

MODULE 1

CHARACTERISTICS OF EXISTING PUBLIC HEALTH CLIMATE CHANGE ADAPTATION INTERVENTIONS: A SCOPING REVIEW

Project Partners:



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MODULE 1: EXECUTIVE SUMMARY

Climate change has and will continue to have growing public health implications for the population of Ontario. Public health authorities have a duty to respond and are progressively working to address the health impacts of climate change. Many public health authorities are conducting climate change and health vulnerability and adaptation assessments. Adaptation planning is the next step public health authorities must take to promote and protect health and wellbeing, enhance resilience, and reduce the health risks associated with climate change.

A scoping review was conducted in partnership between the Public Health Agency of Canada, Ontario Region (PHAC) and Simcoe Muskoka District Health Unit (SMDHU) to support climate-health adaptation planning by local public health authorities across Ontario. The study synthesized knowledge from the literature on climate-health adaptation interventions relevant to Ontario across six climate-sensitive categories. The review highlights potential gaps in knowledge and practice. This work's findings can inform public health adaptation planning and drive future activities in practice and research. A summary of key findings grounded in the result interpretations is identified below.

Climate-sensitive Categories

- Extreme Weather
- Extreme Temperature
- Air Quality
- Vector-borne Disease
- Water and Food Quality and Quantity
- Ultraviolet Radiation

Time Trends

- In recent years, climate-health adaptation interventions applicable to Ontario were increasingly implemented and published.
- The distribution of public health intervention types used and climate-sensitive categories addressed within captured literature has changed between 2014 and 2019. Changes in the frequency of publication reflect a growing empirical knowledge of the complex linkages between climate change and related health risks.

Public Health Adaptation Interventions

- Health Communication
- Health Promotion
- Environmental Adaptations
- Policy
- Planning/Decision-making
- Surveillance
- Guidelines/Frameworks
- Alerts/Advisories/Warnings
- Other

Geographic Trends

- Examples of climate-health interventions from North America (particularly Canada and the USA) and Europe are most likely to apply to the Ontario context.
- There are variations in the distribution of particular climate-sensitive categories and intervention types across geographic areas:

- Areas with experience managing similar health risks can be useful for local adaptation planning (e.g. Australia has good examples of interventions that address ultraviolet radiation).
- Specific regions more frequently apply different intervention types (e.g. Europe, notably the United Kingdom, captured the most examples of policy interventions).

Characteristics of Existing Climate-Health Adaptation Interventions

- The public health intervention types identified most frequently were planning/decision-making, followed by health communication. The least common intervention type addressed was guidelines/framework.
- The most frequently reported climate-sensitive category was vector-borne disease, followed by extreme temperature. Ultraviolet radiation and food and water categories were captured less.
- Certain intervention types are more commonly applied to specific climate-sensitive categories.
- Particular intervention types (primarily environmental adaptation and planning/decision-making) can address more than one main climate-sensitive category in a single intervention and may be an excellent investment to address climate-health risks.
- Less than 7% (n=7) of the collected literature specifically addressed mental health outcomes associated with climate change.

The analysis revealed several potential gaps regarding existing knowledge and practice.

Critical Gaps in Knowledge and Practice

- Some public health intervention types may be under-utilized (e.g. health promotion, policy and guideline/framework intervention types).
- Certain main and specific climate-sensitive categories may warrant greater attention (e.g. ultraviolet radiation, blue-green algae, foodborne illness, winter storms, extreme cold).
- Climate-mental health outcomes are insufficiently addressed.
- Public health authorities may not regularly apply a climate-health lens to all interventions that address climate-health risks and may not publish their experiences on climate-health adaptation interventions.
- Public health authorities need to make stronger efforts to include Indigenous voices in climate-health adaptation strategies.

The report outlines how public health authorities can operationalize the scoping review results to support local public health climate change adaptation planning and highlights critical areas of future research and activities to help this field of knowledge and practice further. A high-level summary of these recommendations are outlined below.

Applying Results to Climate Change and Public Health Adaptation Planning

- Geographic trends can support public health authorities to source relevant examples of climate-health adaptation interventions.
- Characteristics of existing climate-health interventions can support public health authorities to compile an inventory of possible climate-health interventions that can be adapted to implementation locally.
- Interventions that address multiple climate-sensitive categories can help public health authorities plan climate-health adaptation interventions that may provide a more significant investment return.
- Interpretation of the results reveals several vital considerations that can support public health climate change adaptation planning.

Applying Results to Advance Public Health Practice and Knowledge

- Increase knowledge translation activities.
- Explicitly integrate a climate-health lens.
- Invest in climate-health interventions.
- Continue to build an understanding of climate-health risks.
- Take responsibility in becoming educated on how to support Indigenous climate-health adaptation and ensure Indigenous perspectives are being incorporated.

Indigenous voices were not well captured by the scoping review. To address this and reduce the exclusion of Indigenous voices from public health climate change adaptation efforts, a related resource was developed, led by Cambium Indigenous Professional Services (CIPS), to complement the literature review's scope. This complementary project introduces critical concepts of Indigenous ways of knowing and doing and best practices that public health authorities must understand and apply to work with and learn from Indigenous populations concerning climate adaptation. This work, identified in Module Two, can support public health authorities to work with and learn from Indigenous peoples in culturally competent ways concerning climate change adaptation.

1 BACKGROUND

1.1 Introducing Climate Change

This century the global community is facing the unprecedented reality and unequivocal fact that climate change is impacting life as we know it (1-4). Swift, collective, and comprehensive action is required to reduce the impacts of and enhance resilience to climate change.

Climate change refers to the variability of climate¹ or variation in the mean state of climate over an extended period of time (4). Changes to climate systems are evident. To date, there has been approximately a 1°C rise in the global average temperature from preindustrial levels (5). Other climatic changes accompany temperature rise including an increase in atmospheric water vapour², the warming of oceans, sea-level rise, and the melting of sea- and land ice (1, 2, 6). These changes are accompanied by an increase in the frequency, intensity and duration of extreme weather events and natural hazards (e.g. hurricanes), as well as extreme temperatures (7). Climatic changes impact natural and human systems in complex and interrelated ways (2, 5).

1.1.1 Causes of Climate Change

Climate change is an anthropogenic force, meaning it is an outcome of human activity. The current geological epoch has been identified as the Anthropocene, which recognizes the influence of human activity on the earth's systems since the Industrial Era (8, 9).

While there have always been changes to the earth's climate due to natural influences including solar action, volcanic activity, and natural oscillations of regional climate systems, the unprecedented changes observed this century go beyond natural influence (1, 9). It is clear that human activity is the main source of climate change (1, 5, 10). Since the Industrial Era, humans have increasingly burned fossil fuels and altered natural environments (11). These activities are an anthropogenic source of greenhouse gases (GHG) contributing to the build-up of atmospheric GHG levels (6). Carbon dioxide is the main source of increased atmospheric GHG and driver of anthropogenic climate change (10).

¹ Climate is defined as the average or expected weather conditions of a specific location over a long period of time, typically 30 years.

² Atmospheric water vapour is a greenhouse gas. As atmospheric temperatures increase the atmosphere is able to hold a greater concentration of water vapour which in turn enhances heat-trapping capabilities of the atmosphere and amplifies temperature warming.

1.2 Climate Change Impacts

1.2.1 Public Health Impacts of Climate Change

Climate change will have a significant impact on public health this century (1, 2). It will place higher demands on public health and add complexity to public health responses.

Climate change has diverse and widespread impacts on the physical, mental, and sociocultural health and wellbeing of individuals and communities (1, 2, 12, 13). The causal pathways of climate change on human health impacts are numerous and complex. Direct, health impacts include morbidity and mortality associated mainly with changes in extreme weather events and extreme temperatures (14, 15). Indirect effects are mediated through interactions with natural and human systems (15). Climate change will trigger disruptions to the physical, social, and economic systems that individuals and societies rely on, influencing the distribution of the social and ecological determinants of health (16, 17). Examples of health effects mediated through natural systems include vector-borne disease, waterborne disease, and air pollution (2, 14, 15, 18). Examples of those mediated through human systems include food insecurity, social disruption, population displacement, and mental health consequences (2, 5, 14, 15, 18).

