ARCTIC
VOL. 72, NO. 3 (SEPTEMBER 2019) P. 289–299
https://doi.org/10.14430/arctic68719

Identifying and Achieving Consensus on Health-Related Indicators of Climate Change in Nunavut

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(*Received 8 January 2018; accepted in revised version 27 February 2019*)

ABSTRACT. Indigenous peoples of the North are affected by climate change, and future changes in climate are likely to continue to pose serious challenges. Climate change and the resulting change in the environment and communities are believed to further compound existing health issues. There is considerable regional variation within the circumpolar world, and each area of the Canadian Arctic has its own unique environmental and societal characteristics. Therefore, to track the impacts on human health in Nunavut, a monitoring framework—one that takes into account the territory's unique context—must be implemented. The objective of this study was to identify human health indicators of climate change on a global scale with a focus on indicators relevant to the Canadian Arctic atmosphere, habitats, and peoples. The *Piliriqatigiinniq* Community Health Research Model provided the guiding framework for this exploratory study. First, a scoping review of health-related indicators of climate change was conducted. From this review, an initial list of 30 indicators was produced. Second, individuals from multiple sectors were invited to participate in a consensus-building process to identify health-related indicators of climate change for Nunavut. Through individual selection and group discussion, a final set of 20 indicators was chosen by workshop participants. The indicators identified in both phases focused on four key themes: 1) environmental health; 2) morbidity and mortality; 3) population vulnerability; and 4) mitigation, adaptation, and policy. Participants felt these indicators would be useful in practice in Nunavut. Next steps are to implement and monitor the utility of the selected indicators.

Key words: climate change; Inuit; Nunavut; indicators; water; ice; health; public health

RÉSUMÉ. Les peuples autochtones du Nord sont touchés par le changement climatique, et les changements qui se produiront à l'avenir du point de vue du climat continueront vraisemblablement de présenter de sérieux défis pour eux. Le changement climatique de même que les changements environnementaux et communautaires qui en découlent pourraient empirer les problèmes de santé qui sévissent actuellement. Au sein du monde circumpolaire, il existe des variations régionales considérables, et chaque secteur de l'Arctique canadien est doté de caractéristiques environnementales et sociétales uniques. Par conséquent, afin de repérer les incidences du changement climatique sur la santé humaine au Nunavut, il y a lieu de mettre en œuvre un cadre de surveillance qui tient compte du contexte unique du territoire. L'objectif de cette étude consistait à déterminer les indicateurs du changement climatique en matière de santé humaine à l'échelle mondiale, en portant une attention particulière aux indicateurs propres à l'atmosphère, aux habitats et aux peuples de l'Arctique canadien. Le modèle de recherche de santé communautaire *Piliriqatigiinniq* nous a servi de cadre de référence pour cette étude exploratoire. Pour commencer, nous avons passé en revue les indicateurs du changement climatique en matière de santé. Cet exercice nous a permis de dresser une liste initiale de 30 indicateurs. Ensuite, des personnes de plusieurs secteurs ont été invitées à participer à un processus par consensus visant à déterminer les indicateurs du changement climatique en matière de santé pour le Nunavut. La sélection individuelle et une discussion de groupe ont permis aux participants à l'atelier de s'arrêter sur un ensemble définitif de 20 indicateurs. Les indicateurs sélectionnés à chacune des deux phases portaient sur quatre thèmes principaux : la santé de l'environnement; 2) la morbidité et la mortalité; 3) la vulnérabilité de la population; et 4) l'atténuation, l'adaptation et les politiques. Les participants estimaient que ces indicateurs seraient utiles dans le cas du Nunavut. Les prochaines étapes consistent à mettre en application les indicateurs sélectionnés et à en surveiller l'utilité.

Mots clés : changement climatique; Inuit; Nunavut; indicateurs; eau; glace; santé; santé publique

Traduit pour la revue *Arctic* par Nicole Giguère.

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BACKGROUND

In a report published by the Lancet Commission on Climate Change (Watts et al., 2017), climate change was found to endanger health in six key ways: changing patterns of disease and mortality, extreme weather events, food insecurity, water scarcity, heat waves, and threats to built structures, including housing and public infrastructure (Chan, 2008; Costello et al., 2009). Globally, the emerging effects of climate change are apparent, with burgeoning effects in Arctic regions (AMAP, 2017). Air temperatures in the Arctic are rising at twice the global average, causing changes and unpredictability in the behaviour and distribution of snow, ice, water, and permafrost—features critical to life in the Arctic (AMAP, 2017).

