

# Moving Towards Surveillance of Climate Change Health Impacts



Evidence Synthesis  
August 2024

## Public Health Ontario

Public Health Ontario is an agency of the Government of Ontario dedicated to protecting and promoting the health of all Ontarians and reducing inequities in health. Public Health Ontario links public health practitioners, frontline health workers and researchers to the best scientific intelligence and knowledge from around the world.

Public Health Ontario provides expert scientific and technical support to government, local public health units and health care providers relating to the following:

- communicable and infectious diseases
- infection prevention and control
- environmental and occupational health
- emergency preparedness
- health promotion, chronic disease and injury prevention
- public health laboratory services

Public Health Ontario's work also includes surveillance, epidemiology, research, professional development and knowledge services. For more information, visit [publichealthontario.ca](https://publichealthontario.ca).

How to cite this document:

Ontario Agency for Health Protection and Promotion (Public Health Ontario). Moving towards surveillance of climate change health impacts. Toronto, ON: King's Printer for Ontario; 2024.

ISBN: 978-1-4868-8191-8

©King's Printer for Ontario, 2024

## Authors

Rachel Jansen  
Research Coordinator  
Health Promotion, Chronic Disease and Injury Prevention  
Public Health Ontario

Ruth Repchuck  
Research Analyst  
Health Protection  
Public Health Ontario

Breanne Reel  
Research Coordinator  
Health Promotion, Chronic Disease and Injury Prevention  
Public Health Ontario

Sue Keller-Olaman  
Manager  
Health Promotion, Chronic Disease and Injury Prevention  
Public Health Ontario

## Acknowledgements

The authors would like to thank the following individuals for their reviews and insights on the report. This report reflects the work of Public Health Ontario and does not necessarily reflect the opinions or perspectives of individuals we engaged for consultation and feedback, or the organizations that they represent.

Elaina MacIntyre  
Manager  
Environmental and Occupational Health  
Public Health Ontario

Jin Hee Kim  
Public Health Physician  
Environmental and Occupational Health  
Public Health Ontario

Sue Greco  
Environmental Science Specialist  
Environmental and Occupational Health  
Public Health Ontario

Garthika Navaranjan  
Epidemiologist Specialist  
Environmental and Occupational Health  
Public Health Ontario

Louise Aubin  
Director  
Health Protection, Public Health, Health Services  
Regional Municipality of Peel

## Disclaimer

This document was developed by Public Health Ontario (PHO). PHO provides scientific and technical advice to Ontario's government, public health organizations and health care providers. PHO's work is guided by the current best available evidence at the time of publication.

The application and use of this document is the responsibility of the user. PHO assumes no liability resulting from any such application or use.

This document may be reproduced without permission for non-commercial purposes only and provided that appropriate credit is given to PHO. No changes and/or modifications may be made to this document without express written permission from PHO.

## Contents

Introduction .....	1
Key Messages.....	1
Issue and Research Question.....	2
Ontario Context .....	2
Objective .....	3
Methods.....	3
Main Findings.....	4
Pathways between Climate Change and Human Health .....	4
Health Outcomes and Indicators of Climate Change.....	7
Categorized by Climate Hazards .....	8
Categorized by Directness of Impact .....	9
Other Categories.....	9
Methods to Develop and Prioritize Indicators.....	10
Literature Reviews .....	10
Community and/or Expert Consultation.....	10
Criteria to Score or Characterize Indicators.....	10
Tool or Process to Guide a Consistent Approach.....	11
Discussion and Implications for Practice .....	11
Conclusions .....	12
References .....	13
Appendix A: Health Indicators and Outcomes of Climate Change .....	18
Glossary.....	28

# Introduction

---

Climate change is a pressing global issue, which is already impacting the health of populations in Canada and Ontario. According to the Public Health Agency of Canada, public health surveillance involves tracking health events and determinants through the collection, analysis and reporting of data, making it possible to: identify and forecast threats to public health; respond quickly to threats by deploying resources effectively; create practical, evidence-based policies and programs; and meet Canada's international public health obligations. There is limited province-specific guidance in Ontario to support consistent local public health surveillance of health impacts of climate change

This report aimed to identify resources that could contribute to the development of practical and standardized surveillance approaches and activities for the human health effects of climate change, which might be readily applied or adapted to the Ontario context. We present findings related to the overall impact of climate change on health, potential health indicators, and approaches to prioritize indicators for use in a particular context. Relevant audiences include the Ontario Ministry of Health, Public Health Units (PHUs) and public health practitioners, municipalities and any groups with interest in climate change-related health indicators.

## Key Messages

---

- Multiple conceptual frameworks were identified that illustrated the impacts of climate change on human health. These build understanding of where public health surveillance of health effects fits within broader climate change adaptation.
- Resources reported a range of potential health indicators and health outcomes related to climate change. Most resources categorized these according to climate change hazards (e.g., increased temperature, reduced air quality, increase in vectors, etc.). An additional way health indicators and outcomes were categorized was by directness and timing of impacts, which accounted for immediate and longer-term effects (e.g., direct impacts, indirect impacts, deferred impacts).
- We also identified approaches to prioritize indicators for specific jurisdictions from several resources. Resources consistently described the implementation of multiple integrated approaches rather than one single method. The most common approaches included:
  - undertaking literature reviews
  - consultation with community stakeholders and subject matter experts
  - use of guiding tools or processes
  - use of criteria to rank or characterize indicators in a systematic way
- Ontario public health practitioners could consider using this report, alongside existing vulnerability and adaptation assessments, to identify indicators for a standardized surveillance strategy.

# Issue and Research Question

---

Climate change poses significant risks to the health and well-being of populations globally, across Canada and in Ontario.<sup>1-3</sup> Global warming has been occurring for decades and is projected to continue. Furthermore, Canada is warming at a rapid rate that is higher than the global average.<sup>4</sup> According to the World Health Organization, preparing systems for ongoing climate change and building climate resilience should be a goal for health and public health agencies.<sup>5</sup>

There are multiple, integrated components required for a comprehensive approach to address this pressing issue, however this report focuses specifically on one component, **the surveillance of human health impacts of climate change**. The purpose of public health surveillance is to track health events through collection, analysis and reporting of data, which facilitates identification of public health threats, timely responses to health threats, and the creation of practical policies and programs to protect the health of the population.<sup>6</sup> Public health surveillance involves tracking indicators, which are defined by the Canadian Institute for Health Information as summary measures designed to provide comparable and actionable information about topics related to population health or health system performance.<sup>7</sup> There are efforts underway towards climate-related surveillance; in a 2019 survey of Canadian health sector officials, approximately 56% reported that they undertake surveillance and monitoring of the health impacts from hazards related to climate change.<sup>8</sup>

## Ontario Context

According to the currently available Ontario Public Health Standards (OPHS), updated in 2021, boards of health are required to interpret and use surveillance data to communicate risk information to relevant audiences, conduct surveillance of environmental factors in the community, and assess health impacts related to climate change.<sup>9</sup> The OPHS refer to several resources related to these requirements. This includes the Healthy Environments and Climate Change Guideline (this guideline is relevant to the 2021 OPHS).<sup>10</sup> This guideline indicates that assessments should address rising temperatures, vector-borne illness, food and waterborne illness, forest fires, and air pollution using myriad of indicators, such as number of heat and cold alerts for the summer and winter seasons respectively, hospital admissions coinciding with extreme heat, and number of climate change adaptation measures implemented.

The Healthy Environments and Climate Change Guideline also directs the reader to the Ontario Climate Change and Health Toolkit (relevant to the 2021 OPHS).<sup>11</sup> This Toolkit includes a sub-section on the development of indicators with high-level suggestions, such as “an agreed set of minimum indicators.... Working with stakeholders, indicators should be chosen that include quantification of health burdens and qualitative metrics of the process of adaptation”.<sup>11</sup>

Multiple Ontario PHUs have conducted vulnerability and adaptation assessments (V&As) related to climate change, these assessments help identify gaps in health systems and vulnerabilities in population groups. In some cases, multiple V&As have been completed by individual PHUs. However, reporting of health indicators of climate change across Ontario remains inconsistent and a challenge for PHUs to



implement or maintain. Retaining flexibility in climate-related surveillance to suit different PHUs is important because Ontario is diverse in its geography, populations and health risks. However, there is value in having an overall consistent approach with standardized province-level indicators to support ongoing surveillance and reporting of climate related health harms.

## Objective

The objective of this report was to identify resources that could contribute to the development of practical and standardized surveillance approaches and activities in Ontario for human health impacts of climate change. Practical refers to resources or tools that could be readily applied or adapted to the Ontario context. This report focuses on the surveillance of population health outcomes related to climate change. We use the term indicators when a resource described impacts in this way. We use the term outcomes when a resource described population health impacts, risks or outcomes, but did not specify them as indicators for surveillance; however, these may be considered for indicator development. This scope was planned to provide a starting point for climate change surveillance. We acknowledge the importance of indicators for other levels and components of climate change work (e.g., monitoring health system performance, surveillance of environmental outcomes or vulnerability factors), though these are outside the scope of the present report.