Through indirect and direct pathways, climate change will generate new public health needs, while exacerbating existing public health problems and health inequities (2, 17, 19, 20). This expanded need may surpass local public health capacity to respond, and consequently, lead to excess negative health consequences (17).

Moreover, climate change creates additional challenges for public health response (21). Climate change is a complicated health risk, which makes addressing it more complex. For public health to effectively respond to protect human health from the impacts of climate change, reliable, accurate, and current information is essential (2). This requires the application, development and advancement of research, technologies and approaches that are, in part, contingent on available resources. Uncertainty around climate-health risks and the effectiveness of public health approaches to address those risks, and availability of required resources can restrict public health action (21). Furthermore, climate change planning and response requires a long-term approach, which has not been prioritized over more immediate public health concerns (21, 22).

1.2.2 Climate Related Health Outcomes in Ontario

Climate-related health outcomes vary depending on the geographic location, environmental influences and the population of a specific area. While local-level impacts may vary, there are six main climate-sensitive categories that pose health concerns related to climate change within Ontario (23). The main climate-sensitive categories include extreme weather and natural hazards; extreme temperature; air quality; vector-borne disease; food and water safety and security (food and water); and ultraviolet radiation. A summary of projected changes and expected health impacts attributed to each climate-sensitive category within Ontario are highlighted in **Table 1**.

Table 1: Major Climate-Related Health Concerns within Ontario

Climate-sensitive Category	Potential Changes	Expected Health Impacts
Extreme Temperature	<ul style="list-style-type: none"> Changes in the general weather patterns with a warming trend, punctuated by extremes of heat and cold More frequent, severe, and extended heatwaves 	<ul style="list-style-type: none"> Heat-related morbidity and mortality Respiratory and cardiovascular disorders Possible changed patterns for cold-related illness and death
Extreme Weather and Natural Hazards	<ul style="list-style-type: none"> More frequent and severe extreme weather events like thunderstorms and tornados Heavy precipitation causing flooding Increased drought in some regions, affecting water supplies, agricultural production, and influence to wildfires Social and economic changes 	<ul style="list-style-type: none"> Illness, injury, and death from storms, floods, fires, etc. Psychosocial health effects, including exacerbated or triggered mental illness Health impacts due to water and food safety and security Displacement of populations and crowding in emergency shelters Indirect health impacts from ecological changes, infrastructure damage, interrupted essential services (including health care)
Air Quality	<ul style="list-style-type: none"> Increased air pollution from higher levels of ground-level ozone and airborne particulate matter (including smoke and particles from wildfires) Changes in volume, timing and distribution of pollens and molds and increased aeroallergens produced by plants 	<ul style="list-style-type: none"> Eye, nose, and throat irritation and shortness of breath Exacerbation of respiratory conditions Asthma and chronic obstructive pulmonary disease Aggravated allergies Increased risk of cardiovascular diseases Premature death
Vector-borne Disease	<ul style="list-style-type: none"> Changes in biology and ecosystems or geographic distribution of several insects, ticks, and rodents Faster maturation for pathogens within vectors Longer disease transmission season 	<ul style="list-style-type: none"> Increased incidence of vector-borne diseases (i.e. Lyme Disease, West Nile Virus) Introduction of new or re-emerging infectious diseases within Ontario
Food & Water Safety and Security	<ul style="list-style-type: none"> Increased contamination of drinking and recreational water by run-off from heavy precipitation Increase algal blooms and other toxins Behaviour changes associated with warmer weather resulting in increased risk of water and foodborne illnesses Increased economic pressures for food consumption 	<ul style="list-style-type: none"> Increased outbreaks of food- and waterborne illnesses Diarrheal and intestinal disorders Impact on nutrition due to changes in availability of local and traditional foods
Ultraviolet Radiation	<ul style="list-style-type: none"> Increased human exposure to ultraviolet radiation due to stratospheric ozone depletion and behaviour changes associated with warmer weather 	<ul style="list-style-type: none"> Increased cases of sunburns, skin concerns, cataracts and eye damage Immune disorders

Adapted from Berry et al. 2014 (24), and Ebi et al. 2016. (23).

These climate-sensitive categories and associated health outcomes are not mutually exclusive but rather interact with each other. For instance, flooding is categorized as an extreme weather event that may cause injury or mortality (direct health impacts). Flooding can also interact with

other natural and human systems to cause other health impacts associated with waterborne illness, and mental health challenges.

Moreover, climate-sensitive categories can disrupt services and systems including healthcare, education, and transportation in addition to damaging infrastructure and property. These impacts on human systems will influence the social determinants of health, thus contributing to additional health risks and outcomes. These examples highlight the complex causal pathways in which climate change impacts health.

1.3 Variability of Climate Change Impacts on Human Populations

Climate change can impact everyone. However, the impacts of climate change will be experienced differently across geography and those impacts will be shaped by the social, ecological, and physiological determinants of health (the determinants of health) (1, 15). Some individuals and populations will be more vulnerable to the health impacts of climate change (2, 24).

1.3.1 Vulnerability (*Exposure, Sensitivity, and Adaptive Capacity*)

Vulnerability to climate change is the degree to which communities or individuals tend to be adversely affected by climate-related health impacts (25). People are not inherently vulnerable to climate change; rather, vulnerability is constructed by the interaction of the determinants of health, shaped by the distribution of power, and resources (23, 26).

Vulnerability to the health impacts of climate change is predicated upon three interrelated components; exposure, sensitivity, and adaptive capacity (24, 27).

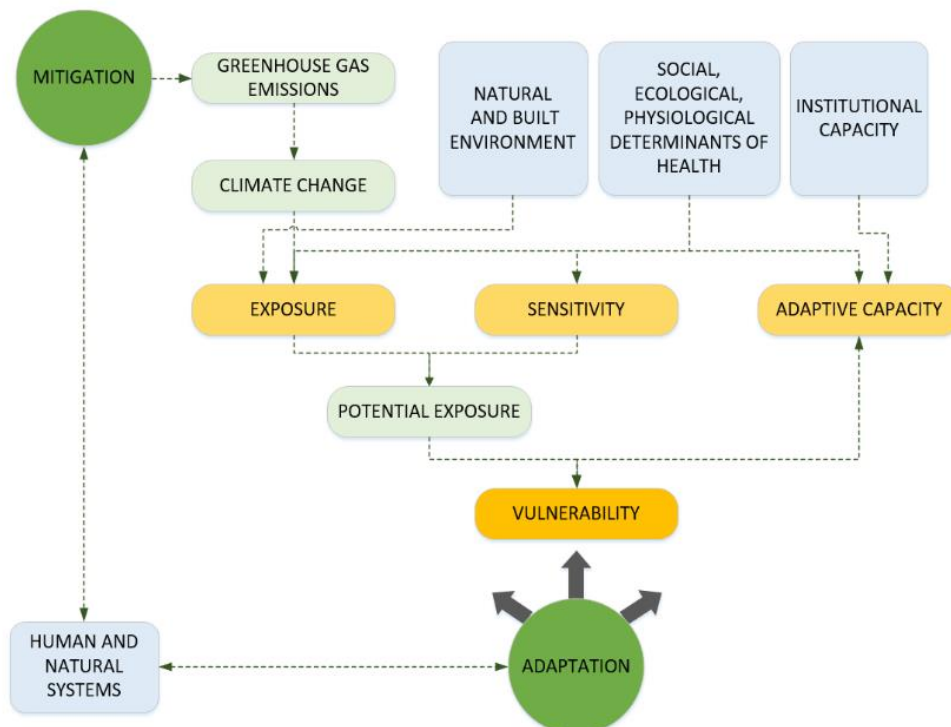
Exposure is the probability that a climate-related event or stressors will come into contact with a particular individual or population (25, 27). Exposure to climate change depends on factors that will determine the nature and magnitude of the exposures (25). These factors include geography, land-use, and topography of a specific region (24) as well as characteristics of the climate-related event like frequency, duration, and magnitude (28). It also includes factors influenced by the social and economic determinants of health such as occupation, poverty, the experience of discrimination, location, and quality of infrastructure where one lives, works, and plays (25).