Indigenous peoples of the North are affected by these changes in climate, and future changes in climate are likely to continue to pose serious human health challenges (ACIA, 2004). Direct impacts on health in the Arctic occur through rising temperatures, increases in the frequency and strength of storms, floods, droughts, and heat waves (Watts et al., 2018). Indirect effects occur through a variety of mechanisms (Watts et al., 2018), such as impacts related to changing sea ice and subsequent changes to harvesting patterns. For Inuit communities, sea ice travel is critical for accessing wildlife resources and travelling between communities during winter months. Uncharacteristic weather patterns, storm events, and ice conditions are increasingly undermining the safety of travel and hunting or fishing activities (ACIA, 2004; Furgal and Seguin, 2006; Laidler, 2006; Laidler et al., 2009; Ford et al., 2014). The increased risks to safety, as well as longer travelling distances, are challenging the harvesting of country foods and may be decreasing access to those foods for some members of the community (Communities of Arctic Bay, Kugaaruk, and Naujaat et al., 2005; Furgal and Seguin, 2006; Ford, 2009).

Additionally, northern communities and southern-based scientists have shared concerns that climate change and the resulting change in the environment and communities further compound existing health issues, including mental health and wellness, nutritional deficiencies, rates of respiratory illness, livelihood and economic stability, safety, and the spread of disease (Watt-Cloutier, 2004; Cunsolo Willox et al., 2012; Boyle et al., 2013; Ford et al., 2014).

Authorities need to be able to assess, anticipate, and monitor human health vulnerability to climate change, in order to plan for the inevitable effects of climate change on human health and to implement mitigative or adaptive responses. Indicators are single measures that provide a tool to assess, monitor, and quantify human health vulnerability, to aid in the design and targeting of interventions, and measure the effectiveness of climate change adaptation and mitigation activities. The importance of monitoring health-related impacts of climate change is increasingly recognized around the globe. The Lancet Countdown on Health and Climate Change (Watts et al., 2018) outlined global indicators of the effects of climate change on health, but not all indicators are relevant to Arctic regions; and among the indicators identified for Arctic regions, not all are relevant to Nunavut. Climate change will affect small, Indigenous Arctic communities most strongly and differently than other regions of the world, and amongst these communities there will be variability in the effects (ACIA, 2004). Consequently, a specific set of relevant indicators is needed for Nunavut in order to accurately monitor the human health impacts of climate change.

The purpose of this research was to conduct a scoping review to identify human health indicators of climate change relevant to the Canadian Arctic that can be tracked over time to assist with the monitoring of the impacts of climate change in Nunavut communities and, via a consensus-building workshop with stakeholders, identify gaps in the indicator list and data sources for the indicators, achieve a collaborative agreement on the indicators that are of priority importance in Nunavut, and subsequently develop a collaborative knowledge dissemination plan.

METHODS

Inuit Guiding Framework

The *Piliriqatigiinniq* Community Health Research Model provided the guiding framework for this exploratory study (Healey and Tagak, 2014). The model highlights five Inuit concepts that informed the research approach: *Piliriqatigiinniq* (the concept of working together for the common good), *Pittiarniq* (the concept of being good or kind), *Inuuqatigiittiarniq* (the concept of being respectful of others), *Unikkaaqatigiinniq* (the philosophy of storytelling and the power and meaning of story), and *Iqqaumaqatigiinniq* (the concept that ideas or thoughts may come into one understanding). The scoping review paid particular attention to the concept of *Iqqaumaqatigiinniq*. The model is built upon the principle that anyone and everyone can be involved in health research in some capacity, as multidisciplinary collaboration strengthens research projects, contributes added perspective to data analysis, and contributes to greater dissemination and implementation of findings across sectors. *Aajiiqatigiingniq* is the Inuit concept of consensus decision making and is an important part of any decision affecting communities in Nunavut. By following this concept, we ensure that both Western and Inuit epistemologies are included in the discussion and guarantee that all voices are heard, understood, and incorporated into decisions. This philosophical approach formed the guiding framework for the study design and the collaborative, consensus-focused workshop. In the workshop, participants came together in the spirit of *Piliriqatigiinniq*. We conducted ourselves ethically, with kindness, respect, and goodness in our approach to the issue (*Pittiarniq* and *Inuuqatigiittiarniq*). We privileged storytelling in the workshop, where all

participants, youth in particular, were encouraged to share stories in the discussion section of the workshop, in order to contextualize the importance of the indicators in the selection process. We came together to think deeply about the process, to reflect on why we were there and the importance of this exercise for our communities both now and into the future, seeking meaning and understanding in the way of *Iqqaumaqatigiiniq*.

