in 1997 (9). Control measures recommended following this outbreak include the continued monitoring of water temperatures to ensure appropriate prevention measures are implemented when water temperature exceed 15°C, including microbiologic analyses and issuing advisories for post-harvesting processing. This outbreak documents the outbreak of *V. parahemolyticus* associated gastrotenteritis above 60° N, more than 1000 kilometers north of British Columbia, the site of the previously most northerly outbreak, and a distinct ocean warning trend which may be responsible for the outbreak.

Paralytic shellfish poisoning is caused by the ingestion of shellfish with concentrated neurotoxins produced by several species of dinofagellates. Concentration of these toxins occurs during massive temperature and weather related algal blooms known as red tides, but can occur in the absence of recognizable red tides. Reports of red tides involving dinoflagellates have increased globally in the past several decades (3). Outbreaks of PSP have been reported world wide and some evidence suggest that the incidence is increasing (10). Symptoms occur within minutes or hours of eating raw or cooked shellfish and include paresthesias (numbness/tingling sensation) of the mouth frequently accompanied by gastrointestinal symptoms. Symptoms usually resolve within days, although in severe cases muscle paralysis, respiratory arrest and death can occur. Residents of the U.S. Arctic have one of the highest reported incidences of PSP in the world and a large population who frequently eat shellfish collected from unmonitored beaches (11, 12). To prevent outbreaks of PSP and other shellfish intoxications, samples of susceptible mollusks are periodically collected in the coastal areas as tested for toxin. When toxin levels exceed 80µg/100g affected areas are quarantined and sale or collection of shell fish is prohibited. Warnings posted in shell fish growing areas and in the news media can alert the public to the hazard. It is not yet know whether climate change may necessitate extension of monitoring to areas not currently known to be at risk.

Foodborne botulism is a paralytic illness caused by ingesting neurotoxins of *Clostridium botulinum*. Clinical illness is characterized by cranial nerve palsies followed by descending flaccid paralysis which can involve the muscles of respiration. Recovery can take weeks or months. The canning and fermentation of foods are particularly conducive to creating the anaerobic conditions that allow *C. botulium* spores to germinate and produce toxin. Germination of *C. botulinum* spores will occur at temperatures greater than 4°C. Preparation of traditional fermented foods, such as fish, fish eggs, seal beaver and whale, by indigenous populations of the U.S. Arctic (13-15), northern Canada provinces and territories (16, 17), and Greenland (18) account for the high incidence of botulism in these regions. These foods prepared by allowing products to ferment at ambient temperatures are often eaten without cooking. Preliminary studies

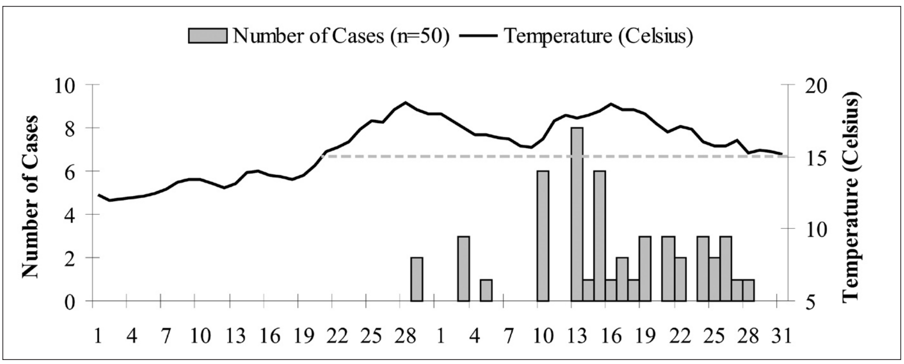

Figure 1. An outbreak of *Vibro parahaemolyticus* associated illness following consumption of farmed oysters occurred in Alaska in 2004, when the seawater temperature exceeded 15°C. The figure shows the number of cases, by date of harvest of consumed oysters, and farm sea water temperature by date. Prior to 2004, the most northern area of reported outbreak of *V parahaemolyticus* gastroenteritis occurred in northern British Columbia, Canada in 1997. (Reprinted from: McLaughlin JB., Depoala A, Bopp CA et al. Emergence of *Vibro parahaemolyticus* gastroenteritis associated with consumption of Alaskan oysters and its global implications. New England J. Med 2005;353(14):1463-1470. Copyright 2005 Massachusetts Medical Society. All rights reserved).

have shown that fermentation of aged seal meat challenged with *C. botulinum* at temperatures above 4°C results in toxin production (19). It is possible that warmer ambient temperatures in these regions associated with climate change may result in an increase the rates of foodborne botulism. While no data is currently available to support this hypothesis, health care providers should be aware of this potential and report occurrences of foodborne botulism to their public health officials. Rapid recognition and public education remain the cornerstones of successful public health interventions to prevent additional cases.