Sensitivity to climate change is the degree to which an individual or population is affected by a climate-related event, either positively or negatively (27). The physiological, social, and ecological determinants of health affect how climate change will impact the health of individuals and communities. These factors include, but are not limited to age, gender, health status, socioeconomic conditions such as income, education, housing, experiences of marginalization and discrimination, access to health services, other essential services, infrastructure, and access to ecological resources like water (15, 24, 27). Moreover, sensitivity is directly impacted by the effectiveness of existing adaptation measures (27).

Adaptive capacity is the ability of communities or individuals to successfully adapt to and manage changes posed by climate change (27, 29). Adaptive capacity is influenced by access to resources, abilities and knowledge of individuals and communities in addition to the state of infrastructure, and access to services such as health care (25, 27-29). The adaptive capacity of individuals, communities, and governments are interconnected; the extent to which local governments can cope influences the capability of individuals and communities to cope (27, 30). Adaptive capacity is tied to social capital in terms of the ability of a society to act together (28). Moreover, greater resilience; the ability to prepare for, cope with, recover from, and adapt to adverse climate-related events reflects stronger adaptive capacity (25).

The degree to which each component is affected will influence overall vulnerability to climate-related health impacts. Moreover, the experience of climate change can make individuals more vulnerable due to its influence on the determinants of health. As such, vulnerability is not only about climate change, but also life conditions that interact with climate change to either enhance or reduce overall risk (23). Vulnerability to the health impacts of climate change exists on a continuum.

Figure 1: Conceptual Model of Climate Change Vulnerability



Adapted from European Environment Agency. 2008 (31).

1.3.2 *Disproportionate Impacts and Health Inequities of Climate Change*

Specific populations are disproportionately affected by climate change. Climate change is a health equity issue, meaning there are unfair and avoidable differences among groups of people resulting in a disproportional burden of health impacts. These differences predominantly reflect the social determinants of health which can increase exposure and sensitivity and reduce adaptive capacity. Moreover, climate change can destabilize the determinants of health and make it more challenging for people with the least access to resources to prepare for and cope with future climate-related events. In this way, climate change can further increase health inequities (19, 30). In consequence, the least resourced and most marginalized populations are often disproportionately impacted by climate change (15, 30).

Based on existing assessments on exposure, sensitivity, and adaptive capacity, specific individuals and populations have been identified as more likely to be vulnerable to the health impacts of climate change. Such populations include:

- Older adults
- Infants and children
- Pregnant women
- Individuals with underlying health conditions
- Individuals who work outside
- Individuals with constrained access to social and economic resources
- Remote communities
- Racialized and marginalized populations

Public health authorities have a strong history of working with stakeholders to address the needs of and support populations with greater risks. However, public health engagement with Indigenous communities is less well established and is recognized within the current Ontario Public Health Standards as area of current, focused growth for public health authorities in Ontario (32). In working to supporting the needs of Indigenous communities, public health professionals are often hindered by gaps in knowledge and understanding of Indigenous peoples, the experience and impacts of colonialism, and ways to engage meaningfully.

1.3.2.1 *Indigenous Populations Disproportionately Impacted by Climate Change*

Indigenous peoples and communities are disproportionately affected by climate change and its associated health outcomes (33, 34). While Indigenous peoples continuously demonstrate a high capacity to adapt to change both historically and presently, rapid changes associated with colonialism and anthropogenic climate change make this more challenging (34, 35).

Disproportionate impacts of climate change on Indigenous peoples are primarily constructed by the experience of colonization and marginalization, which undermines other determinants of health (36). Ecological conditions that support Indigenous cultures, identities, health, self-

determination and economies that are central to adaptive capacity, are and continue to be changed due to climate change (34). These changes can make geographic locations and close relationships to the environment become components of vulnerability (33, 37, 38).

Such determinants contribute to increased sensitivity and exposure while reducing adaptive capacity. Despite this, Indigenous populations continue to retain resilience and adaptive capacity, often rooted in cultural and spiritual identity (33, 34, 39-41). While Indigenous communities are often depicted as vulnerable to climate change, vulnerability is different within and between Indigenous groups based on the distribution of the determinants of health (42). Not all communities or individuals are vulnerable to climate change to the same degree.

It is essential to recognize that assessments on exposure, sensitivity, and adaptive capacity do not always focus on or include Indigenous populations (43). Moreover, those that do are typically conducted using Western conceptualizations of science, which can limit Indigenous experiences and perceptions due to dissimilarities in knowledge systems, values, power dynamics, and access (43-45). Lack of accurate and culturally appropriate assessments may restrict the development of adaptive capacity (38).

Public health authorities must learn to work with and learn from Indigenous communities in culturally appropriate means to enhance adaptive capacity and resilience to climate change. Indigenous knowledge and practices are a source of adaptive capacity (35).

1.4 Climate Change Action for Public Health

Public health activities involve efforts that promote and protect health and prevent disease to improve overall health and wellbeing of a population or community and reduce health inequities within and between populations (32). Public health works to address health and wellbeing of the whole population, across all stages of life through upstream approaches that act across various channels (32).

It is clear that climate change has and will continue to have growing public health implications for the population of Ontario, and public health authorities have a duty to respond. Moreover, while climate change has been named the greatest threat to public health (2), it has also been recognized as the greatest opportunity (46).

Climate change adaptation and mitigation can directly reduce the burden of ill-health, address inequities in the social and ecological determinants of health, alleviate poverty, and enhance community and health system resilience (46). In addition, investments in climate actions have cost savings benefits (46, 47).

1.4.1 Climate Change Adaptation and Mitigation

Climate change mitigation and adaptation are essential to combat climate change and reduce associated health risks (17, 30). Climate change mitigation has historically received more emphasis than adaptation (48). However, the IPCC (Interventional Panel on Climate Change)

Fourth Assessment Report (AR4) states, “that neither adaptation nor mitigation alone can avoid all climate change impacts’ however, they can complement each other and together can significantly reduce the risk of climate change” (49).

1.4.1.1 Mitigation

Climate change mitigation is defined as human actions that reduce, restrict, or remove GHGs from the atmosphere (17). Mitigation targets the sources of GHG emissions to reduce the amount released into the atmosphere or enhance GHG sinks that remove it from the atmosphere (1, 6). Thus, mitigation acts as a form of primary prevention to limit the magnitude and rate of climate change and associated health hazards (10, 17, 30, 48, 50).

Mitigation efforts should be implemented at various scales, including all levels of government, by industry and at the personal level (30). Public health plays a role in climate change mitigation. Some public health activities that support climate change mitigation includes encouraging community designs that reduce car use, advocacy for active and public transportation infrastructure, and preserving and enhancing green space (29).

1.4.1.2 Adaptation

Climate change adaptation is the process of preparing for and adjusting to actual or expected changes and impacts resulting from climate change (1, 6). Adaptation actions help communities cope with the effects of climate change that cannot be avoided by mitigation efforts (30). Climate change adaptation aims to reduce vulnerability and enhance resilience to the impacts of climate change by ensuring that appropriate social and economic systems are in place (17).

Adaptation in a public health context involves the process of designing, implementing, monitoring, and evaluating interventions to reduce climate-health impacts or to take advantage of opportunities (51). Adaptation needs to address societal, cultural, economic, and political contexts that contribute to vulnerability (51). Adaptation addresses the impacts of climate change and thus reflects secondary and tertiary prevention (50, 52). Effective adaptation requires ongoing assessment and actions (51). Without adequate adaptation, communities will not be prepared to manage the health risks of climate change.

1.4.1.3 Nexus between Adaptation and Mitigation

The adaptation-mitigation nexus reflects the connections that link climate change adaptation and mitigation. The two approaches to climate action are not mutually exclusive and are inherently interconnected and synergistic (30, 48, 53). Adaptation and mitigation work together to produce a more significant influence on reducing vulnerability to climate change than either would separately (30, 48, 53). Adaptation efforts often have mitigation benefits, and vice versa (48). Mitigation efforts can reduce the magnitude of climate change impacts that adaptation efforts would need to manage (1, 53). Similarly, adaptation efforts contribute to reducing atmospheric GHGs, reducing the challenges and cost of mitigation efforts (1, 53).

Adaptation and mitigation strategies often have cross-cutting goals and objectives in which one approach can support the other (30, 53). This is illustrated by green space interventions which can support adaptation by reducing the Urban Heat Island effect, managing surface water runoff, and promoting mental health while also acting as a carbon sink and reducing the need for artificial cooling, effectively reducing atmospheric GHGs (30, 54).