Scoping Review Method

In the first phase of the study, during the autumn of 2014, we conducted a scoping review of health-related indicators of climate change. Our initial research question was, "What is known about health-related indicators of climate change in the North?" We conducted a search in peer-reviewed journals through biomedical, social sciences, and multidisciplinary databases—PubMed, Google Scholar and Web of Science—using combinations of key words such as Arctic, climate change, Indigenous, Inuit, Nunavut, health, vulnerability, and their synonyms and related terms. Our criterion for inclusion was the discussion of health-related indicators of climate change in Arctic communities. We identified 96 papers, including both qualitative and quantitative methodologies, as well as literature reviews. The indicators identified in the papers were consolidated into a list of 30 that served as the basis for discussion and to be presented at the Indicator Selection Workshop. The scoping review was limited by searching for only English-language publications. Other circumpolar areas publish in a variety of languages, and therefore the information obtained may be biased toward North American studies.

Indicator Selection Workshop Method

In the second phase of this project, an invitation to participate was distributed widely throughout Nunavut. Stakeholders from the Government of Nunavut Climate Change Secretariat, the Nunavut Research Institute, Nunavut Tunngavik Inc. (the Nunavut Inuit land claims organization), and Qaujigiartiit Health Research Centre participated. In addition, three youth participants from Sanirajaq (Hall Beach), Ikpiarjuk (Arctic Bay), and Mittimatalik (Pond Inlet), who were invited through an invitation distributed through the Nunavut Inuit Youth Council, participated in the workshop. The group met in Iqaluit in January 2015 to discuss the indicators that were identified in the scoping review and to participate in a consensus-building process to identify health-related indicators of climate change for Nunavut. All participants, with the exception of two, were Nunavummiut (people of Nunavut) and lifelong residents of one or more of the following communities: Iglulik, Iqaluit, Sanirajaq, Ikpiarjuk, Mittimatalik, Kangiq&iniq (Rankin Inlet), and Panniqtuuq (Pangnirtung). The two participants who were not originally from Nunavut had been living in the territory for 1 – 2 years at the time of the workshop. Participants were between the ages of 18 and 38.

We provided all participants with an overview of the literature, as well as a review of the definition and use of indicators. The 30 indicators on the list derived from the scoping review were placed on the walls of the room. Participants were invited to add indicators if they perceived a gap in the list provided.

Consensus decision-making was used to decide which indicators would be used to monitor the health impacts of climate change in Nunavut. Each participant was given 10 stickers to place on the 10 indicators they felt were the most important. When an indicator was not present, they were encouraged to add it on a piece of paper and place a sticker on it. After this process, the group discussed all of the stickered indicators, starting with the most-stickered and finishing with the least. The indicators that did not receive any stickers were removed from the list.

RESULTS

Scoping Review

We identified several themes based on the authors' working knowledge and experience in Nunavut. In addition, some new themes emerged during our review. We present the key themes and findings below. The 30 human health indicators of climate change identified through our review are grouped below, by theme.

Environmental health indicators are integral to the measurement and monitoring of the impacts of climate change on human health and to informing the development of interventions (Hambling, et al., 2011). Environmental changes can directly or indirectly impact human health by affecting the stability and predictability of the natural and built environments on which humans rely for positive health outcomes (English et al., 2009). Environmental health indicators proposed in the literature that reflect potential impacts of climatic changes in the circumpolar Arctic are greenhouse gas emissions and air quality, temperature and humidity, pollen, wildfires, drought, harmful algae blooms that can produce nerve and liver toxins (English et al, 2009); the northward shift in distribution of permafrost, coastal erosion of slopes, landslide frequency, and the health of terrestrial and marine ecosystems (Ford and Smit, 2004); sea ice thickness and areal extent (Ford and Smit, 2004; Laidler, 2006); and river hydrology in reduced water levels recorded in Baker Lake (Fox, 2002).

Morbidity and mortality indicators comment on disease and death. Morbidity refers to any deviation from physiological or psychological well-being and often is used to refer to the incidence of a disease within a population. In populations where survival is improved because of modernization, morbidity is useful to give an accurate picture of the health status of that population. Mortality refers to the number of people who died in a population.

In relation to climate change, morbidity and mortality indicators highlight the cause of illness or death in a population due to factors related to climate change. In the literature, morbidity and mortality indicators that may apply to Arctic regions are morbidity and mortality rates during extreme heat events, rates of extreme weather event injuries and mortality, respiratory and allergic disease and mortality rates related to air quality and pollens (Chan, 2008); and rates of environmental infectious diseases such as West Nile virus, botulism, and trichinosis (Chan, 2008; Parkinson et al., 2014).