## Methods

---

A combination of rapid review and environmental scan methods were used to identify resources for this report. A systematic search of indexed literature was conducted by a Public Health Ontario (PHO) Library Information Specialist in the following databases: Ovid MEDLINE (November 29, n=1,610), Ovid Global Health, EBSCOhost Environment Complete, and EBSCOhost CINAHL Complete (December 14, n=2,180).

A scan of grey literature through targeted and snowball searching methods was conducted for the following organizations/jurisdictions: Health Canada; Public Health Agency of Canada; Environment and Climate Change Canada; Canadian Public Health Association; National Collaborating Centre for Environmental Health; National Collaborating Centre for Health Public Policy; Toronto Public Health; British Columbia Centre for Disease Control; Institut national de santé publique du Québec; SUPREME integrated heat health warning system in Quebec; United States Centers for Disease Control and Prevention (CDC); State of California; Center for Global Health; National Center for Emerging and Zoonotic Infectious Diseases; Minnesota Department of Health; North Carolina Climate & Health Program; National Association of County and City Health Officials; American Public Health Association; Australia/NSW Health; United Kingdom Health Security Agency; Climate Change Committee; World Health Organization; European Centre for Disease Prevention and Control.

Duplicate independent screening was conducted for 20% of the indexed studies and inter-rater agreement over 80% was achieved before switching to single author screening. Grey literature was searched and screened initially by a single author, with a second author review of the full texts to confirm eligibility. Throughout screening, conflicts were resolved with discussion. Eligible records were

published in 2013 onwards, focused on climate change, included human health outcomes (or more specifically, indicators) of climate change, and the link between climate change and human health outcomes/indicators was organized or structured in some way (e.g., in a framework or index). We aimed to identify records focused specifically on public health surveillance of indicators, but given the scarcity of these specific records we did not make this a requirement for inclusion.

The scope of this report focused on surveillance of human health indicators of climate change. While some included resources may have incorporated non-health indicators (e.g., health system adaptation) or non-health outcomes of climate change, these were not systematically extracted. Some further records were included that described health outcomes of climate change albeit not precisely as indicators for surveillance, but they provided useful context for indicator development. It is possible additional relevant resources were missed due to resource constraints (e.g., duplicate independent screening was conducted for only 20% of indexed literature). Due to the non-quantitative nature of the included resources, synthesis was descriptive and narrative, structured around themes that emerged from identified resources.

## Main Findings

---

After screening search results for eligibility, nine indexed studies<sup>12-20</sup> and 15 grey literature records<sup>5,21-33</sup> were included for a total of 24 resources. Resources originated from Canada, United States, United Kingdom, Australia, Spain, or were international in scope. Some resources focused on select regions within countries (e.g., territory of Nunavut, state of Kentucky), and others focused on a national or international scope. The results focus on resources that could contribute to the development of practical and standardized surveillance approaches and activities in Ontario and are summarized in three subsections:

1. pathways between climate change and human health
2. health indicators or outcomes of climate change
3. methods to develop and prioritize human indicators of climate change

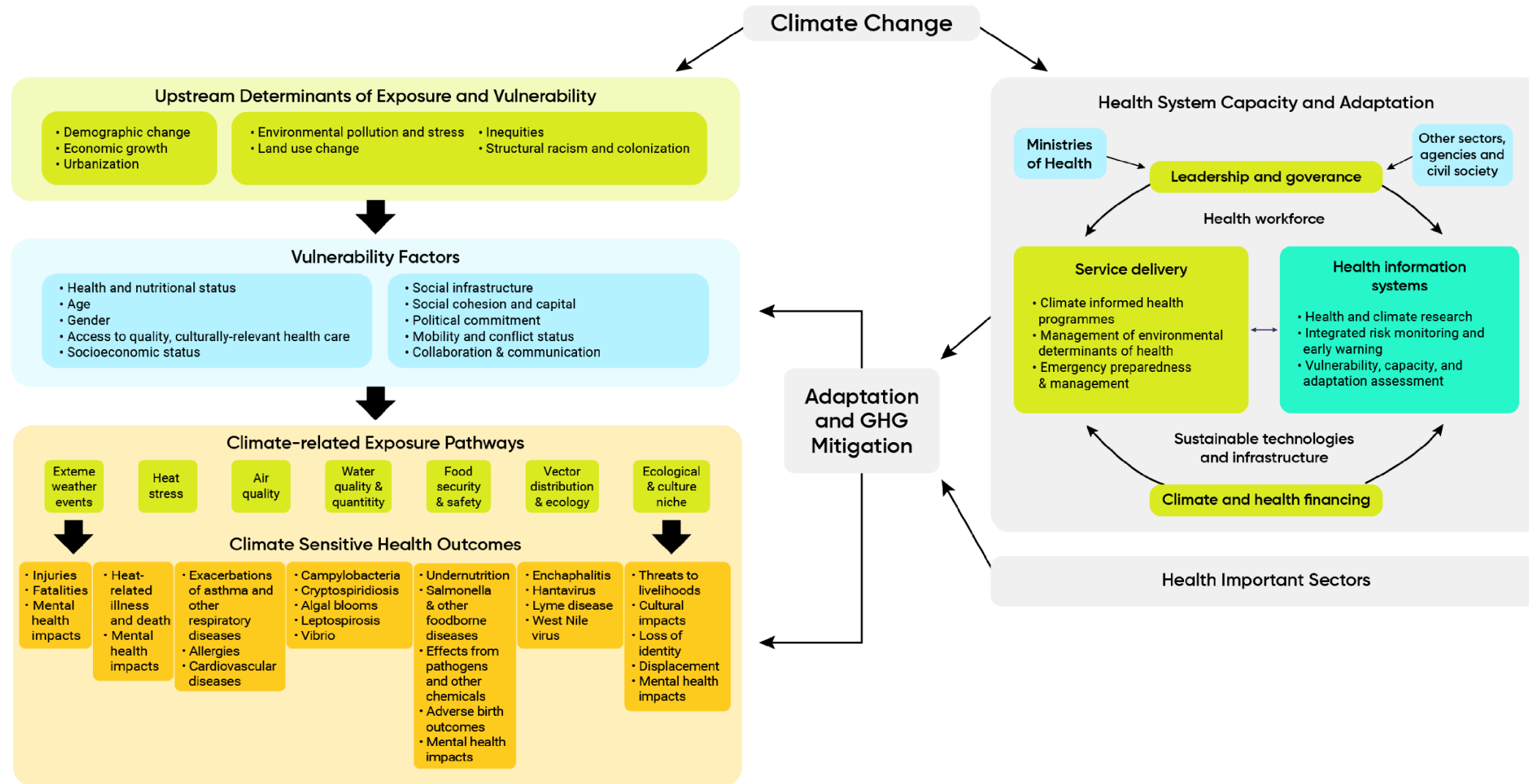
## Pathways between Climate Change and Human Health

We identified several resources with conceptual frameworks that illustrated the overall pathways between climate change and human health outcomes.<sup>5,17-19,21-24,27,28,30,31,33</sup> There were some common themes observed across these high-level conceptual frameworks. There was consistent emphasis on integrated approaches to address climate change, such as considering factors beyond health impacts (e.g., vulnerability, adaptation and mitigation), and considering other sectors beyond health (e.g., land use, electricity supply and other industries). While these frameworks did not report specific surveillance guidance, they provided a foundation in which to ground more tangible surveillance activities. Although this report focuses on human health outcomes, other important indicators were also observed (e.g., health system performance, vulnerability factors).

Select records highlighted the importance of integrating different perspectives and types of knowledge, and/or accounting for the inequitable impact of climate change on Indigenous and other equity-deserving populations.<sup>23,27,29-31</sup> A Health Canada resource outlined important gaps and inequities relevant to climate change surveillance for Indigenous Peoples in Canada.<sup>34</sup> First Nations, Inuit, and Métis peoples already experience disproportionately higher levels of health and socio-economic inequities which are directly related to historical and ongoing colonial policies and practices which enable oppressive and systemic discrimination. Forced relocations mean many Indigenous Peoples now tend to live in geographic regions experiencing climate change at more rapid rates (e.g., Northern and remote locations). Indigenous Peoples may experience higher exposure to climate risks in relation to natural and built environments (e.g., poor housing, water, sanitation, and environmental contaminants), leading to elevated levels of adverse health outcomes such as water and foodborne diseases, exacerbations of chronic and infectious diseases, increased injuries and deaths from natural hazards and extreme weather, to name only a few. An additional resource that focused on urban areas in the Mediterranean referred to equity and climate justice, and directly called for the consideration of systems of oppression in their conceptual framework.<sup>19</sup> This resource was developed with an emphasis on social and health inequalities, and specifically prompted the consideration of capitalism, colonialism and patriarchy throughout all components of the framework (i.e., structural determinants, intermediate determinants, direct and indirect climate change consequences, vulnerability, health and health inequalities). These resources highlighted the need for an equity lens in the development of public health processes and practices related to climate change.