Climate change adaptation and mitigation actions can also result in conflict or trade-offs that should be considered (30, 48, 53). This can arise due to responses or priorities that compete with one another (48). An example of a conflict that may occur between adaptation and mitigation efforts is the use of air conditioning as a method to adapt to extreme heat, which infringes on mitigation efforts by contributing to GHG emissions. Investing in sustainable energy and energy retrofits can moderate the trade-off between mitigation and adaptation.

1.4.2 Co-Benefits of Climate Change Action

Climate change action presents an extraordinary opportunity to promote and protect health and wellbeing (15, 55, 56). Addressing the root cause of climate change through mitigation will provide physical and mental health gains. Some ways in which mitigation actions can support health include: reduced air pollution, increased physical activity, decreased meat consumption, increased access to fruits and vegetables, and improved access to green space (15, 55-60).

Many adaptation actions have additional mitigation and health co-benefits (55, 56, 60).

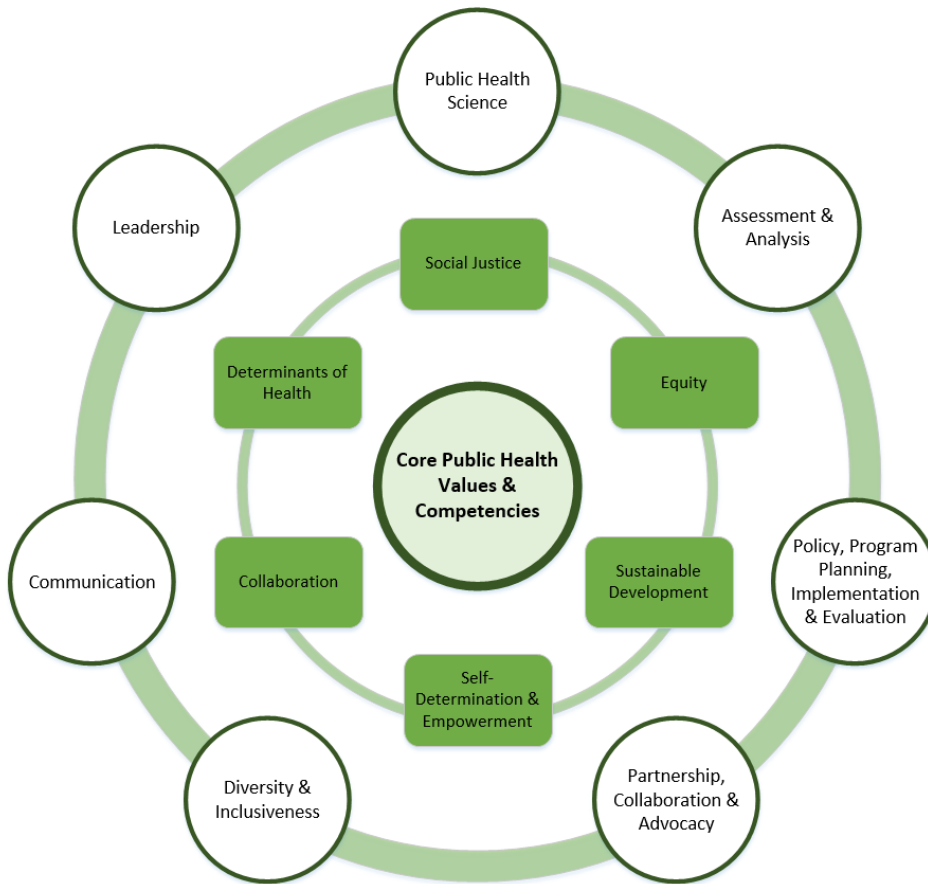
Examples include green space and active transportation which can promote physical activity, positive mental health outcomes, improved air quality, and enhanced access to nutritious foods (55, 60, 61). Moreover, adaptation efforts can improve the determinants of health for additional health benefits beyond reducing climate-health risks (15).

In addition to health co-benefits, investing in climate change actions will have cost-saving benefits for individuals, organizations, and government (55, 56, 60, 62, 63). Climate actions are essential to reduce climate-health risks, but they also provide no-regret benefits that will support health and wellbeing.

1.4.3 Aligning Public Health Competencies with Climate Change Action

Public health is well suited to address climate change. Core functions, competencies, and values of public health are also required for climate adaptation (46, 50, 52, 64). Austin et al. state that, “local public health authorities are uniquely positioned to hold a large role as a key collaborator and initiator in reducing the health burden of climate change, given their implementation role, knowledge of their local population, and proximity to the impacts of climate change on health” (21). Core competencies of public health are highlighted in **Figure 2: Core Public Health Values and Competencies**.

Figure 2: Core Public Health Values and Competencies



Information Source: Public Health Agency of Canada, 2008 (65).

Many public health programs and services are necessary responses to climate change (15). Such activities include surveillance of vector-borne disease, responding to waterborne and foodborne illness outbreaks, early warning systems regarding heat, vulnerability mapping, and health communication and promotion. Moreover, core public health functions that work to address health inequities, and improve population health status reduce vulnerability to the health impacts of climate change (15). Climate change actions provide win-win situations to improve overall health and wellbeing of a population while reducing vulnerability and enhancing resilience to climate-health impacts.

2 INTRODUCTION

The effects of climate change on the health and wellbeing of the Ontario population is becoming increasingly apparent and understood. As more empirical evidence is undertaken and disseminated, climate-related events and associated risks are becoming more visible, and climate activism has increased awareness of the threat.

Climate change health adaptation in Ontario is in the early stages (66). Public health authorities are progressively working to address the health impacts of climate change. Many are engaged in or planning to conduct climate change and health vulnerability and adaptation assessments. Adaptation planning is the next step public health authorities must take to promote and protect health and wellbeing, enhance resilience and reduce the risks associated with climate change.

To support climate-health adaptation planning by public health authorities across Ontario, a scoping review was conducted to:

- Comprehensively review and consolidate literature on public health interventions that support climate change adaptation and address expected health impacts associated with climate-sensitive categories within Ontario;
- Summarize and disseminate findings to the public health community to inform practice and strengthen the understanding of public health interventions that address climate-health risks; and
- Identify gaps in the evidence base for climate-health adaptation interventions.

This scoping review aims to highlight the range, characteristics, and gaps in the literature available on public health interventions for climate change adaptation. The findings of this work can inform public health adaptation planning and drive future research activities.

Additionally, a related yet distinct project was conducted to complement the scope of the literature review. This complementary project captures Indigenous perspectives on climate change adaptation related to health and wellbeing. This work was led by Cambium Indigenous Professional Services (CIPS), an independent Indigenous owned consulting company whose team is uniquely all Indigenous with experience consulting and collaborating with local governments, public health, and Indigenous communities on climate change and health projects. The product provides an introduction to critical concepts, Indigenous ways of knowing and doing in addition to several examples of Indigenous-led climate change adaptation interventions. This information can support public health authorities to work with and learn from Indigenous populations in culturally competent ways concerning climate change adaptation. This project is presented in Module Two. Additional information on how this complementary project came to be is highlighted in **section 3.8**.

3 METHODS

3.1 Scoping Reviews

A scoping review provides an opportunity to synthesize knowledge and increase understanding of the range and characteristics of existing literature on climate-health adaptation and related knowledge gaps to inform public health practice, decision-making, and future research (67-69). Scoping reviews can assess the literature on broad topic areas with emerging evidence from diverse study methodologies while maintaining a systematic approach (67, 70-72).

The methodology for this scoping review followed the methodological framework established by Arksey and O'Malley (71) with enhancements as proposed by Levac, Colquhoun, and O'Brien (70). Additional insights were acquired by reviewing the experience and further recommendations from several other authors (67-69, 72-74). The review entailed the following six stages:

1. Identifying the research question;
2. Identifying relevant literature;
3. Study selection;
4. Charting the data;
5. Collating, summarizing and reporting the results; and
6. Consultation and knowledge exchange.