Zoonotic infectious diseases

Warmer temperatures may influence the spread and proliferation of infectious diseases that are spread to humans from animals. Warmer temperatures may allow a host animal species with a normally low rate of infection to survive winters in larger numbers thereby increasing the number of both susceptible and infected animals and the opportunity to pass infections to humans. Warmer temperatures may result in changes in vegetation and animal food sources allowing host animal species and their diseases to enter a new region. It has been observed that beaver in Alaska are migrating north into areas that have become more habitable by expanding vegetation and habitat (20). Beaver are common mammalian hosts for *Giardia lamblia*, a protozoan parasite that causes diarrhea in humans following ingestion of contaminated drinking water. It is possible that human disease caused by *Giardia* may occur in regions where untreated surface water is commonly used as a drinking water source and where *Giardia* infections have not previous occurred.

Both *Giardia* and another protozoan parasite *Cryptosporidium parvum* have been implicated in waterborne outbreaks of diarrhea following heavy rainfall (3, 21). Climate change may increase the risk of extreme weather related events such as heavy rain, snow fall, melting permafrost and flooding, which could result in widespread contamination of traditional water sources and damage to community sanitation infrastructures (22; Fig. 2).

Figure 2. Damage to a sewage lagoon following flooding in a village in western Alaska places the community at risk for food and waterborne infectious diseases, such as those caused by enteric viruses (hepatitis A) and bacteria (*E.coli, Salmonella, Shigella*), and parasites such as *Giardia*, and *Cryptosporidium*.

Echinococcus multilocularis is a parasitic tapeworm found throughout Arctic region (23-25) The life cycle of *E. mutilocularis* involves foxes, dogs and rodents (voles) whose range could vary with a changing climate. Humans are incidentally infected when they ingest eggs passed by dogs or foxes. Climatic conditions that favor the expansion of the either fox or vole population may in turn increase infection rates in humans in regions previously not previously reported. *Echinococcus granulosis* occurs worldwide, including the Arctic, and has a life cycle in the wild involving the wolf and reindeer or elk. Incidental human infections occur in association with domesticated reindeer and dogs. The incidence of human echinococcosis has declined in Norway, Finland, and the US Arctic with the replacement of dogs with snow machines for reindeer herding, and human infection and is now a rare occurrence in these areas. However echinococcosis continues as a common and increasing disease among reindeer herders in northeastern Siberia due in part to a decline in medical and veterinary services in these remote northern regions of the Russian Federation (26, 27). The influence of climate change on echinococcal infection in natural hosts and humans is not yet known.

Rabies is enzootic throughout the Arctic, where infection occurs most commonly in the fox. Climatic conditions that favor an increase in the fox population such as an increase in the rabbit and rodent populations may in turn lead to an increase in the incidence of human exposures.

Brucellosis is a bacterial disease of many hoofed animals and carnivores. It can cause a wide variety of symptoms in humans and the fatality rate is around 2% if untreated (28). Bison, caribou, reindeer, foxes and bears can carry the disease (29). Climate change that affects the distribution of theses species could increase or decrease the risk from brucellosis in humans.

Tularemia is caused by *Francisella tularensis*, occurs sporadically throughout the Arctic, and has various manifestations depending on how the infection was obtained. *F. tularensis* commonly infects hares, rabbits, muskrats, voles, beaver and squirrels. Transmission to humans results from exposure to an infected animal (skinning wild animals), the bite of an infected arthropod (tick or deer fly) ingestion of contaminated food or water or inhalation of dust from contaminated soil hay or grain. Disease can occur in all months of the year but incidence may be highest in adults during the fall months (during rabbit hunting season) and in children during the summer when ticks and deer flies are abundant. Changes in the epidemiology of tularemia-related climate change in the Arctic have not been reported.

The geographic distribution of many arthropod vectors is limited by minimum and maximum temperatures, humidity and availability of breeding sites (for mosquitoes distribution is also tied to precipitation). As temperature increases, the period of time required for microbe replication decreases resulting in greater microbe density. Also blood-feeding arthropods often increase their biting frequency and replication rates resulting in an increase in disease incidence (5).

A number of arthropod vector borne viruses that cause illness in humans are known to circulate in small animals and humans in U.S. Arctic and northern regions of the Russian Federation. These include: California encephalitis virus, James Town Canyon Virus, Northway virus, Snowshoe Hare virus. These viruses as well as several others (Tahyna, Inkoo, Sindbus, Getah and Batai viruses) circulate in ecologically similar landscapes of northern latitudes of the northern Russian Federation (30).

Jamestown Canyon and Snowshoe Hare viruses are considered emerging threats to the public health in the US, Canada, and the northern regions of the Russian Federation, causing flu-like illness and central nervous system diseases (aseptic meningitis and encephalitis). In northern regions of the Russian Federation, Tahyna and Inkoo viruses have been associated with human disease, virus infection results in flu-like illnesses (65%), but central nervous system manifestations also occur in about 35% of cases. Chronic diseases developed in up to one-third of cases with onset from one to 2.5 years after infection. Batai virus infection in the northern region of the Russian Federation can result in fever and aseptic meningitis. No human disease has been associated with Northway virus or Getah viruses, but sub-clinical infections due to Northway virus have been documented in the U.S. Arctic, Alberta in northern Canada, and with Getah viruses in northern regions of the Russian Federation. Climate change may influence the both density and distribution of both animal host and insect vectors which could result in an increase in human illness or a shift in the geographical range of human illness caused by the agents.