See Figure 1 for an example of a conceptual framework from a Health Canada resource, *Health of Canadians in a Changing Climate*.<sup>1</sup> This framework included components that were commonly observed across several similar resources, all in relation to climate change. These included: health system capacity and adaptation, health important sectors, upstream determinants of exposure and vulnerability, additional vulnerability factors, climate-related exposure pathways, and climate-sensitive health outcomes. One can follow the path from each of the climate-related exposure pathways (e.g., extreme weather events) to the climate-sensitive health outcomes (e.g., injuries, fatalities, mental health outcomes). One can consider how the other framework components may impact or interact with these pathways to health outcomes (e.g., how might social infrastructure influence the severity of injuries from extreme weather events in various settings or populations?). Resources such as this conceptual framework provide a broad approach to the many pieces of work that facilitate a comprehensive understanding and approach to address climate change. These can help public health agencies to situate practical, tangible surveillance activities within the “big picture” of climate change adaptation. Further, public health practitioners may consider the climate-sensitive health outcomes as starting points for population health indicator development (explored further in sub-sections below).

**Figure 1: Pathways through which Climate Change Affects the Health of Canadians**



**Source:** Berry P, Schnitter R, Noor J. Chapter 1, climate change and health linkages. In: Berry P, Schnitter R, editors. Health of Canadians in a changing climate. Ottawa, ON: Her Majesty the Queen in Right of Canada, as represented by the Minister of Health; 2022. Figure 1.3. Available from: <https://changingclimate.ca/site/assets/uploads/sites/5/2021/03/1-CLIMATE-HEALTH-LINK-CHAPTER-EN.pdf>

## Health Outcomes and Indicators of Climate Change

All 23 resources identified for this report included some type of list of health impacts of climate change. The structure of these resources varied (e.g., visual illustration, conceptual framework, structured list), as did the categorization of health outcomes or indicators. As defined above, indicators are measures designed to provide comparable and actionable information about population health. While all resources included some form of health outcomes, it is important to note that not all resources specifically stated these to be indicators designed for surveillance. This report did not endeavor to examine the robustness or feasibility of indicators, but to provide an overview of options observed across resources.

Table 1 provides a summarized list of indicators identified across resources. Below, we outline how the resources commonly organized all health indicators and outcomes. Finally, a table of the categories and outcomes or indicators identified across all 23 resources can be found in [Appendix A](#).

**Table 1: Summary of Identified Health Indicators of Climate Change**

Category	Indicators
General	<ul style="list-style-type: none"> <li>• Daily all-cause mortality</li> <li>• Daily non-accidental mortality</li> <li>• Mental health, e.g., reports of depression, anxiety related to climate change</li> <li>• Disability-adjusted life years (DALYs) lost from climate change</li> </ul>
Temperature-related	<ul style="list-style-type: none"> <li>• Heat-related mortality, hospitalizations and ED visits</li> <li>• Cases of sunburns, skin cancers, cataracts and eye damage</li> <li>• Excess daily all-cause mortality during heat season</li> <li>• Annual cold-related mortality and morbidity</li> <li>• Cold-related hospital visits</li> </ul>
Water-related	<ul style="list-style-type: none"> <li>• Flood-related mortality and injuries (e.g., drowning, hospitalizations, ED visits)</li> <li>• Estimated number of people suffering flood-related adverse mental health impacts</li> <li>• Number of people displaced from home for more than 30 days because of flood damage</li> <li>• Health services flooded</li> <li>• Care homes flooded</li> <li>• Drinking water quality</li> <li>• Bathing water quality</li> <li>• Incidence of acute gastrointestinal illness cases/outbreaks following heavy precipitation events</li> <li>• Incidence of waterborne diseases overall, and/or following heavy precipitation event (e.g., vibriosis, disease caused by parasites, bacteria or algae)</li> <li>• Number of injuries or mortality from sea ice instability</li> </ul>

Category	Indicators
Food-related	<ul style="list-style-type: none"> <li>• Proportion of community members with nutritionally and culturally adequate diets</li> <li>• Prevalence of stunting in children under five years old</li> <li>• Incidence of climate-related food-borne diseases (e.g., Campylobacter, E. coli, Giardia, Salmonella)</li> </ul>
Extreme weather	<ul style="list-style-type: none"> <li>• Morbidity and mortality from extreme weather events (e.g. injuries, infections, mental health outcomes)</li> <li>• Number of cases presenting to primary care for mood or behavioural disorders after extreme weather events</li> <li>• Morbidity and mortality rates of populations exposed to toxic chemicals during extreme weather events</li> </ul>
Vector-related	<ul style="list-style-type: none"> <li>• Vector-borne disease incidence (e.g., incidence of Lyme disease, West Nile virus, Rift valley fever, dengue fever, hantavirus)</li> <li>• Changes in the incidence and geographic range of climate-sensitive infectious diseases</li> </ul>
Air quality	<ul style="list-style-type: none"> <li>• Mortality and/or premature mortality attributable to poor air quality (e.g., particulate matter, ozone)</li> <li>• Cardiovascular or respiratory health outcomes from aeroallergens or poor air quality (ground-level ozone, particulate matter)</li> <li>• Number of hospital visits attributable to smog</li> <li>• Number of hospital visits due to exposure to wildfire smoke</li> <li>• Number of hospital visits attributable to allergies</li> <li>• Cancer rates for respiratory disease</li> </ul>

## Categorized by Climate Hazards

The most common way health indicators and outcomes were categorized was by climate hazards, often in combination with select health outcome categories (e.g., mental health); this was observed in 12 resources.<sup>16-18,21,23-25,27-31,33,35</sup>

Brief examples of the most common climate hazard categories, and select examples of associated health outcomes and indicators, are listed below (non-exhaustive). Some health outcomes and indicators appeared in more than one climate hazard category. For example, respiratory and cardiovascular morbidity could stem from extreme temperature and from air pollution. A brief list of examples is listed here, and the full lists can be found in [Table A1](#).

- **Temperature-related:** e.g., heat-related mortality and morbidity, health impacts of wildfires.
- **Extreme weather:** e.g., injuries, infection, mortality and mental health impacts during or following extreme floods or storms.

- **Vector-related:** e.g., incidence of Lyme disease and West Nile virus.
- **Water and food-related:** e.g., drinking water quality, algal blooms, salmonella and other foodborne infections, food insecurity.
- **Air quality:** e.g., mortality attributable to poor air quality, asthma and allergy related emergency department visits and hospitalizations.

## Categorized by Directness of Impact

The second most common way to categorize health outcomes of climate change was by the directness of impact.<sup>17,19,32,35</sup> Among four resources, these were presented as health outcomes, none specifically referred to these as indicators. There was considerable overlap with the outcomes categorized by climate hazard, described above. There were five levels of impacts identified across these four resources, in some cases, outcomes categorized by directness or indirectness were also sub-categorized in relation to climate hazards (e.g., temperature, extreme weather, emissions). A brief list of examples is below, and the full lists can be found in [Table A2](#).

- **Direct impacts of climate change:** e.g., increased heat-related mortality, heat exhaustion, heat stroke; injuries and mortality from floods, storms, and wildfires.
- **Indirect impacts of climate change:** e.g., food insecurity, stress and anxiety, maternal and fetal health concerns related to exposure to heat and air pollution.
- **Climate change effects mediated through natural systems:** e.g., shifting geographic and seasonal distribution of diseases (cholera, Lyme disease) and ecological changes (harmful algal blooms).
- **Climate change effects mediated by human systems:** e.g., occupational health harms (heat strain, heat stroke, heat exhaustion in under-prepared workplaces), mental health, violence and conflict.
- **Deferred climate change effects:** e.g., exacerbation of chronic mental and physical conditions, higher mortality among elderly.

## Other Categories

There were a small number of resources that used other approaches to categorize health outcomes and indicators of climate change (e.g., by health system, by data source). The specific outcomes and indicators within these resources largely overlapped with those listed above (i.e., those categorized by climate hazard and/or directness of impact).<sup>20,22</sup> Four resources provided a list of priority health outcomes or indicators of climate change, but did not categorize them.<sup>12,13,15,26</sup> The full lists can be found in [Table A3](#) and [Table A4](#).

## Methods to Develop and Prioritize Indicators

We identified eight records which described specific methods or processes to not only identify, but to develop or prioritize health indicators, resulting in a tangible proposed list of climate change indicators to consider for surveillance in a particular context.<sup>12-14,16,19,22,25,26</sup> The settings of these resources were: the territory of Nunavut, Canada (national scope), state of Kentucky, United States (national scope), United Kingdom (regional and national scope), state of Tasmania, and Spain. While all indicators from these resources may not be directly applicable to Ontario (e.g., rising sea levels), the overall approaches to identifying and prioritizing context-specific indicators could be transferrable to Ontario or any setting. In all of these resources, two or more of the following four approaches were implemented to prioritize or characterize indicators suited to a particular region or context.

### Literature Reviews

Seven resources described literature reviews in their methods to identify and/or to better understand potential indicators.<sup>12,14,16,19,22,25,26</sup> Five resources conducted literature reviews for the purpose of identifying potential indicators of climate change,<sup>12,14,16,25</sup> or components of a conceptual framework.<sup>19</sup> In these five cases, this was an early step in the entire process, and the literature review was followed by additional methods to further refine or better understand the identified indicators. In contrast, two resources described conducting literature reviews and targeted consultation of scientific literature to develop a more detailed understanding of indicators that had already been identified or proposed, and to further develop the indicators for use in surveillance.<sup>22,26</sup>

### Community and/or Expert Consultation

Six resources described engagement with community stakeholders and/or consultation with subject matter experts to identify, validate and/or prioritize indicators.<sup>12,13,16,19,22,26</sup> Two resources centered their methods around consensus-building workshops with representatives and stakeholders from the community.<sup>12,13</sup> These studies were conducted to identify and prioritize health indicators or health risks of climate change for specific regions (Nunavut and Tasmania). In both studies, the workshops facilitated community stakeholder attendees to identify health risks, discuss and prioritize these using pre-defined processes, and produce a final list of health indicators or risks considered important to the region. Four resources involved consultation with subject matter experts such as peer-reviewers, climatologists, emergency management officials and experts in the fields of public health and health equity.<sup>16,19,22,36</sup> There were varying levels of expert involvement reported across these resources.