3.2 Research Team and Partners

The Simcoe Muskoka District Health Unit (SMDHU) and the Ontario Regional Office of the Public Health Agency of Canada (PHAC) collaborated to conduct this scoping review. The research team consisted of individuals who are knowledge users and experts in climate change and public health, epidemiology, and knowledge translation. Librarians from both agencies supported the development of the inclusion criteria and conducted the search strategies.

Cambium Indigenous Professional Services (CIPS), was commissioned to capture Indigenous perspectives and wisdom on climate change adaptation. CIPS is an environmental consulting company that is uniquely Indigenous-owned and entirely Indigenous staffed. Details about the collaboration between SMDHU, PHAC, and CIPS are described in **section 3.8** of this report.

A knowledge translation advisory committee was established to provide guidance in developing knowledge translation products to communicate the findings of the literature review that will have broad relevance for public health in Ontario.

3.3 Review Question and Scope

3.3.1 Research Question

The scoping review was guided by the research question, 'What are the range and characteristics of public health interventions that support climate change adaptation and address expected health impacts associated with climate-sensitive categories within Ontario?'

Key terms contained within the research question were defined to support decision-making and enhances consistency between the aim, objectives, and inclusion/exclusion criteria (70). This strategy increases methodological transparency and rigour of the study (67). Key terms include:

- **Public health interventions:** Activities that aim to promote and protect health, prevent or reduce illness, or reduce risk exposures. Interventions include, but are not limited to, policies, programs, planning, surveillance, communications, best practices, and guidelines. For this project, public health interventions do not include risk assessments or research on associations between climate-related exposures and health outcomes.
- **Climate change adaptation:** Actions, such as policies and programs, which prepare for and respond to actual or projected climate change impacts that help individuals and communities increase resilience to the effects of climate change and reduce associated health burdens. Climate change adaptation works to reduce harms or exploit benefits associated with climate change.
- **Health impacts:** Physical and mental health outcomes that are either a direct or indirect outcome of climate change, and which are experienced within the context of Ontario.
- **Climate-sensitive categories:** Extreme temperature, extreme weather, and natural hazards, air quality, vector-borne disease, ultraviolet radiation, and water and food quality and availability.

3.3.2 Scope and Inclusion Criteria

The scoping review aimed to comprehensively review and consolidate literature on public health adaptation interventions, and summarize findings to develop an evidentiary basis on the range of public health interventions that may be suitable to address climate-health impacts to inform local public health climate change adaptation planning. The following objectives were identified to achieve this aim:

- Identify and describe existing public health interventions that address health impacts due to climate change across six climate-sensitive categories relevant to Ontario;
- Disseminate the findings of the scoping review to inform public health practice;
- Integrate findings into knowledge translation products that will support public health practice within Ontario; and
- Develop an evidentiary basis to inform local public health climate change adaptation planning.

Included literature was published in either French or English between 2014 and 2019. The review initially intended to capture literature published between 2009 and 2019, to align with the first Lancet commission report on climate change and health (2). A subsequent decision was made to limit the publication dates to 2014 and 2019 to enhance study relevance to public health since climate-health adaptation is a quickly developing topic area (67). Moreover, 2014 saw an increase in the volume of literature published on climate change and health and coincided with the IPCC fifth assessment report (AR5) (6, 75). With this decision, the authors acknowledge that this review will not capture some relevant climate-health adaptation interventions published before 2014. Additionally, the initial selection of articles excluded non-English articles due to language constraints of the research team. However, language capabilities within the team evolved, and the re-run search included French articles.

Captured literature included peer-reviewed and grey literature (derived from governments, reputable organizations, and/or recognized experts). The AACODS³ checklist was applied to determine whether grey literature was of sufficient quality for inclusion (76). No limitations were placed on the type of studies included. This decision lends itself to the breadth, flexibility, and characteristics of scoping reviews. The search strategy was limited to the geographic regions of North America, South America, Europe, Australia, and New Zealand to enhance results relevant to the Ontario context while capturing experiences from a variety of locations.

Inclusion criteria assessed during study selection included the following:

- At least one public health intervention, as previously defined, had to be included in the article.
- The intervention had to be a primary focus of the article and have public health relevance, although it did not need to stem from public health authorities.
- The intervention of focus was required to support climate change adaptation and/or address the physical and mental health impacts associated with climate-sensitive categories relevant to Ontario.
- Climate-sensitive categories identified suitable to Ontario (**Figure 3**) had to be clearly distinguished.

Due to the scope of this review, it is feasible that some climate-sensitive health outcomes that may become more prevalent in the near future were excluded from this review. Moreover, the study did not capture the impact of climate change on the social determinants of health and

³ AACODS checklist (authority, accuracy, coverage, objectivity, date, significance) enables quality appraisal of grey literature.

associated health outcomes. Adaptation interventions were categorized based on the definitions highlighted in **Table 2**. Further adaptation interventions that may have health benefits, but did not have clear relevance to public health may have also been excluded from this study.

Figure 3: Climate-sensitive Categories Relevant to Ontario, Included in the Scoping Review

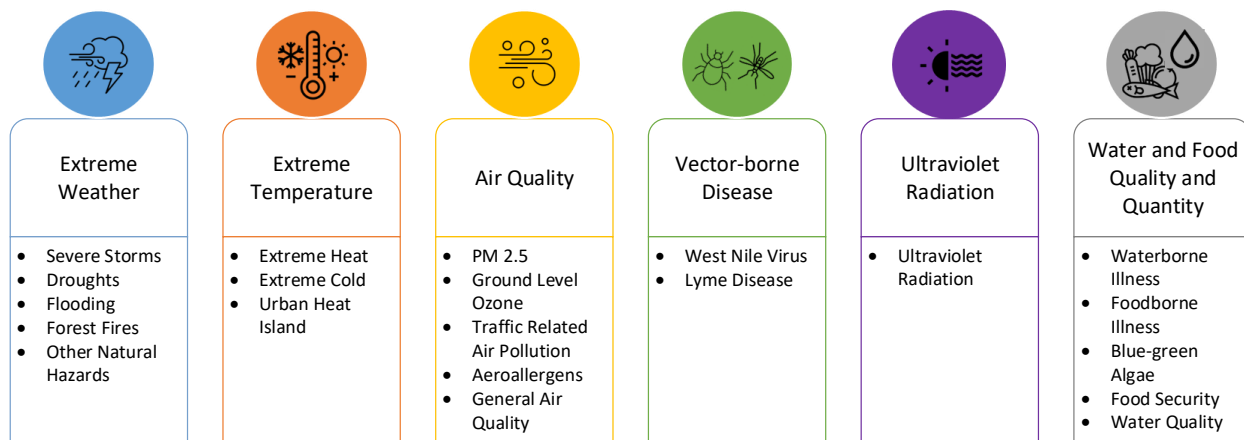


Table 2: Intervention Type Categories, Included in the Scoping Review

Public Health Intervention	Description
Health Communication	The use of communication strategies to inform and influence the decision and actions of individuals and communities to enhance health (77).
Health Promotion	Approaches that engage and empower people to increase capacity to exercise health-promoting behaviours. For this review, health promotion interventions focus on health behaviours and behaviour changes to reduce health risks, and increase control over and improve health.
Environmental Adaptations	Strategies that develop change, modify, or improve structural environmental elements (natural and/or human-made) to support healthy environments.
Policy	A plan for action on a particular topic or objective that may outline rules, principles, roles, responsibilities, values/beliefs, and/or an intention for action across various levels of actors to support public health (78, 79).
Planning/Decision-making	Strategies or tools that support the planning and/or decision-making process regarding actions that promote and protect health, prevent or reduce illness, or reduce risk exposures.
Surveillance	The systematic collection, analysis, interpretation, and dissemination of health data on an ongoing basis, to gain knowledge of the pattern of disease occurrence and potential in a community, to control and prevent disease (80).
Guidelines/Frameworks	Highlights a basic structure that underlines a process, system or concept and/or can provide general rules, principles or advice. Intended to support or guide the development or implementation of actions that support public health efforts.

Alerts/Advisories/Warnings	Actions that communicate a real or potential exposure to a particular health risk to have it avoided or managed to improve health outcomes.
Other	For this review, other interventions are those that have relevance to public health but do not neatly fit within the other categories identified.