A health indicator is a measure designed to summarize information about a given priority topic in population health or health system performance. *Population vulnerability indicators* comprise the largest segment of the literature on climate change-related impacts on health. In the analysis of population vulnerability to climate change, it is important to recognize that specific populations will be vulnerable to different climate-sensitive outcomes. Vulnerable populations are people who are independent on a daily basis, but during and after an emergency may require assistance to meet their basic needs. For example, those with preexisting asthma and chronic obstructive pulmonary disease will be particularly vulnerable to temperature-related effects of O_3. Children have also been identified as especially susceptible to many of the effects of climate change, such as flooding, heat, and air pollution (UNFCCC, 2016). A 2016 report by the United Nations Framework Convention on Climate Change highlighted how severe tropical cyclones demolished schools, health care facilities, and water supplies, and traumatized children and their families. Vulnerability can be assessed by not only documenting baseline exposures, but also by taking into account population sensitivities, the capacity to adapt, and how individuals and society respond to climate threats.

Population vulnerability indicators identified in the literature and potentially relevant to northern regions are preexisting chronic disease, disability status (physical or mental), elderly living alone (Horton, 2010); children and infants, poverty status, and flooding, which compromises the safety of built structures, including homes and public buildings and increases vulnerability to water-borne illness and mould (English et al., 2009); heat vulnerability and drought (Chan, 2008; English et al., 2009); safety vulnerability due to increased weather unpredictability and variability (e.g., changing wind directions and unpredictable ice conditions) (Ford and Smit, 2004); and culture loss vulnerability from a variety of factors, such as access to harvesting and species availability (Ford and Smit, 2004; Watt-Cloutier, 2004; Healey et al., 2011); sea-level rise and coastal erosion (ACIA, 2004; English et al., 2009) and stress and depression (Ford and Smit, 2004; Cunsolo Willox et al., 2012, 2013).

Increasing attention has been paid to indicators of public health adaptation to climate change in the past decade (Hambling et al., 2011; Ford et al., 2014; Neira, 2014;Watts et al., 2018). *Mitigation, adaptation, and policy indicators* are needed to measure the status of public health efforts to avoid, prepare for, and effectively respond to the risks of climate change (Hambling et al., 2011).

Data on mitigation and adaptation indicators are sparse (English et al., 2009). Proposed indicators include municipal heat island mitigation plans, community access to cooling centers during heat waves, state surveillance systems that collect data on the human health effects of climate change, a public health workforce trained in climate change research, surveillance, or adaptation (English et al., 2009); and heat wave early warning systems (English et al., 2009; Hambling, et al., 2011. A city or region may also set up an adaptation climate change task force that includes a representative from the health sector.

Workshop

Via consensus, 20 indicators were selected by the participants to be useful for monitoring the potential human health impacts of climate change in Nunavut (Table 1). Fifteen indicators were not prioritized by participants in the initial exercise or in the subsequent discussion and were removed from the list. Participants noted that the selection process was very difficult because many of the indicators were connected or overlapped. There was a significant amount of discussion about direct and indirect measures, proxy measures, timeliness of measures, and accuracy of data sources. Participants also discussed the possibility of combining indicators into indices. This discussion is common in epidemiology and is an important part of identifying workable indicators.

Gap analysis by participants produced five indicators that were not included in the review, but that they believed would be useful for tracking the human health impacts of climate change in Nunavut. These additional indicators were 1) mental health (reports of stress, depression, or anxiety due to climate change, 2) use of renewable energy, 3) number of community-based education initiatives to raise awareness about climate change and bridge the knowledge gap between older and younger generations, 4) number of cities and municipalities participating in climate change initiatives (i.e., sustainable community development plans, climate change adaptation plans, renewable energy programs), and 5) number of Nunavut organizational, institutional, and departmental agencies participating in climate change initiatives.

In order of importance, the following 20 indicators were selected by the workshop participants via consensus.

1. *Food Security Vulnerability*: Connected to other indicators, the discussion of food security vulnerability included access to country food, harvesting, and store-bought food. In addition to weather-related food shortages being an issue, participants stressed that the cost of fuel to hunt, or jet fuel to transport store-bought foods, increased vulnerability.

TABLE 1. List of indicators identified in the scoping review, selection status by workshop participants, and source of the indicator.