### Criteria to Score or Characterize Indicators

Four resources described scoring or characterization of health indicators based on systematic criteria.<sup>14,22,25,26</sup> Scoring criteria differed across studies, but common criterion included availability, feasibility, replicability and comparability over time. Characterizing indicators using these approaches allowed a systematic way to judge which indicators may be more or less suited to a specific context.



## Tool or Process to Guide a Consistent Approach

Four resources described the use of a specific tool or process to guide consistent steps and decision making in relation to health outcomes/indicators of climate change.<sup>12,13,16,26</sup> For example, Akearok et al. identified and prioritized health indicators of climate change relevant to Nunavut through several steps, and the overall process was guided by the Inuit Piliqatigiinniq Community Health Research Model.<sup>12</sup> This model was not specific to climate change or to surveillance, but grounded the community research in key Inuit concepts which emphasized working together, kindness and respect, the importance of storytelling, collaboration, combining thoughts into one understanding, and consensus-based decision making.

Another example of a specific process used to identify indicators was implemented by the United States Environmental Protection Agency (EPA). The EPA reported a consistent transparent process to screen, select, develop and report on indicators of climate change affecting health, and other sectors.<sup>26,37</sup> EPA considers candidate indicators through coordinated outreach, stakeholder engagement, and reviewing the latest scientific literature. Selection is based on standard criteria, then promising indicators are developed into proposed indicator summaries. This development process involves additional consultation of published literature, subject matter experts and online databases to collect data. Finally, indicators are re-evaluated to ensure they remain relevant, comprehensive and sustainable, this process involves monitoring new data and expert review. Technical documentation is available for each current indicator.

## Discussion and Implications for Practice

---

It was agreed across resources that surveillance of climate change health impacts by public health agencies is an important component of addressing climate change. However, specific guidance to implement this practice was limited. Sometimes, surveillance content was embedded in broader climate change efforts and it was not straightforward to disentangle specific surveillance activities from other activities and programs. For these reasons, the scope of included resources in this report extended beyond a strict surveillance focus in several cases.

The results in this report describe potential approaches to consider for surveillance of climate change health impacts in Ontario, a large and diverse province. While a consistent set of indicators is useful for surveillance, tailoring indicators for regional or local issues is also important. For example, PHUs in the North West/North East regions of Ontario may have health concerns that are not applicable to PHUs in the South West to East regions, and vice versa.

V&As were not the focus of this report, these assessments completed in relation to climate change can be considered closely linked to the planning of surveillance activities. V&As tend to serve as a “snapshot” in time, in contrast to the ongoing tracking of measures that occurs in surveillance. However, V&As also provide suggestions or recommendations to consider alongside the findings in this report. These may provide essential region-specific context and suggestions that could help inform the needs or gaps in communities, and feasibility of potential indicators. These may also facilitate better understanding of what information and systems are already in place and could be built upon to develop more ongoing surveillance efforts (e.g., priority health concerns, data sources). There are detailed Health Canada guidance resources to support V&A processes.<sup>31,38</sup>

Additional implications to consider for Ontario are explored below:

- There are conceptual frameworks that explore the connections between climate change and human health outcomes. The existing conceptual frameworks typically incorporate additional factors outside of surveillance of health indicators, such as vulnerability, mitigation, and other contextual factors influencing the connections between climate and health. While these did not report specific surveillance guidance, they provide a foundation in which to ground more tangible surveillance activities.
- The use of multiple approaches can be considered to develop consistent surveillance indicators for Ontario. A single method is likely insufficient to adequately explore and prioritize important health indicators for a specific region. This was demonstrated in the resources which consistently used multiple integrated methods. These approaches included: literature reviews, use of guiding frameworks and tools, consultation with community stakeholders and subject matter experts, and/or criteria to rank or characterize indicators in a consistent way.
- A more granular look at how health indicators of climate change are organized is an additional step to explore. While there was considerable variability in health outcomes and indicators across resources, many grouped these in similar ways (i.e., by climate hazard). These can provide a foundation from which to build public health surveillance activities focused on climate change and health.
- Stratifying indicators by directness of effect was observed in several resources. It is important to consider immediate effects, but there are also long-term, indirect and deferred repercussions of climate change, and planning proactive surveillance of these effects may be worthwhile.
- An optimal surveillance system to strive for would link data from local, provincial, national and possibly international levels. This approach could be well positioned to detect emerging trends or threats not only in Ontario, but in neighbouring regions, or regions that are similar in geography and/or populations.
- This report aimed to explore public health surveillance of health outcomes of climate change. This objective was undertaken with the aim to propose a starting point and some feasible steps for climate and public health practitioners in Ontario to consider, and to complement the V&A work already completed.

## Conclusions

---

This report on surveillance of the impact of climate change on human health provides an overview of existing work and available resources for undertaking this process. Specifically, we describe how these impacts are typically conceptualized, and more practically, how indicators might be organized for the purpose of surveillance activities. In addition, this report touches on how public health practitioners in Ontario might consider a process for prioritizing potential surveillance indicators, such as review of literature, community stakeholder and expert consultation, use of a clear process, and/or use of consistent criteria. These results can be considered alongside suggestions and context within PHU-level V&As that have been completed in Ontario.

# References

---

1. Berry P, Schnitter R, Noor J. Chapter 1, Climate change and health linkages [Internet]. In: Berry P, Schnitter R, editors. Health of Canadians in a changing climate: advancing our knowledge for action. Ottawa, ON: Government of Canada; 2022 [cited 2024 May 23]. Available from: <https://changingclimate.ca/health-in-a-changing-climate/chapter/1-0/>
2. Bai L, Li Q, Wang J, Lavigne E, Gasparrini A, Copes R, et al. Increased coronary heart disease and stroke hospitalisations from ambient temperatures in Ontario. *Heart*. 2018;104(8):673-9. Available from: <https://doi.org/10.1136/heartjnl-2017-311821>
3. Chen H, Wang J, Li Q, Yagouti A, Lavigne E, Foty R, et al. Assessment of the effect of cold and hot temperatures on mortality in Ontario, Canada: a population-based study. *CMAJ Open*. 2016;4(1):E48-58. Available from: <https://doi.org/10.9778/cmajo.20150111>
4. Zhang X, Flato G, Kirchmeier-Young M, Vincent L, Wan H, Wang X, et al. Chapter 4, Temperature and precipitation across Canada [Internet]. In: Bush E, Lemmen DS, editors. Canada's changing climate report. Ottawa, ON: Government of Canada; 2019 [cited 2024 May 23]. p. 112-93. Available from: [https://changingclimate.ca/site/assets/uploads/sites/2/2018/12/CCCR\\_Chapter4-Temperature-and-Precipitation-Across-Canada.pdf](https://changingclimate.ca/site/assets/uploads/sites/2/2018/12/CCCR_Chapter4-Temperature-and-Precipitation-Across-Canada.pdf)
5. World Health Organization (WHO). Operational framework for building climate resilient and low carbon health systems [Internet]. Geneva: WHO; 2023 [cited 2024 May 23]. Available from: <https://iris.who.int/bitstream/handle/10665/373837/9789240081888-eng.pdf?sequence=1>
6. Public Health Agency of Canada. Surveillance [Internet]. Ottawa, ON: Government of Canada; 2024 [modified 2024 Mar 05; cited 2024 May 01]. Available from: <https://www.canada.ca/en/public-health/services/public-health-practice/surveillance.html>
7. Canadian Institute for Health Information (CIHI). What is an indicator? [Internet]. Ottawa, ON: CIHI; 2024 [cited 2024 May 01]. Available from: <https://www.cihi.ca/en/access-data-and-reports/health-system-performance-measurement/what-is-an-indicator#:~:text=Health%20indicators%20are%20summary%20measures,health%20or%20health%20system%20performance>
8. Berry P, Enright P, Varangu L, Singh S, Campagna C, Gosselin P, et al. Chapter 10, Adaptation and health system resilience [Internet]. In: Berry P, Schnitter R, editors. Health of Canadians in a changing climate: advancing our knowledge for action. Ottawa, ON: Government of Canada; 2022 [cited 2024 May 23]. Available from: <https://changingclimate.ca/health-in-a-changing-climate/chapter/10-0/>
9. Ontario. Ministry of Health. Ontario public health standards: requirements for programs, services, and accountability. Protecting and promoting the health of Ontarians. Effective: June, 2021 [Internet]. Toronto, ON: Queen's Printer for Ontario; 2021 [cited 2024 Mar 27]. Available from: [https://www.health.gov.on.ca/en/pro/programs/publichealth/oph\\_standards/docs/protocols\\_guide\\_lines/Ontario\\_Public\\_Health\\_Standards\\_2021.pdf](https://www.health.gov.on.ca/en/pro/programs/publichealth/oph_standards/docs/protocols_guide_lines/Ontario_Public_Health_Standards_2021.pdf)