3.4 Search Strategy

A librarian conducted the search strategy, which was tailored to the specific requirements for the electronic databases Medline, Embase, and Scopus. Searches were conducted on February 21, 2019, and again on November 7, 2019. The search was repeated to ensure the review remained up to date on the latest available literature. The search terms used aligned with the research question and scope and were derived from the following topic areas: public health, interventions, climate-sensitive categories, and geographic scope.

The re-run search conducted in November 2019, included articles published in either English or French. Since the search strategy did not include French key terms, only materials that had a translated English abstract were captured. There were no limitations placed on the type of peer-review articles collected. Results of both searches were imported into the citation manager RefWorks. Duplicates were automatically removed using RefWorks. Additional duplicates were removed as they were identified throughout the research process.

A search for grey literature was conducted in two custom Google search engines, the Carleton University Government Information Search Engine and the Harvard Think Tank Search Engine, as well as the Canadian Electronic Library database. A manual search was also conducted on the following websites: World Health Organization, European Centre for Disease Prevention and Control (ECDC), Canadian Public Health Association, and the Departments of Health for the United Kingdom, Australia, and New Zealand. The choice of these websites was based on past search experience and a *priori* decision to search grey literature for six hours of the Librarians time. The reviewers also applied a snowball technique in which outwardly relevant citations were searched.

3.5 Literature Selection

Literature was selected using a two-stage screening process that assessed literature based on a *priori* eligibility criteria highlighted in **section 3.3.2**. Two members of the research team independently screened titles and abstracts of retrieved literature. The reviewers pre-tested the eligibility criteria for 10 articles to refine the eligibility criteria before continuing with the remaining abstracts. Articles with promising titles and abstracts were included in a full article review. The reviewers applied the same pretesting process to the full article review. The research team met regularly throughout both stages of the screening process to discuss problems and manage uncertainties related to the study selection. In the case that an

agreement could not be reached on an article, a third member of the research team evaluated the article to make a final decision on its inclusion.

3.6 Data Characterization and Extraction

A charting tool developed using Microsoft Excel captured literature characteristics including publication year, publication type, publication source, geographical region derived, climate-sensitive category, public health intervention type, whether mental health was addressed in addition to a high-level summary. The research team piloted the use of the charting tool by independently charting 10 articles. Adjustments to the charting tool were made to increase clarity and consistent use of the tool. For instance, non-defined geography category was added to capture articles derived from multiple regions, or where derived region was not specified. The research team met regularly throughout the process to ensure consistency and resolve any discrepancies or uncertainties. Based on discussions, a consensus was made on any discrepancies or by a third member of the research team. A final data cleaning process was completed to ensure the literature was charted consistently.

Public health intervention categories and climate sensitive categories were not charted exclusively. Several climate sensitive-categories and intervention types may have been captured within one intervention. Moreover, one article may have included several interventions. Charting was done by articles, not by intervention.

3.7 Analyzing, Summarizing, and Reporting

An analysis guidance document was created to aid in the analysis and interpretation of the data to answer the descriptive research question. This document highlighted what value the collected data could contribute and how it could be analyzed and interpreted. For example, the document highlighted that data on publication year could identify the distribution of articles across publication years and trends by year for intervention type, climate-sensitive category, and mental health, and outlined how to express this. Additional core elements highlighted within the document related to geographic regions, intervention types, climate-sensitive categories, mental health and multiple climate-sensitive categories.

Two members of the research team worked independently to descriptively analyze the data. This resulted in two versions of interpretations of the same data, useful to capture different perspectives. The two members of the research team worked together to resolve any analysis discrepancies and brought any unresolved discrepancies to the research team for their input and feedback.

Univariate frequency was calculated and displayed as percentages for publication years, geographies, climate-sensitive categories, intervention types, mental health, and interventions that address multiple climate-sensitive categories. Moreover, cross-tabulations between two variables were calculated to look at the relationship between them and was expressed as

percentages. These descriptive statistics are useful to summarize the characteristics of the data and identify potential gaps. Data tables and heat charts were produced to summarize and display the distribution of key characteristics. The review did not strive to assess the quality or weight of the evidence for a given intervention.

The research team engaged in thematic analysis to describe the data about mental health and interventions that address multiple climate-sensitive categories in more detail and to differentiate these interventions from others that may have been included within one article.

3.8 Collaboration

SMDHU, an independent local public health unit, and the PHAC Ontario Regional Office, collaborated through a grant proposal process to recruit a master's student to conduct the review. The core work team was comprised of staff from SMDHU and PHAC. Other experts in the field were engaged as part of the knowledge translation advisory committee.

In the early stages of study selection, it was recognized that the search strategy did not explicitly include terms that reflected Indigenous ways of knowing and doing and accordingly associated literature on climate-health adaptation important to the context for Indigenous peoples was not captured. Recognizing this was an oversight that could have harmful implications for Indigenous peoples and communities, the research team sought guidance from Indigenous health experts and literature to determine how to address the issue. A decision was made to fund the development of a resource led by an Indigenous organization that would support public health authorities to include Indigenous voices in climate change adaptation interventions.

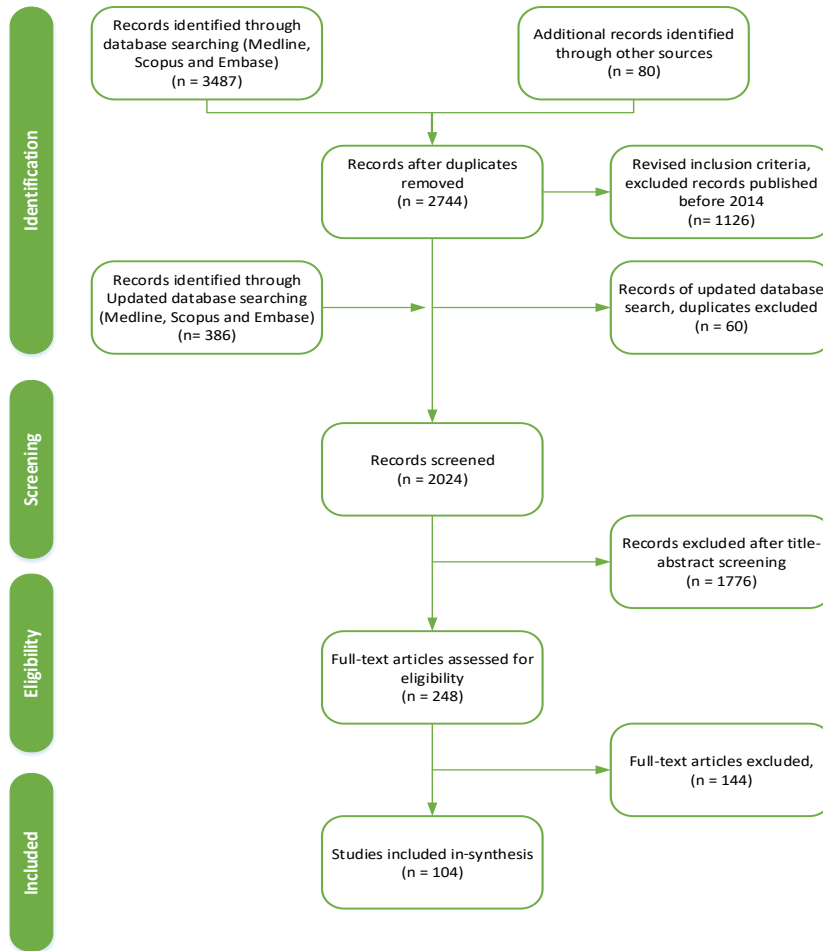
Cambium Indigenous Professional Services leveraged their experience working on multiple climate change projects with Indigenous communities to write a supporting standalone chapter to address climate-health adaptation as it relates to Indigenous peoples.

4 RESULTS

4.1 Results of Search Strategy and Literature Selection

The search strategy yielded 2,024 articles included in the abstract and title review and 248 full articles assessed for relevance **Figure 4**. 104 relevant articles were identified, comprising of peer-reviewed literature (n= 89) and grey literature (n=15). 97% (n=101) of relevant literature was published in English (n=101; 97%). Only 3 French-language articles were included, likely attributed to the use of English search terms.