Another arthropod vectorborne virus of recent concern is West Nile Virus (WNV), which was first detected in North American in 1999 in an outbreak of encephalitis in New York City (31). Each year thereafter, the disease has infected human, horse,

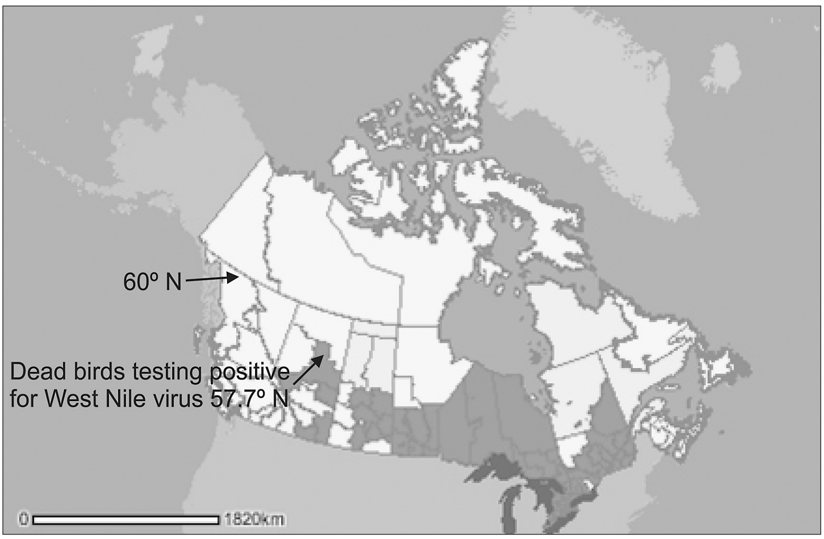

Figure 3. Northern spread of West Nile virus in birds: Canada 2004. Figure shows dead birds submitted and tested for West Nile virus in 2004. West Nile virus can infect many bird and mammal species and is transmitted by mosquitoes. Migratory birds are responsible for its spread to other regions. Mosquitoes are responsible for the spread of the virus to other birds, animals and humans. Mosquito species known to transmit West Nile virus are found in the Arctic. (Source: Public Health Agency of Canada. http://www.cnphi-wnv.ca/healthnet/)

mosquito and bird populations in the continental United States and the border provinces of Canada. The normal life cycle of WNV involves mosquitoes and birds. The mosquito feeds upon an infected bird and they become infected with WNV. The mosquito then transmits the virus by feeding on another bird, human or horse. Humans and horses represent "dead end" hosts; probably because the level of viremia is not high enough to allow mosquitoe's that subsequently bite them to become infected. Many species of mosquito are know to carry and transmit WNV, some of which are endemic in the U.S. Arctic (eg *Aedes canadiensis, A. vexans, Culex pipiens, C. restuans*). The establishment of WNV in the US Arctic would require the correct combination of birds, mosquitoes, and climate. The northward spread of WNV activity detected in birds in 2004 has extended as far north as the 57.7° N in the Canadian province Manitoba (Figure 3). WNV has yet to be detected in birds in the U.S. Arctic.

Recommendations

To detect and respond to changes in infectious disease epidemiology caused by climate change will require strenghtening public health infrastructure and ensuring surveillance for diseases most likely to be influenced by climate with particular attention to those with potentially large public health impacts (i.e. WNV). While most Arctic countries maintain passive surveillance systems, Arctic populations are relatively small making the detection of emerging infectious disease trends difficult. This difficulty could be overcome by establishing a coordinated circumpolar infectious disease surveillance system. Until recently the sharing of infectious disease data of public health importance across international boarders has not been a common practice. In 1999 the International Circumpolar Surveillance system was established (32). This system links clinical laboratories and public health authorities throughout the Arctic to monitor infectious diseases of concern in Arctic regions. Currently the system monitors invasive bacterial diseases in the U.S. Arctic, northern Canada, Greenland, Iceland, Norway Finland and northern Sweden and aims to expand to include public health authorities in northern regions of the Russian Federation. The network helped identify an outbreak of invasive serotype 1 pneumococcal disease in young adults and this event helped begin subsequent implementation of pneumococcal vaccine in three regions of northern Canada (33, 34), as well as possible emergence of invasive disease caused by *Haemophilus influenzae* type a in children in the North American Arctic (35). If coordinated with appropriate climate data, such a network could also be used to monitor the emergence of climate-sensitive infectious diseases providing both early detection opportunities for public health intervention and additional evidence of the effect of climate change on infectious disease emergence.

Other recommendations include:

- The continued research to further our understanding of the associations between weather, weather extremes, climate and infectious diseases,
- Continuing research on disease detection methods,

- Monitoring of animal host and arthropod vectors involved in transmission of infectious diseases and most likely to be influenced by climate change.
- Early warning systems should be developed to generate public health advisories and to generate preventive public health messages, such as use of insect repellants, boiling water orders, shellfish bed closings, and temporary bans on seafood or subsistence food consumption.
- Health care providers should be aware of the potential for the emergence of new pathogens in their regions and report unusual occurrences to public health officials.

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