10. Ontario. Ministry of Health and Long-term Care, Population and Public Health Division. Healthy environments and climate change guidelines, 2018 [Internet]. Toronto, ON: Queen's Printer for Ontario; 2018 [cited 2024 Mar 28]. Available from: [https://www.health.gov.on.ca/en/pro/programs/publichealth/oph\\_standards/docs/protocols\\_guidelines/Healthy\\_Environments\\_and\\_Climate\\_Change\\_Guideline\\_2018\\_en.pdf](https://www.health.gov.on.ca/en/pro/programs/publichealth/oph_standards/docs/protocols_guidelines/Healthy_Environments_and_Climate_Change_Guideline_2018_en.pdf)
11. Ontario. Ministry of Health and Long-Term Care. Ontario climate change and health toolkit [Internet]. Toronto, ON: Queen's Printer for Ontario; 2016 [cited 2024 Mar 28]. Available from: <https://files.ontario.ca/moh-ontario-climate-change-toolkit-en-2016-08-01.pdf>
12. Akearok GH, Holzman S, Kunnuk J, Kuppaq N, Martos Z, Healey C, et al. Identifying and achieving consensus on health-related indicators of climate change in Nunavut. *Arctic*. 2019;72(3):289-99. Available from: <https://doi.org/10.14430/arctic68719>
13. Bell EJ, Turner P, Meinke H, Holbrook NJ. Developing rural community health risk assessments for climate change: a Tasmanian pilot study. *Rural Remote Health*. 2015;15(3):3174. Available from: <https://doi.org/10.22605/RRH3174>
14. Cheng JJ, Berry P. Development of key indicators to quantify the health impacts of climate change on Canadians. *Int J Public Health*. 2013;58(5):765-75. Available from: <https://doi.org/10.1007/s00038-013-0499-5>
15. Ebi KL, Boyer C, Bowen KJ, Frumkin H, Hess J. Monitoring and evaluation indicators for climate change-related health impacts, risks, adaptation, and resilience. *Int J Environ Res Public Health*. 2018;15(9). Available from: <https://doi.org/10.3390/ijerph15091943>
16. Houghton A, Austin J, Beerman A, Horton C. An approach to developing local climate change environmental public health indicators in a rural district. *J Environ Public Health*. 2017;2017:3407325. Available from: <https://doi.org/10.1155/2017/3407325>
17. Jurgilevich A, Käyhkö J, Räsänen A, Pörsti S, Lagström H, Käyhkö J, et al. Factors influencing vulnerability to climate change-related health impacts in cities - a conceptual framework. *Environ Int*. 2023;173:107837. Available from: <https://doi.org/10.1016/j.envint.2023.107837>
18. Liu AY, Trtanj JM, Lipp EK, Balbus JM. Toward an integrated system of climate change and human health indicators: a conceptual framework. *Clim Change*. 2021;166(3-4). Available from: <https://doi.org/10.1007/s10584-021-03125-w>
19. Marí-Dell'Olmo M, Oliveras L, Barón-Miras LE, Borrell C, Montalvo T, Ariza C, et al. Climate change and health in urban areas with a Mediterranean climate: a conceptual framework with a social and climate justice approach. *Int J Environ Res Public Health*. 2022;19(19). Available from: <https://doi.org/10.3390/ijerph191912764>
20. Moulton AD, Schramm PJ. Climate change and public health surveillance: toward a comprehensive strategy. *J Public Health Manag Pract*. 2017;23(6):618-26. Available from: <https://doi.org/10.1097/phh.0000000000000550>

21. Centers for Disease Control and Prevention. health (CDC). Preparing for the regional health impacts of climate change in the United States [Internet]. Atlanta, GA: CDC; 2024 [cited 2024 Jul 15]. Available from: [https://stacks.cdc.gov/view/cdc/99147/cdc\\_99147\\_DS1.pdf](https://stacks.cdc.gov/view/cdc/99147/cdc_99147_DS1.pdf)
22. Climate Change Committee (CCC). CCC adaptation monitoring framework [Internet]. CCC; 2023 [cited 2024 Feb 21]. Available from: <https://www.theccc.org.uk/publication/ccc-adaptation-monitoring-framework/>
23. Rudolph L, Harrison C, Buckley L, North S. Climate change, health, and equity: a guide for local health departments [Internet]. Oakland, CA: Public Health Institute and Washington, DC: American Public Health Association; 2018 [cited 2024 Feb 21]. Available from: [https://climatehealthconnect.org/wp-content/uploads/2018/10/APHA\\_ClimateGuide18\\_pp10web\\_FINAL.pdf](https://climatehealthconnect.org/wp-content/uploads/2018/10/APHA_ClimateGuide18_pp10web_FINAL.pdf)
24. Public Health Agency of Canada. Chief Public Health Officer of Canada's report on the state of public health in Canada 2022: mobilizing public health action on climate change in Canada [Internet]. Ottawa, ON: His Majesty the King in Right of Canada, as represented by the Minister of Health; 2022 [cited 2024 Feb 21]. Available from: <https://www.canada.ca/content/dam/phac-aspc/documents/corporate/publications/chief-public-health-officer-reports-state-public-health-canada/state-public-health-canada-2022/report-rapport/report.pdf>
25. UK Health Security Agency. Climate change and public health indicators: scoping review [Internet]. London: Crown copyright; 2023 [cited 2024 Feb 21]. Available from: <https://assets.publishing.service.gov.uk/media/64e8756763587000d1dbf6b/climate-change-and-public-health-indicators-scoping-review.pdf>
26. United States Environmental Protection Agency (EPA). Climate change indicators: health and society [Internet]. Washington, DC: EPA; 2023 [cited 2024 Feb 21]. Available from: <https://www.epa.gov/climate-indicators/health-society>
27. U.S. Global Change Research Program. The impacts of climate change on human health in the United States: a scientific assessment [Internet]. Washington, DC: U.S. Global Change Research Program; 2016 [cited 2024 Feb 21]. Available from: <https://health2016.globalchange.gov/>
28. Centers for Disease Control and Prevention (CDC). Climate change and occupational safety and health [Internet]. Atlanta, GA: CDC; 2014 [updated 2016 Dec 07; cited 2024 Feb 21]. Available from: <https://blogs.cdc.gov/niosh-science-blog/2014/09/22/climate-change/>
29. Health Canada. Risks to health from climate change [Internet]. Ottawa, ON: Government of Canada; 2022 [modified 2024 Jun 10; cited 2024 Feb 21]. Available from: <https://www.canada.ca/en/health-canada/services/climate-change-health/risks-to-health.html>
30. Health Canada. Health of Canadians in a changing climate: advancing our knowledge for action [Internet]. Ottawa, ON: Her Majesty the Queen in Right of Canada, as represented by the Minister of Health; 2022 [cited 2024 Feb 21]. Available from: [https://ftp.maps.canada.ca/pub/nrcan\\_rncan/publications/STPublications\\_PublicationsST/329/329522/gid\\_329522.pdf](https://ftp.maps.canada.ca/pub/nrcan_rncan/publications/STPublications_PublicationsST/329/329522/gid_329522.pdf)

31. Health Canada. Climate change and health vulnerability and adaptation assessments: workbook for the Canadian health sector [Internet]. Ottawa, ON: Government of Canada; 2022 [modified 2022 Sep 12; cited 2024 Feb 21]. Available from: <https://www.canada.ca/en/health-canada/services/publications/healthy-living/climate-health-adapt-vulnerability-adaptation-assessments-workbook.html>
32. Smith KR, Woodward A, Campbell-Lendrum D, Chadee DD, Honda Y, Liu Q, et al. Human health: impacts, adaptation, and co-benefits [Internet]. In: Core Writing Team; Pachauri RJ, Meyer L, editors. Climate change 2014: impacts, adaptation, and vulnerability. Part A: global and sectoral aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge, UK: Cambridge University Press; 2014 [cited 2024 Jul 11]. p. 709-54. Available from: [https://www.ipcc.ch/site/assets/uploads/2018/02/WGIIAR5-Chap11\\_FINAL.pdf](https://www.ipcc.ch/site/assets/uploads/2018/02/WGIIAR5-Chap11_FINAL.pdf)
33. World Health Organization (WHO). Measuring the climate resilience of health systems [Internet]. Geneva: WHO; 2022 [cited 2024 May 23]. Available from: <https://www.who.int/publications/item/9789240048102>
34. National Collaborating Centre for Indigenous Health (NCCIH). Chapter 2, Climate change and Indigenous People's health in Canada [Internet]. In: Berry P, Schnitter R, editors. Health of Canadians in a changing climate: advancing our knowledge for action. Ottawa, ON: Government of Canada; 2022 [cited 2024 May 27]. Available from: <https://changingclimate.ca/health-in-a-changing-climate/chapter/2-0/>
35. World Health Organization (WHO). Operational framework for building climate resilient health systems [Internet]. Geneva: WHO; 2015 [cited 2024 Feb 09]. Available from: <https://www4.unfccc.int/sites/NAPC/Documents/Supplements/WHO%20climate%20resilient%20health%20systems%20015.pdf>
36. United States Environmental Protection Agency (EPA). Climate change indicators: heat-related illnesses [Internet]. Washington, DC: EPA; 2023 [updated 2024 Jun 27; cited 2024 Feb 22]. Available from: <https://www.epa.gov/climate-indicators/heat-related-illnesses#>
37. United States Environmental Protection Agency (EPA). Data sources and methods [Internet]. Washington, DC: EPA; 2023 [updated 2023 Aug 31; cited 2024 Feb 21]. Available from: <https://www.epa.gov/climate-indicators/data-sources-and-methods>
38. Health Canada. Climate change and health vulnerability and adaptation assessments: a knowledge to action resource guide [Internet]. Ottawa, ON: Government of Canada; 2021 [cited 2024 May 28]. Available from: <https://www.canada.ca/en/health-canada/services/publications/healthy-living/climate-health-adapt-vulnerability-adaptation-assessments-resource-guide.html>
39. Resinger AD, Cammarano A, Fischlin A, Fuglestvet JS, Hansen G, Jung Y, et al. Annex I: glossary [Internet]. In: Lee H, Romero J, editors. Climate change 2023: synthesis report. Geneva: Intergovernmental Panel on Climate Change; 2023 [cited 2024 May 28]. Available from: [https://www.ipcc.ch/report/ar6/syr/downloads/report/IPCC\\_AR6\\_SYR\\_AnnexesIndex.pdf](https://www.ipcc.ch/report/ar6/syr/downloads/report/IPCC_AR6_SYR_AnnexesIndex.pdf)