Figure 4: PRISMA Flow Diagram



Adopted from Moher et al., 2009 (81)

4.2 Trends by Year

4.2.1 Number of articles published by year

The majority of included articles were published in the last two years of the study period; 2019 (29%; n=30) and 2018 (24%; n=25). There was an increase in published articles captured from the year 2015 to 2019. **Table 3** highlights the distribution of included articles by publication year.

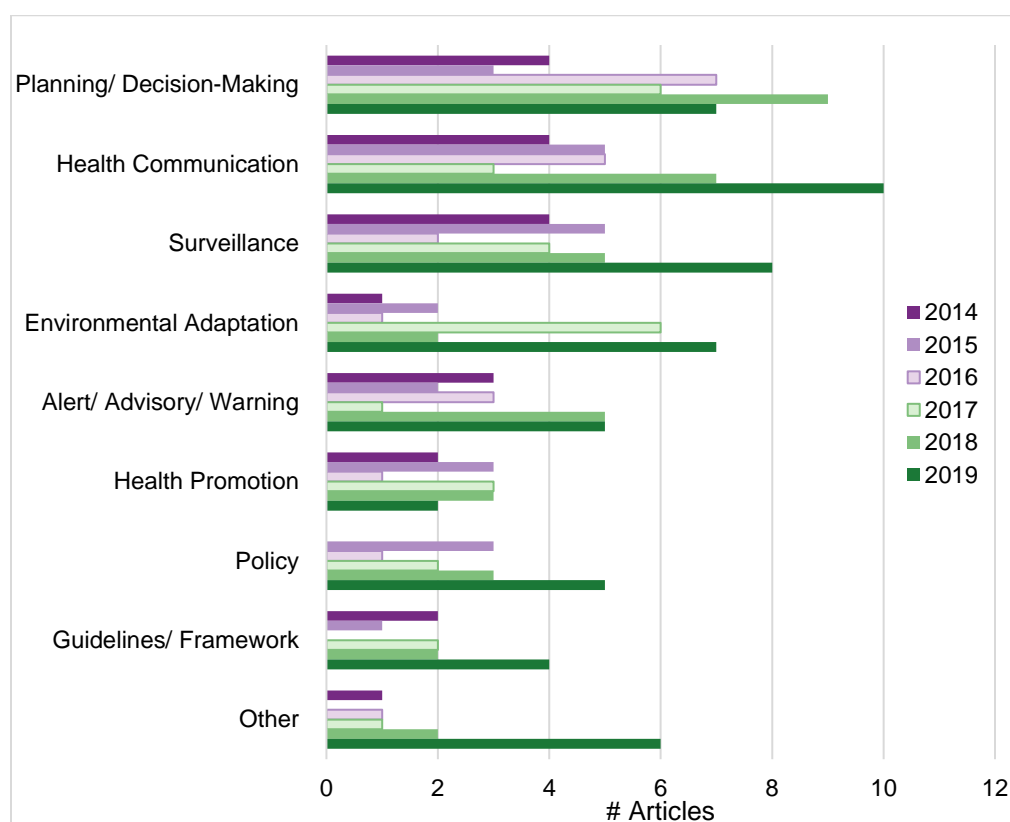
Table 3: Distribution of Articles by Publication Year

Publication Date	n	%
2014	14	13%
2015	9	9%
2016	11	11%
2017	15	14%
2018	25	24%
2019	30	29%

4.2.2 Time Trends by Intervention Type

The range of intervention types portrayed within the captured literature has evolved between 2014 and 2019, as identified in **Figure 5** (for more detail see **Appendix A**). Health communication, planning/decision-making, and surveillance interventions were consistently among the most frequent intervention types captured across all publication years. Health communication and environmental adaptation interventions experienced the greatest increase in the number of publications between 2014 and 2019. The number of articles that included health promotion interventions did not increase between 2014 and 2019 and was among the least common intervention types captured over this duration. All other intervention types were included in a higher number of articles in 2019 than in 2014.

Figure 5: Distribution of Public Health Intervention Types by Publication Year

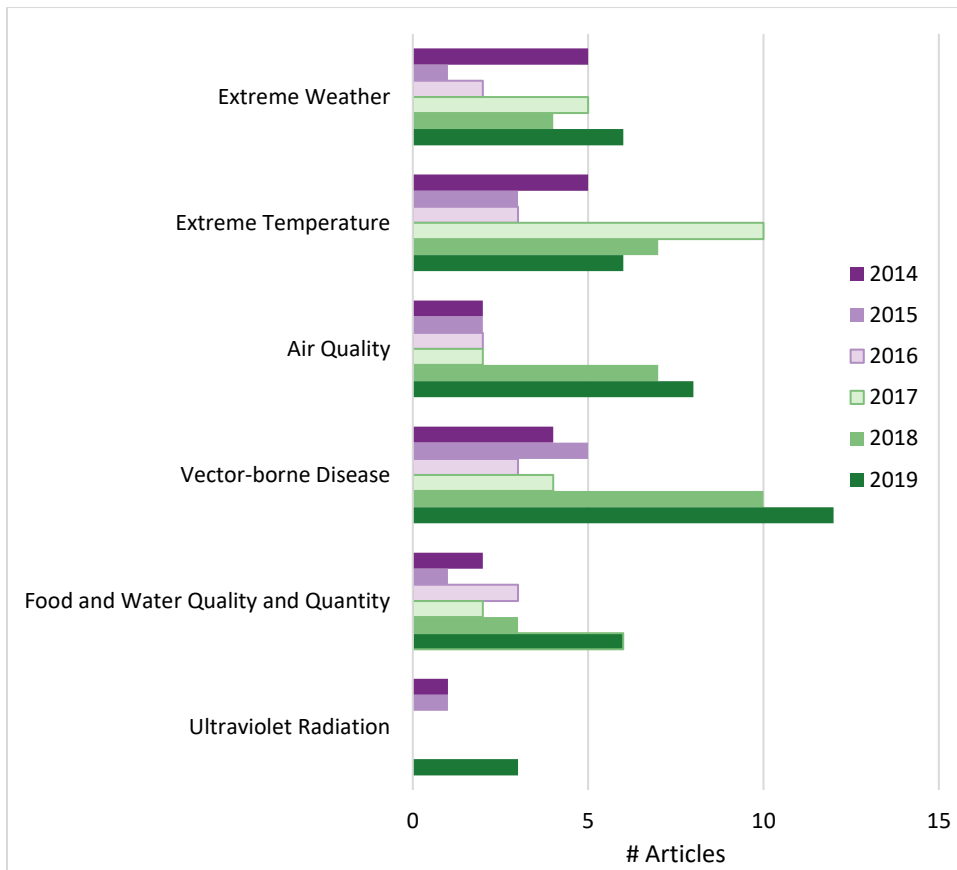


4.2.3 Time Trends by Main Climate-sensitive Category

Among all captured articles, the dominant climate-sensitive categories addressed have changed between 2014 and 2019 publication years, as illustrated in **Figure 6** (for greater detail see **Appendix B**). Among articles published in 2014, the most frequent climate-sensitive categories addressed were extreme weather (36%; n=5) and extreme temperature (36%; n=5). In contrast,

the most frequent climate-sensitive category captured in articles published in 2019 was vector-borne disease (40%; n=12).

Figure 6: Distribution of Climate-sensitive Categories by Publication Year



Vector-borne disease, extreme temperature, and extreme weather were among the most frequently addressed climate-sensitive categories across all publication years. This is consistent with overall climate-sensitive categories patterns highlighted in **section 4.5**.

The number of articles that address each climate-sensitive category increased from 2014 to 2019. The climate-sensitive categories vector-borne disease and air quality experienced the greatest increase in the number of publications captured between 2014 and 2019, accounting for 29% and 40% of all articles published in 2014, and 2019 respectively. The inclusion of air quality among literature increased considerably in 2018 (28%, n=7). Before 2018, the number of articles that addressed air quality was consistently low (n=2).

Literature published in 2019 included the most number of articles for five of the six climate-sensitive categories. The greatest number of articles that address extreme temperature (n=10) were published in 2017, accounting for 67% (n=10) of all articles published in 2017. Among relevant literature, the number highlighting extreme temperature has decreased since 2017.