Indicator	Selected/not selected	Source
Environmental health indicators:		
Greenhouse gas emissions and air quality	No	Scoping review
Temperature and humidity	Yes	Scoping review, participants[1]
Pollen	No	Scoping review
Wildfires	No	Scoping review
Drought	No	Scoping review
Harmful algae blooms and shellfish poisonings	Yes	Scoping review
Permafrost (distribution, melt, shift)	Yes	Scoping review
Sea ice (thickness, areal extent, location, duration)	Yes	Scoping review
Water security (e.g., river hydrology)	Yes	Scoping review
Slopes – coastal erosion, landslide frequency	No	Scoping review
The health of terrestrial and marine ecosystems	Yes	Scoping review
Morbidity and mortality indicators:		
Morbidity and mortality from extreme heat	No	Scoping review
Extreme weather event injuries and mortality	Yes	Scoping review
Number of injuries or mortality from sea ice instability	Yes	Participants
Rates of environmental infectious diseases	Yes	Scoping review
Respiratory and allergic disease and mortality related to air quality and pollens	Yes	Scoping review
Mental health – reports of stress, depression or anxiety due to climate change	Yes	Added by participants
Population vulnerability indicators:		
Preexisting chronic disease	No	Scoping review
Disability status (physical or mental)	Yes, combined into one index	Scoping review
Elderly living alone	Yes, combined into one index	Scoping review
Children and infants	Yes, combined into one index	Scoping review
Poverty status	Yes, combined into one index	Scoping review
Heat vulnerability	No	Scoping review
Flooding risk	No	Scoping review
Safety vulnerability – increased weather unpredictability and variability	No	Scoping review
Culture loss vulnerability – access to harvesting and species availability; coastal erosion; stress, depression, or anxiety	Yes	Scoping review
Mitigation indicators:		
Use of renewable energy	Yes	Added by participants
Municipal heat island mitigation plans	No	Scoping review
Adaptation indicators:		
Community access to cooling centers during heat waves	No	Scoping review
Heat wave early warning systems	No	Scoping review
Surveillance systems per state that collect data on the human health effects of climate change	No	Scoping review
Public health workforce trained in climate change research, surveillance, or adaptation	Yes	Scoping review
Number of cities and municipalities participating in climate change initiatives (i.e., sustainable community development plans, climate change adaptation plans, renewable energy programs etc.)	Yes	Added by participants
Number of Nunavut organizational, institutional, and departmental agencies participating in climate change initiatives	Yes	Added by participants
Number of community-based education initiatives to raise awareness about climate change and bridge the knowledge gap between older and younger generations	Yes	Added by participants

[1] This indicator was modified by participants and is reported in Table 2 as "increase in heat alerts or warnings."

2. *Culture Loss Vulnerability*: It is important to recognize that culture and wellness are linked and that these are very important in Nunavut. Being on the land is part of a way of life for most Nunavummiut. The land unifies families and strengthens relationships between people. It plays a critical role in connecting the older and younger generations and facilitating the transfer of knowledge between generations.
3. *Number of Cities and Municipalities Participating in Climate Change Initiatives*: It is important to monitor how and why initiatives are taking place. If a community does not have climate change initiatives in place, participants suggested it would be important to explore barriers (resources, awareness, etc.). If such data were available, it could contribute to the creation of opportunities to share programs, plans, or initiatives across communities and could be an indicator that cities are thinking of sustainable solutions and/or preparedness.
4. *Permafrost (Distribution, Melt, or Shift)*: This indicator relates to the structural stability of buildings and infrastructure, access to the land, and connections to the food system. For example, in the Yukon, observations of lakes drying up have been attributed to permafrost melt in that region (Roy-Leveillee, 2014).
5. *Mental Health*: Climate change and mental health (in terms of rates of depression or anxiety related to climate change) are linked in the eyes of our communities and

in those of the medical community (Cunsolo-Willox et al., 2015; Vogel, 2017).