40. Ontario. Ministry of Health. Ontario Public Health Standards: requirements for programs, services, and accountability [Internet]. Toronto, ON: King's Printer for Ontario; 2023 [updated 2024 Jun 28; cited 2024 May 28]. Available from: <https://www.ontario.ca/page/ontario-public-health-standards-requirements-programs-services-and-accountability>
41. World Health Organization (WHO). Vulnerability and adaptation assessments [Internet]. Geneva: WHO; n.d. [cited 2024 May 28]. Available from: <https://www.who.int/teams/environment-climate-change-and-health/climate-change-and-health/capacity-building/toolkit-on-climate-change-and-health/vulnerability>

# Appendix A: Health Indicators and Outcomes of Climate Change

While all resources included some form of health outcomes of climate change, it is important to note that not all resources specifically stated these to be indicators designed for surveillance. Resources that included **indicators** are noted in the Type of Resources column in the tables below.

**Table A1: Health Indicators and Outcomes of Climate Change Categorized by Climate Hazard**

Author	Year	Setting	Type of Resource	Health Indicators or Outcomes
CDC	2024 <sup>21</sup>	United States	Conceptual framework, providing a visual display of the impacts of climate change on human health	<ul style="list-style-type: none"> <li>• <b>Air pollution:</b> asthma; cardiovascular disease</li> <li>• <b>Changes in vector ecology:</b> malaria; dengue; encephalitis; hantavirus; Rift Valley fever; Lyme disease; Chikungunya; West Nile virus</li> <li>• <b>Increasing allergens:</b> respiratory allergies; asthma</li> <li>• <b>Water quality impacts:</b> cholera; cryptosporidiosis; campylobacter; leptospirosis; harmful algal blooms</li> <li>• <b>Water and food supply impacts:</b> malnutrition; diarrheal disease</li> <li>• <b>Environmental degradation:</b> forced migration; civil conflict; mental health impacts</li> <li>• <b>Extreme heat:</b> heat-related illness and death; cardiovascular failure</li> <li>• <b>Severe weather:</b> injuries; fatalities; mental health impacts</li> </ul>
CDC	2014 <sup>28</sup>	United States	Conceptual framework with occupational health effects of climate change	<ul style="list-style-type: none"> <li>• <b>Temperature:</b> heat stress and fatigue; increased chemical intolerance</li> <li>• <b>Air pollution:</b> cardiovascular disease; respiratory disease</li> <li>• <b>UV:</b> eye effects; immune dysfunction; skin cancer</li> <li>• <b>Extreme weather:</b> traumatic injuries; acute death; allergies/asthma; mental stress</li> <li>• <b>Vector-borne:</b> infectious disease; allergies/asthma; dermatitis</li> <li>• <b>Industrial transitions:</b> musculoskeletal disorders; mental stress; unknown new hazards; cardiovascular disease</li> <li>• <b>Built environment:</b> lung cancer; tight building syndrome</li> </ul>



Author	Year	Setting	Type of Resource	Health Indicators or Outcomes
Health Canada	2022 <sup>31</sup>	Canada	Workbook template, with examples of climate hazards and health indicators	<ul style="list-style-type: none"> <li>• <b>Extreme temperature:</b> number of heat or cold related hospital visits; number of deaths attributable to heat or cold; number of heat or cold-related illnesses</li> <li>• <b>Extreme weather events:</b> morbidity and mortality from extreme weather events (e.g., injuries, infections, mental health outcomes)</li> <li>• <b>Air quality:</b> cardiovascular or respiratory health outcomes from aeroallergens or poor air quality (ground-level ozone, particulate matter); number of hospital visits attributable to smog; number of hospital visits due to exposure to wildfire smoke; number of hospital visits attributable to allergies; number of deaths attributable to poor air quality</li> <li>• <b>Food and water security:</b> proportion of community members with nutritionally and culturally adequate diets; per capita water use</li> <li>• <b>Food- and water-borne illnesses:</b> illnesses or outbreaks due to food-, or water-borne diseases</li> <li>• <b>Vector-borne diseases:</b> West Nile Virus incidence; Lyme disease incidence; other vector-borne disease incidence</li> <li>• <b>Stratospheric ozone depletion:</b> cases of sunburns, skin cancers, cataracts and eye damage</li> </ul>
Health Canada	2022 <sup>29</sup>	Canada	List of health risks associated with climate change	<ul style="list-style-type: none"> <li>• <b>Natural hazards:</b> heat stroke; psychological impacts; cardiovascular and respiratory diseases.</li> <li>• <b>Water-related health risks include:</b> threats to drinking water and irrigation supplies; increases in water-borne diseases such as giardiasis, cryptosporidiosis, campylobacteriosis; physical injuries and mental health impacts from extreme weather events such as floods and droughts; threats to health and well-being due to the socio-economic and environmental consequences of water insecurity; impacts from sea-level rise and loss of ice in Canada</li> <li>• <b>Food safety and security:</b> increased introduction of pathogens to food; increased chemical contaminants into food systems; nutrition; mental health outcomes; food sovereignty</li> <li>• <b>Air quality:</b> increase airborne allergens; exposure to wildfire smoke</li> <li>• <b>Mental health:</b> worsening of existing mental illness such as psychosis; new-onset mental illness such as post-traumatic stress disorder; mental health stressors such as grief, worry, anxiety and vicarious trauma; lost sense of place, which refers to the perceived or actual detachment from community, environment or homeland; distress; higher rates of hospital admissions; increased suicide ideation or suicide; increased negative behaviours</li> </ul>

Author	Year	Setting	Type of Resource	Health Indicators or Outcomes
Health Canada	2022 <sup>30</sup>	Canada	Framework with climate sensitive health outcomes	<ul style="list-style-type: none"> <li>• <b>Extreme weather events:</b> injuries; fatalities; mental health impacts</li> <li>• <b>Heat stress:</b> heat-related illness and death; mental health impacts</li> <li>• <b>Air quality:</b> exacerbations of asthma and other respiratory diseases; allergies; cardiovascular disease</li> <li>• <b>Water quality and quantity:</b> campylobacter; cryptosporidiosis; algal blooms; leptospirosis; vibrio</li> <li>• <b>Food security and safety:</b> under-nutrition; salmonella &amp; other foodborne diseases; effects from pathogens and other chemicals; adverse birth outcomes; mental health impacts</li> <li>• <b>Vector distribution and ecology:</b> encephalitis; Hantavirus; Lyme disease; West Nile virus</li> <li>• <b>Ecological and culture niche:</b> threats to livelihoods; cultural impacts; loss of identity; displacement; mental health impacts</li> </ul>
Houghton	2017 <sup>16</sup>	Kentucky	List of health indicators of climate change	<ul style="list-style-type: none"> <li>• <b>Extreme heat:</b> number of heat-related deaths; number of heat stress hospitalizations and emergency department visits</li> <li>• <b>Drought:</b> drought-related health outcomes cited as "in-development"</li> <li>• <b>Flooding:</b> number of unintentional drowning-related mortalities; flooding-related hospitalizations and emergency department visits</li> </ul>
Liu	2021 <sup>18</sup>	United States	Framework demonstrating the pathways from climate change to human health outcomes	<ul style="list-style-type: none"> <li>• <b>Extreme heat:</b> heat-related deaths and illness</li> <li>• <b>Outdoor air quality:</b> premature death; acute and chronic cardiovascular and respiratory illness; asthma mortality; asthma and allergic disease-related hospitalizations; asthma and allergic disease-related emergency room visits</li> <li>• <b>Flooding:</b> drowning; injuries; mental health consequences; gastrointestinal and other illness</li> <li>• <b>Vector-borne infection:</b> Lyme disease</li> <li>• <b>Water-related infection:</b> Vibrio vulnificus induced diarrhea and intestinal illness; wound and blood-stream infections; death</li> <li>• <b>Food-related infection:</b> Salmonella infection; gastrointestinal outbreaks</li> <li>• <b>Mental health and well-being:</b> distress; grief; behavioural health disorders; social impacts; resilience</li> </ul>