6. *Number of Health Surveillance Systems Related to Climate Change*: This indicator relates to preparedness—if we are regularly and systematically collecting data, then we will be better equipped to take action.
7. *Sea Ice (Thickness, Extent, Location, Duration)*: This indicator is directly linked to food security, culture loss, safety, and injury mortality and morbidity. Sea ice location and the amount of time that the ice is present and traversable were identified as important indicators, in addition to thickness and extent. Participants discussed impacts on the health of the marine ecosystem, including water temperature, microorganisms, and impact on the food chain. Sea ice is also an important indicator for those studying coastal infrastructure—longer ice-free periods expose coastal infrastructure to more wind and erosion. As well, sea ice plays a role in economic development; for example, more or less support for ice-based fisheries, opening the Northwest Passage for the shipping season, resource harvesting and development, and tourism.
8. *Number of Injuries or Mortality Related to Extreme Weather Events*: Participants observed and discussed an increase in frequency of extreme weather events in the Arctic. Measuring the health-related impacts of these extreme events is important for monitoring risk to public health, as well as for monitoring adaptive and mitigating interventions of climate change. This indicator also relates to economic losses, such as in the case from Coral Harbour in January 2015 when a group of hunters were stranded on an ice floe outside the harbor as the ice broke off from the main ice pack and floated away, separating the hunters from their path home and requiring assistance from the National Search and Rescue Response team. The group lost $100 000 worth of hunting equipment in the incident on the sea ice. An increase in extreme weather events also has an impact on preparedness and search and rescue. If community members are unprepared for extreme weather events and run into trouble, they will require search and rescue assistance. However, search and rescue is heavily dependent on community volunteers, who are then also put at risk in such extreme weather events. The "cascading effects" of extreme weather are also important to recognize, as in the example from Chesterfield Inlet, where the community experienced a four-day white-out. The community is only accessible by air in winter. Because of extreme weather that lasted many days during the winter of 2015, the plane was unable to land. As a result, a part required to fix the one water truck in the community couldn't be delivered. The truck wasn't able to service the health centre; therefore there was no water and the centre had to close, which meant that no one in the community could access emergency health care.
9. *Number of Organizations, Institutions, or Departments Participating in Climate Change Initiatives*: This indicator relates to emergency preparedness, search and rescue and, therefore, to mitigation and adaptation initiatives. This indicator also pertains to upstream monitoring, the collection of baseline data of preparedness and planning, and could inform the allocation of resources and policy development on a territorial level, not just the community-level, which is where the action is most likely to take place (e.g., search and rescue).
10. *Number of Heat Wave Early Warning Systems*: This indicator relates to mitigation and adaptation, as many buildings in Nunavut are not designed for hot weather ventilation. For example, many buildings, because they are designed to remain insulated from the cold, do not have windows that open. An increasing frequency of heat waves would provide evidence for a change in building practices and other initiatives.
11. *Human Cases of Environmental Infectious Disease*: Lyme disease is the most common vector-borne disease in the United States and Europe. Encephalitis is also becoming a public health concern (Costello et al., 2009; Medlock and Leach, 2015). Health risks due to climatic changes will differ between countries that have developed health infrastructures and those that do not. Human settlement patterns in different regions influence disease trends. Climatic anomalies associated with the El Niño–Southern Oscillation phenomenon and resulting drought and floods are expected to increase in frequency and intensity. These droughts and floods have been linked to outbreaks of malaria in Africa, Asia and South America. Climate change has far-reaching consequences and touches on all life-support systems. It is therefore a factor that is placed high among those that affect human health and survival (Githeko, 2000). The detection and confirmation of an environmental exposure to infectious illness is critical to the health of communities. In addition to these issues, participants discussed the need for a health surveillance system that would increase Nunavut's ability to monitor pathogens and exposures over time.
12. *Health of Terrestrial and Marine Ecosystems*: We provided participants with examples of this indicator, including range extensions of some fish species and killer whales, the northward movement of tree line, changes in timing of caribou migration, polar bear migration, and species die-offs related to extreme weather events or disease. Participants discussed changes in migration patterns and biodiversity, particularly with respect to how those changes will affect people. This indicator relates to human health, environmental infectious disease, as well as environmental contaminants and levels of potentially harmful substances in wildlife, fish, birds, and plants. The Arctic marine ecosystem is undergoing significant change. For example, new emerging fish species, such

as capelin (*Mallotus villosus*) are becoming a main part of the diet for seals (Hop and Gjøsæter, 2013).

13. *Number of Injuries or Mortality from Sea Ice Instability*: Participants selected this indicator for the same reasons as the *sea ice extent and distribution indicator.*
14. *Vulnerability of Elderly Living Alone, Poverty, Children, Infants, and Individuals with Disabilities*: Vulnerable people are less likely to have the resources to adapt to the effects of climate change on an individual level. Participants discussed the feeling of alienation or isolation.
15. *Size of Public Health Work Force Available and Trained in Climate Change Research, Surveillance, and Adaptation*: This is a measure of Nunavut's capacity to address health-related climate change challenges. This indicator relates to planning and preparedness as well, because mitigation and adaptation initiatives are stalled if there is no staff to implement the plans.
16. *Indicators of Water Security*: Participants discussed the availability and quantity of potable water, consumption patterns, and new pathogens or bacteria in potable water. Most Nunavut communities have only one primary source of drinking water and no secondary source. The availability of potable water is impacted by the climate change-related changes to river hydrology (e.g., Baker Lake, Nunavut).