Author	Year	Setting	Type of Resource	Health Indicators or Outcomes
Public Health Agency of Canada	2022 <sup>24</sup>	Canada	Conceptual framework with climate-sensitive health outcomes	<ul style="list-style-type: none"> <li>• <b>Extreme weather events:</b> injury; death; mental health impacts; limited access to essential supplies and services</li> <li>• <b>Heat stress:</b> heat stroke; dehydration; cardiovascular and respiratory impacts; mental health impacts; pregnancy complications</li> <li>• <b>Air quality:</b> exacerbation of respiratory conditions (e.g., asthma); cardiovascular diseases; allergies</li> <li>• <b>Infectious diseases:</b> Lyme disease; West Nile virus; Hantavirus</li> <li>• <b>Food quality safety and security:</b> food-borne illness; under-nutrition; food insecurity; cultural and nutritional loss of food</li> <li>• <b>Water quality safety and security:</b> water-borne diseases caused by parasites or bacteria; algal blooms</li> <li>• <b>Slow onset climate events:</b> effects on physical and mental health; increased food and water insecurity; poverty; forced migration; conflict</li> </ul>
Rudolph	2018 <sup>23</sup>	United States	Guidance with health effects of climate change	<ul style="list-style-type: none"> <li>• <b>More frequent heat waves (and urban heat island effect):</b> heat stroke; dehydration; aggravated cardiovascular illnesses; aggravated respiratory disease</li> <li>• <b>Increased flooding and storms (property loss, infrastructure damage, water contamination):</b> injury and death; water borne illness; increased cases of vector-borne diseases such as Lyme disease, malaria, Zika virus and West Nile virus</li> <li>• <b>More intense wildfires (property loss, infrastructure damage, water contamination):</b> aggravated respiratory disease</li> <li>• <b>Increased pollution and GHG emissions (increased allergens):</b> increased allergy-related illnesses; aggravated cardiovascular illnesses; aggravated respiratory disease</li> <li>• <b>Changes in precipitation and median temperature (expanded geographical range, changes in vector behaviours):</b> increased cases of vector-borne diseases such as Lyme disease, malaria, Zika virus and West Nile virus.</li> </ul>

Author	Year	Setting	Type of Resource	Health Indicators or Outcomes
United Kingdom Health Security Agency	2023 <sup>25</sup>	United Kingdom	List of health <b>indicators</b> defined as experienced effects on human systems that can be attributed to environmental or climate hazards	<ul style="list-style-type: none"> <li>• <b>Heat waves and heat risk to health:</b> annual heat-related mortality; annual heat illness; use of outdoor space for physical activity; health impacts of wildfires</li> <li>• <b>Cold and cold risk to health:</b> annual cold-related mortality and morbidity</li> <li>• <b>Flooding and flood risks to health:</b> death or injury from flood events; estimated number of people suffering flood-related adverse mental health impacts; number of people displaced from home for more than 30 days because of flood damage</li> <li>• <b>Vector-borne disease:</b> number (rate) of Lyme disease cases; autochthonous cases of vector-borne disease</li> <li>• <b>Food systems and health impacts:</b> incidence of foodborne diseases</li> <li>• <b>Water quality and quantity and their health impacts:</b> drinking water quality; bathing water quality</li> <li>• <b>Health services:</b> health services flooded</li> <li>• <b>Social care services:</b> care homes flooded</li> <li>• <b>Health impacts from mitigation action:</b> mortality attributable to PM<sub>2.5</sub> by sector</li> </ul>
United States Global Change Research Program	2016 <sup>27</sup>	United States	Conceptual framework with health outcomes of climate change	<ul style="list-style-type: none"> <li>• <b>Temperature-related:</b> deaths; illness; hospital and emergency department visits</li> <li>• <b>Air quality:</b> premature death; hospital/ER visits for acute respiratory symptoms; allergic sensitivity or disease; lung cancer, chronic obstructive pulmonary disease, cardiovascular disease associated with PM<sub>2.5</sub> exposure; lost school or work days</li> <li>• <b>Extreme events:</b> drowning; injuries; mental health consequences; gastrointestinal and other illness</li> <li>• <b>Vector-borne:</b> Lyme disease and other illnesses carried by ticks</li> <li>• <b>Water-related:</b> diarrhea and intestinal illness; wound infections; eye and ear infections; septicemia, primarily in immunocompromised people; death</li> <li>• <b>Food safety:</b> Salmonella infection; gastrointestinal outbreaks</li> <li>• <b>Mental health:</b> distress, grief, depression; strain on social relationships; substance use; PTSD and anxiety disorders; resilience, post-traumatic growth</li> </ul>

Author	Year	Setting	Type of Resource	Health Indicators or Outcomes
World Health Organization	2022 <sup>33</sup>	International	Guidance document with sample <b>indicators</b> to measure population health outcomes of climate change	<ul style="list-style-type: none"> <li>• <b>Extreme weather events:</b> number of deaths, missing persons and persons affected by climate-related disaster per 100,000 people</li> <li>• <b>Heat-related outcomes:</b> excess mortality associated with exposure to periods of high ambient temperature</li> <li>• <b>Air pollution or aeroallergens:</b> number of emergency department visits for exacerbations of asthma and chronic obstructive pulmonary disease during and after wildfires</li> <li>• <b>Waterborne diseases and other water-related impacts:</b> incidence of acute gastrointestinal illness cases/outbreaks following heavy precipitation events</li> <li>• <b>Vector-borne and zoonotic diseases:</b> changes in the incidence and geographic range of climate-sensitive infectious diseases, such as the incidence of dengue fever per 100,000 population per week or month</li> <li>• <b>Malnutrition and foodborne diseases:</b> prevalence of stunting in children under five years old; incidence of climate-related food-borne diseases (e.g., Campylobacter, E. coli, Giardia, Salmonella) in the spring and/or summer months</li> <li>• <b>Mental and psychosocial health outcomes:</b> number of cases presenting at primary care for mood or behavioral disorders after extreme weather events</li> <li>• <b>Equity impacts:</b> mortality impacts of extreme heat based upon income/neighbourhood</li> </ul>

**Table A2: Health Indicators and Outcomes of Climate Change Categorized by Directness of Impact**

Author	Year	Setting	Type of Resource	Health Indicators or Outcomes
Inter governmental Panel on Climate Change	2014 <sup>32</sup>	International	Scientific assessment, with conceptual framework including health outcomes of climate change	<ul style="list-style-type: none"> <li>• <b>Direct impacts:</b> heat and cold related impacts; floods and storms; UV radiation</li> <li>• <b>Effects mediated through natural systems:</b> vector-borne and other infectious diseases (e.g., malaria, Dengue, tick-borne diseases, other vector-borne disease); food and water-borne infections (e.g., vibrio; other parasites, bacteria and viruses); air quality</li> <li>• <b>Effects mediated by human systems:</b> nutrition (e.g., under-nutrition, stunting, wasting, underweight); occupational health (e.g., heat strain, heat stroke, heat exhaustion, work capacity loss, other occupational health concerns); mental health; violence and conflict</li> </ul>
Jurgilevich	2023 <sup>17</sup>	International	Framework demonstrating the pathway from climate change to human health impacts. Includes multiple examples of climate hazards and uses the framework to characterize effects on human health (e.g. ambient temperature on respiratory and CVD morbidity and mortality).	<p><b>Ambient temperature</b> (heat or cold):</p> <ul style="list-style-type: none"> <li>• <b>Direct impacts:</b> cardiovascular mortality; cardiovascular morbidity; respiratory mortality; respiratory morbidity; decreased maternal, fetal and neonatal health; decreased occupational health</li> <li>• <b>Deferred impacts:</b> chronic kidney disease; neurodegenerative disease; higher mortality among elderly</li> </ul> <p><b>Extreme weather events</b> (floods, storms, local sea level rise):</p> <ul style="list-style-type: none"> <li>• <b>Direct impacts:</b> mortality (drowning); injuries; hypothermia; acute anxiety; exacerbation of pre-existing medical conditions; morbidity and mortality in people dependant on electric medical equipment</li> <li>• <b>Deferred impacts:</b> mental health issues; exacerbation of chronic mental and physical conditions; acute myocardial infarction (result of distress)</li> </ul> <p><b>Heat + ozone and PM emissions:</b></p> <ul style="list-style-type: none"> <li>• <b>Indirect impacts:</b> respiratory and cardiovascular morbidity; premature deaths; maternal, fetal and neonatal health</li> </ul> <p><b>Excess precipitation, floods and storms (linked to water and soil quality, indoor air quality):</b></p> <ul style="list-style-type: none"> <li>• <b>Indirect impacts:</b> water-borne diseases; exposure to harmful substances; respiratory symptoms (asthma, rhinitis); rash; ocular symptoms; hypersensitivity; headache, dizziness; diarrhea,; stress and anxiety</li> </ul> <p><b>Increase in disease-spreading vectors:</b></p> <ul style="list-style-type: none"> <li>• <b>Indirect impacts:</b> vector-borne diseases</li> </ul>