    Waste management indicators are also important for water security. Population growth and climate change increase system vulnerability. For example, wastewater is often discharged into the marine environment (sometimes filtered through tundra) because communities have limited resources to meet national guidelines. The discharge of wastewater raises concerns about contaminants leaching into the water and affecting wildlife. Where permafrost is melting, material can also leach into potable water supplies.
17. *Use of Renewable Energies*: This is a good indicator of mitigation. It helps generate awareness, promotes innovative technologies, and is already measured quite consistently across Canada.
18. *Air Quality (Respiratory and Allergic Disease and Mortality Related to Air Pollution and Pollens)*: Participants discussed the impact of road dust in the summer months, as well as the need for air quality testing both indoors and outdoors.
19. *Harmful Algae Blooms or Shellfish Poisonings*: Harmful algae blooms (HABs), which can produce nerve and liver toxins, have been reported as occurring longer in duration and of greater intensity because of increased temperatures due to climate change and nutrient runoff (McMichael et al., 2006; O'Neil et al., 2012). Human exposure is of concern through both drinking water contamination and recreational exposure. Human exposure to HABs can cause eye and skin irritation, vomiting and stomach cramps, diarrhea, fever, headache, pains in muscles and joints, and weakness. Chronic exposure in drinking water supplies is suspected to have links with liver damage and cancer. Potential indicators include shellfish poisoning and blue-green algae and red tide outbreaks. Participants noted that HABs are starting to show up in the western Arctic, and that they are now noticing two blooms, where there only used to be one. The additional bloom has been attributed to warming waters and a resulting increase in nutrient availability for the algae. This indicator also relates to the health of marine ecosystems because microbial-level changes are where the most immediate changes will be observed in the short-term and thus require monitoring.
20. *Number of Education Initiatives to Fill the Knowledge Gap between Older and Younger Generations*: Youth noted the need for the monitoring of education initiatives that are intended to bridge generational perspectives and knowledge about climate change and health. For example, participants discussed how the search and rescue event near Coral Harbour was the result of a dispute between older and younger hunters and their perceptions of safety on the sea ice. It is an important indicator of adaptation and mitigation (Table 2).

DISCUSSION

A 2018 report released by the Auditor General of Canada found that the Government of Nunavut was not adequately prepared to assess and respond to the impacts of climate change. An important part of assessment is the development of indicators to monitor changes over time. The scoping review we have presented here produced a set of human health indicators of climate change that could potentially be used for monitoring activities in Nunavut. To date, there have been no other attempts to define a list of indicators to monitor the human health impacts of climate change in the territory. Consequently, use of this list of indicators will be important for the ongoing monitoring of climate change impacts on health in Nunavut. Future research should monitor and evaluate the utility of these indicators in practice.

Literature on the use of consensus-building processes to decide indicators for the broad human health impacts of climate change in the Arctic is limited. Nilsson et al. (2013) describe a process for selecting indicators for environmental health impacts in an Arctic health context; prior to our study, this is the only other account of the use of this process to select such indicators. The Nilsson et al. (2013) workshop discussion sorted an initial list of indicators by informative value and costs for data collection on a low-medium-high scale. Importance and feasibility of measurement was discussed in this context. Participants selected critical indicators: per capita renewable water, water-borne diseases, drinking water-related contaminants, water quality assurance, water safety plans, and food availability, accessibility, and safety.

TABLE 2. Stakeholder-selected health-related indicators of climate change for Nunavut and sources of data.

Indicator	Data source
Environmental health indicators:	
Increase in heat alerts/warnings	• Environment Canada, Government of Canada
HABs: harmful algae blooms; human shellfish poisonings	• Outbreak monitoring in freshwater and ocean waters. Shellfish poisonings are often underreported.
Permafrost (distribution, melt, shift)	• Nunavut Permafrost Databank • Canada-Nunavut Geoscience Office • Dept. of Environment, Government of Nunavut
Sea ice (thickness, areal extent, location, duration)	• Canadian Ice Service (Environment Canada)
Water security (including river hydrology, availability and quantity of potable water, consumption patterns, presence of pathogens)	• Environmental Health Section, Department of Health, Government of Nunavut • Hydrometric Service, Environment Canada, Government of Canada • Nunavut Water Board • Aboriginal Affairs and Northern Development Canada (AANDC), Government of Canada • Study-based data collection
Health of terrestrial and marine ecosystems	• Nunavut General Monitoring Plan, AANDC, Government of Canada • Nunavut Wildlife Management Board • Nunavut Impact Review Board • Nunavut Water Board • Department of Fisheries and Oceans, Government of Canada • Fisheries and Sealing Division, Dept. of Environment, Government of Nunavut • Canadian Wildlife Service • Study-based data collection • Long-term monitoring research projects (e.g., Polar Data Catalogue administered by ArcticNet)
Morbidity and mortality indicators:	
Number of injuries or mortality from extreme weather events	• StatsCanada • CIHI • Environment Canada
Number of injuries or mortality from sea ice instability	• Search and Rescue, Community and Government Services, Government of Nunavut
Human cases of environmental infectious disease/positive test results in reservoirs/sentinels/vectors	• Public and environmental health surveillance data
Air quality – Respiratory/allergic disease and mortality related to increased air pollution and pollens	• Administrative data - Incidence/prevalence rates of respiratory/allergic disease • Modeling
Mental health – reports of depression, anxiety related to climate change	• Study-based?
Population vulnerability indicators:	
Elderly living alone, poverty status, children, infants and individuals with disabilities	• Census
Food security vulnerability (elderly, those in poverty, infants, and disabled)	• Nunavut Food Security Coalition data sources
Culture loss vulnerability (due to compromised access to harvesting grounds; erosion of shoreline compromises safety of structures, including homes and public buildings; stress and depression; safety; species availability)	• Nunavut Climate Change Section Data Repository • Federal/Territorial collaborative hazard mapping project • Canada-Nunavut Geoscience Office • Study-based data collection, cross-sectional datasets
Mitigation indicators:	
Use of renewable energy	• Energy Secretariat, Government of Nunavut • Department of Economic Development and Transportation, Government of Nunavut • Canadian High Arctic Research Station (mandate to work on renewable energy research)
Adaptation indicators:	
Number of health surveillance systems related to climate change	• None currently exist.
Public health work force available and trained in climate change research, surveillance, and adaptation	• Study data-based data collection
Number of community-based education initiatives to raise awareness about climate change and bridge the knowledge gap between older and younger generations	• Study data-based data collection
Policy Indicators:	
Number of cities and municipalities participating in climate change initiatives (e.g., sustainable community development plans, climate change adaptation plans).	• Nunavut Climate Change Section Data Repository (online) • Climate Change and Health Adaptation Program, Health Canada, Government of Canada
Number of Nunavut organizational/institutional/departmental agencies participating in climate change initiatives	• Nunavut Climate Change Section Data Repository (online) • Climate Change and Health Adaptation Program, Health Canada, Government of Canada

Several indicators identified in our scoping review were rejected by workshop participants. However, because of the variability in how climate change affects and will affect other circumpolar regions, these indicators may be beneficial for tracking the impacts of climate change on human health in these areas. Other circumpolar countries are in various stages of climate change monitoring and adaptation, and community-level climate change vulnerability research is limited in these regions (McDowell et al., 2016). The results of this study and consensus workshop may make a contribution toward the selection of relevant indicators in neighbouring Arctic regions.

By following the *Piliriqatigiinniq* Community Health Research Model, and the concept of *Aajiqatigiinniq*, we ensured that our study reflected Nunavut communities from design to implementation to knowledge sharing. We ensured that workshop participants were given the opportunity to add indicators to the list prior to the selection activity, as well as in post-workshop knowledge sharing and dissemination activities. Participants' addition of five indicators to the list, which were later selected for use in Nunavut, highlights the importance of community involvement and consensus-based decision making. Consensus among workshop participants ensured that the selected indicators are simultaneously useful for stakeholders and applicable, pragmatic, and relevant to Nunavut's context. All participants agreed that this set of 20 indicators would be very useful for community-, regional-, territorial-, and national-level planning, intervention development, and monitoring. Furthermore, rooting the discussion in an Inuit research framework—the *Piliriqatiginniq* Community Health Research Model and the Inuit consensus process (*Aajiqatigiinniq*)—contributed to an overall sense of *Piliriqatigiinniq* and *Qanuqturniq* (seeking solutions to challenges). Participants valued the opportunity to participate in and contribute to this exercise and indicated that they had learned something new through the process. Since the workshop, the indicator list has been disseminated broadly throughout Nunavut and is being used as a basis for the development of a community-led monitoring program.

As a collective, we must continue to identify areas for collaboration and advancement of climate change research, mitigation, and adaptation initiatives in Nunavut. Mitigation of the health effects of climate change will require input from all sectors of government and society, collaboration between many academic disciplines, and new ways of international cooperation (Costello et al., 2009). Involvement of local communities in monitoring, discussing, advocating, and assisting with the process of adaptation is crucial (Furgal and Seguin, 2006; Costello et al., 2009; Healey et al., 2011). An integrated and multidisciplinary approach to reduce the adverse health effects of climate change will be achieved by taking action on the events linking climate change to illness and implementing public health systems to deal with adverse outcomes (Costello et al., 2009).

Taking these findings into account, future research should focus on community-led approaches to identify priority areas for study and for intervention to address climate change mitigation and adaptation in Arctic communities.

ACKNOWLEDGEMENTS

This project was funded by the Health Canada Climate Change and Health Adaptation in Canada's North funding program in 2014–15.

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