Author	Year	Setting	Type of Resource	Health Indicators or Outcomes
Mari-Dell'Olmo	2022 <sup>19</sup>	Spain	Framework with health impacts of climate change	<ul style="list-style-type: none"> <li>• <b>Direct impacts of climate change:</b> physical and mental health; lesions; mortality</li> <li>• <b>Indirect impacts of climate change:</b> malnutrition; transmissible diseases; non-transmissible diseases; mental health and quality of life; mortality</li> </ul>
World Health Organization	2015; <sup>35</sup> and 2023 Update <sup>5</sup>	International	Framework which includes examples of health risks and impacts due to climate change	<p><b>Direct effects</b></p> <ul style="list-style-type: none"> <li>• <b>Increased temperature, increased intensity of heat waves, increase fire risk:</b> excess heat-related mortality; increased incidence of heat exhaustion and heat stroke; exacerbated circulatory, cardiovascular, respiratory and kidney diseases; increased premature mortality related to ozone and air pollution produced by fires, particularly during heat waves</li> <li>• <b>Decreased number of cold days and nights:</b> lower cold-related mortality and reduced cardiovascular and respiratory diseases, particularly for the elderly in cold and temperate climate</li> </ul> <p><b>Effects mediated through natural systems</b></p> <ul style="list-style-type: none"> <li>• <b>Higher temperatures and humidity; changing and increasingly variable precipitation; higher sea surface and freshwater temperatures:</b> accelerated microbial growth, survival, persistence, transmission, virulence of pathogens; shifting geographic and seasonal distribution of diseases (e.g. cholera, schistosomiasis) and ecological changes (e.g. harmful algal blooms); lack of water leading to poor hygiene; flood damage to water and sanitation infrastructures; contamination of water sources through overflow</li> <li>• <b>Higher temperatures and humidity; changing and increasingly variable precipitation:</b> accelerated parasite replication and increased biting rates; prolonged transmission seasons; re-emergence of formerly prevalent diseases; changing distribution and abundance of disease vectors; reduced effectiveness of vector control interventions</li> </ul> <p><b>Effects heavily mediated by human systems:</b></p> <ul style="list-style-type: none"> <li>• <b>Higher temperatures and changes in precipitation:</b> lower food production in the tropics; lower access to food due to reduced supply and higher prices; combined effects of undernutrition and infectious diseases; chronic effects of stunting and wasting in children</li> <li>• <b>Higher temperatures and humidity:</b> outdoor and unprotected workers obliged to work either in physiologically unsafe conditions or to lose income and livelihood opportunities</li> </ul>

**Table A3: Health Indicators and Outcomes of Climate Change in Other Categories**

Author	Year	Setting	Type of Resource	Health Indicators or Outcomes
Cheng	2013 <sup>14</sup>	Canada	List of health indicators of climate change	<p>Categorized by <b>data source</b>:</p> <ul style="list-style-type: none"> <li>• <b>Modeled</b>: excess daily all-cause mortality due to heat; premature deaths due to air pollution (ozone and particulate matter 2.5); preventable deaths from climate change; disability-adjusted life years (DALYs) lost from climate change.</li> <li>• <b>Non-modeled</b>: daily all-cause mortality; daily non-accidental mortality; West Nile Disease incidence; Lyme borreliosis incidence</li> </ul>
Climate Change Committee	2023 <sup>22</sup>	United Kingdom	Framework to monitor climate change adaptation across multiple sectors, including but not limited to the health sector	<p>Categorized by <b>health/public health system</b>:</p> <ul style="list-style-type: none"> <li>• <b>Improved public health</b>: disease surveillance and vector monitoring; long term weather plan implementation and climate change in local risk registers; health co-benefits across other sectors; climate-related health inequities; equitable access to green space</li> <li>• <b>Protect population health from the impacts of climate change and utilise potential benefits</b>: weather-related mortality, morbidity, disruption, anxiety; mental and physical health benefits from being outside; climate-sensitive infectious disease prevalence; air quality</li> </ul>
Moulton	2017 <sup>20</sup>	United States	List of indicators for climate change and human health	<p>Categorized by <b>health outcome</b>:</p> <ul style="list-style-type: none"> <li>• <b>Heat-related</b>: heat-related death rate; rate of deaths, hospitalizations, and ED visits during summer months; number and rate of heat stress ED visits and hospitalizations; excess daily all-cause mortality</li> <li>• <b>Utilization of health services</b>: ED and ambulatory care visits, hospital admission mortality, mental health outcomes</li> <li>• <b>Morbidity and mortality</b>: daily non-accidental mortality; preventable deaths from climate change; DALYs lost from climate change; injuries and deaths due to extreme weather events; cancer rates for respiratory disease; food-borne, waterborne, and vector-borne diseases; annual incidence of confirmed Vibrio infections; incidence of Lyme disease cases in humans; incidence of West Nile virus cases in humans; human cases of valley and dengue fever and of hantavirus; allergic disease related to climate change; morbidity and mortality rates of populations exposed to toxic chemicals during extreme weather events; premature deaths due to air pollution, e.g., ozone and PM<sub>2.5</sub></li> </ul>



**Table A4: Health Indicators and Outcomes of Climate Change with No Categories**

Author	Year	Setting	Type of Resource	Health Indicators or Outcomes
Akearok	2019 <sup>12</sup>	Nunavut	List of health-related <b>indicators</b> of climate change	Number of injuries or mortality from extreme weather events; number of injuries or mortality from sea ice instability; human cases of environmental infectious disease/positive test results in reservoirs/sentinels/vectors; air quality – Respiratory/allergic disease and mortality related to increased air pollution and pollens; mental health – reports of depression, anxiety related to climate change
Bell	2015 <sup>13</sup>	Tasmania	List of health risks of climate change	Bushfire; depression; waterborne diseases; sunburn; heatstroke; Ross river virus; reduced exercise due to inclement weather; chronic illnesses shaped by declining socioeconomic wellbeing; skin cancer; cataracts; food insecurity; air quality-related health issues; viruses; allergies; psychosocial impacts of break-up of families due to distance commuting for jobs; Dengue fever
Ebi	2018 <sup>15</sup>	Canada	List of health impact <b>indicators</b> of climate change	Excess mortality associated with exposure to high ambient temperatures; all-cause and cause-specific morbidity and mortality associated with other extreme weather events; respiratory disease mortality from exposure to air pollutants such as ozone and particulate matter; changes in the incidence and geographic range of climate-sensitive infectious diseases, with the specific diseases chosen varying depending on which are important or expected to be important in a country or region; under-nutrition (generally measured as stunting)
EPA	2023 <sup>26</sup>	United States	List of <b>indicators</b> of climate change affecting health	Heat-related deaths; heat-related illnesses; cold-related deaths; Lyme disease; West Nile virus; ragweed pollen season

# Glossary

---

**Climate change:** A change in the state of the climate that can be identified (e.g., by using statistical tests) by changes in the mean and/or the variability of its properties and that persists for an extended period, typically decades or longer.<sup>39</sup> Climate change may be due to natural internal processes or external forcings such as modulations of the solar cycles, volcanic eruptions and persistent anthropogenic changes in the composition of the atmosphere or in land use.

**Global warming:** Global warming refers to the increase in global surface temperature relative to a baseline reference period, averaging over a period sufficient to remove interannual variations (e.g., 20 or 30 years).<sup>39</sup> A common choice for the baseline is 1850–1900 (the earliest period of reliable observations with sufficient geographic coverage), with more modern baselines used depending upon the application.

**Health indicators:** summary measures designed to provide comparable and actionable information about priority topics related to population health or health system performance.<sup>7</sup>

**Health outcomes (definition for the purpose of this report):** In the absence indicators (defined above), this report also included more general descriptions of health outcomes linked to climate change reported by included resources. These are sometimes referred to as “climate-sensitive health outcomes”.

**Ontario Public Health Standards (OPHS):** identify the minimum expectations for public health programs and services to be delivered by Ontario's 34 boards of health/public health units.<sup>40</sup> The OPHS are published by the Minister of Health as outlined in Section 7 of the Health Protection and Promotion Act. Boards of health/public health units are accountable for implementing the OPHS including the protocols and guidelines that are referenced within.

**Public health surveillance:** tracking health events and determinants through the collection, analysis and reporting of data, making it possible to: identify and forecast threats to public health, such as disease outbreaks; respond quickly to threats by deploying resources effectively; create practical, evidence-based policies and programs; and meet Canada's international public health obligations.<sup>6</sup>

**Vulnerability and adaptation assessment (V&A):** a process to help identify weakness in health systems, population groups, vulnerable to impacts and effect ways to respond.<sup>38</sup> V&As do not only improve the understanding of the linkages between climate change and health, they can also serve as a baseline analysis against which changes in disease risks and protective measures can be monitored. They can also provide the opportunity for building capacity and can strengthen the case for investment in health protection.<sup>41</sup>

**Public Health Ontario**

661 University Avenue, Suite 1701

Toronto, Ontario

M5G 1M1

416.235.6556

[communications@oahpp.ca](mailto:communications@oahpp.ca)

[publichealthontario.ca](http://publichealthontario.ca)

Ontario 