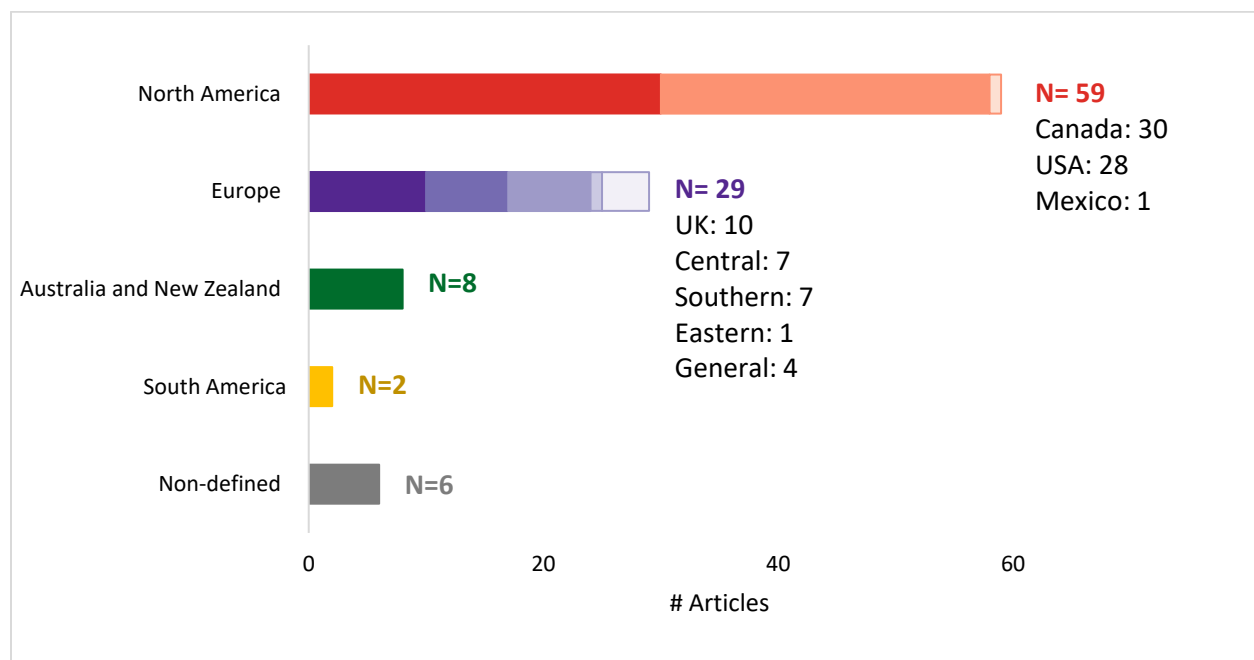
Ultraviolet radiation was among the least commonly addressed climate-sensitive category across all years and was only captured in 5% (n=5) of all relevant articles.

4.3 Trends by Geography

4.3.1 Geographic Distribution of Relevant Literature

The geographic distribution of included literature (**Figure 7**) is mainly from North America (57%; n=59), particularly from Canada (29%; n=30) and USA (27%; n=28), and Europe (28%, n=29) particularly from the United Kingdom (10%, n=10). Several articles (n=4) derived from authorities representing Europe as a whole and were captured under the specific geographic category 'general Europe'. Overall fewer articles were derived from the geographic regions South America, Australia, New Zealand, and non-defined regions. (For greater detail of the distribution of articles by main and specific geographic region, see **Appendix C** and **Appendix D**). Variations in the geographic distribution for specific intervention types and climate-sensitive categories are highlighted in section 4.3.2 and 4.3.3.

Figure 7: Distribution of Articles by Geography Region



4.3.2 Geographic Distribution by Intervention Type

The geographic distribution of articles by intervention type is illustrated in **Table 4**. Articles derived from the main geographic region of North America most frequently applied all intervention types, except for policy interventions. This aligns with the distribution of all articles across the main geographic regions as outlined in **section 4.3.1**. When looking at all articles that address policy, the majority derived from Europe (36%; n=5), specifically the United Kingdom (21%; n=3), as well as from non-defined regions (29%; n=4).

Table 4: Distribution of Articles by Main Geographic Regions and Public Health Intervention Type

Region	Public Health Intervention Type																	
	Health Communication		Health Promotion		Environmental Adaptations		Policy		Planning / Decision-making		Surveillance		Guidelines / Frameworks		Alerts / Advisories / Warnings		Other	
	(N=34)		(N=14)		(N=19)		(N=14)		(N=36)		(N=28)		(N=11)		(N=19)		(N=11)	
	n ^a	% ^a	n ^a	% ^a	n ^a	% ^a	n ^a	% ^a	n ^a	% ^a	n ^a	% ^a	n ^a	% ^a	n ^a	% ^a	n ^a	% ^a
Europe	4	12%	2	14%	5	26%	5	36%	12	33%	6	21%	3	27%	2	11%	2	18%
United Kingdom	1	3%	1	7%	-	-	3	21%	4	11%	1	4%	1	9%	1	5%	-	-
Central Europe	2	6%	1	7%	2	11%	-	-	2	6%	1	4%	1	9%	-	-	-	-
General Europe	-	-	-	-	1	5%	1	7%	3	8%	1	4%	-	-	1	5%	1	9%
Eastern Europe	-	-	-	-	-	-	1	7%	-	-	-	-	1	9%	-	-	-	-
Southern Europe	1	3%	-	-	2	11%	-	-	3	8%	3	11%	-	-	-	-	1	9%
North America	23	68%	7	50%	13	68%	3	21%	19	53%	18	64%	6	55%	13	68%	9	82%

Canada	12	35%	3	21%	8	42%	2	14%	13	36%	10	36%	3	27%	7	37%	4	36%
USA	10	29%	4	29%	5	26%	1	7%	6	17%	8	29%	3	27%	6	32%	5	45%
Mexico	1	3%	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
South America	1	3%	1	7%	-	-	-	-	1	3%	1	4%	1	9%	-	-	-	-
Australia, New Zealand	2	6%	2	14%	-	-	2	14%	2	6%	-	-	-	-	2	11%	-	-
Non-defined	4	12%	2	14%	1	5%	4	29%	2	6%	3	11%	1	9%	2	11%	-	-

^a Articles may include more than one public health intervention type, so values for n may not add up to the total number of articles published each year (N). Percentages likewise may not sum to 100%.

4.3.3 Geographic Distribution by Climate-sensitive Categories

Literature derived from the main geographic region of North America most frequently addressed all main climate-sensitive categories except for ultraviolet radiation (**Table 5**). Ultraviolet radiation was among the least frequently addressed climate-sensitive category by articles derived from four of the five main geographic regions. When looking at all articles that address ultraviolet radiation, Australia/ New Zealand was the region which most frequently addressed this climate-sensitive category (40%; n=2).

Table 5: Distribution of Articles by Main Geographic Region and Main Climate-sensitive Category

Region	Climate-sensitive Category											
	Extreme Weather		Extreme Temperature		Air Quality		Vector-borne Disease		Ultraviolet Radiation		Food and Water	
	(N=23)		(N=34)		(N=23)		(N=38)		(N=5)		(N=16)	
	n ^a	%	n ^a	%	n ^a	%	n ^a	%	n ^a	%	n ^a	%
Europe	4	17%	12	35%	7	30%	7	18%	1	20%	4	25%
United Kingdom	-	-	4	12%	3	13%	-	-	1	20%	1	6%
Central Europe	1	4%	4	12%	1	4%	2	5%	-	-	-	-
General Europe	2	9%	1	3%	1	4%	2	5%	-	-	2	13%
Eastern Europe	1	4%	-	-	-	-	-	-	-	-	-	-
Southern Europe	-	-	3	9%	2	9%	3	8%	-	-	1	6%
North America	14	61%	18	53%	12	52%	28	74%	1	20%	9	56%
Canada	6	26%	11	32%	7	30%	15	39%	1	20%	5	31%
USA	8	35%	7	21%	4	17%	13	34%	-	-	4	25%
Mexico	-	-	-	-	1	4%	-	-	-	-	-	-
South America	2	9%	-	-	-	-	-	-	-	-	1	6%
Australia, New Zealand	2	9%	2	6%	1	4%	1	3%	2	40%	1	6%
Non-defined	1	4%	2	6%	3	13%	2	5%	1	20%	1	6%

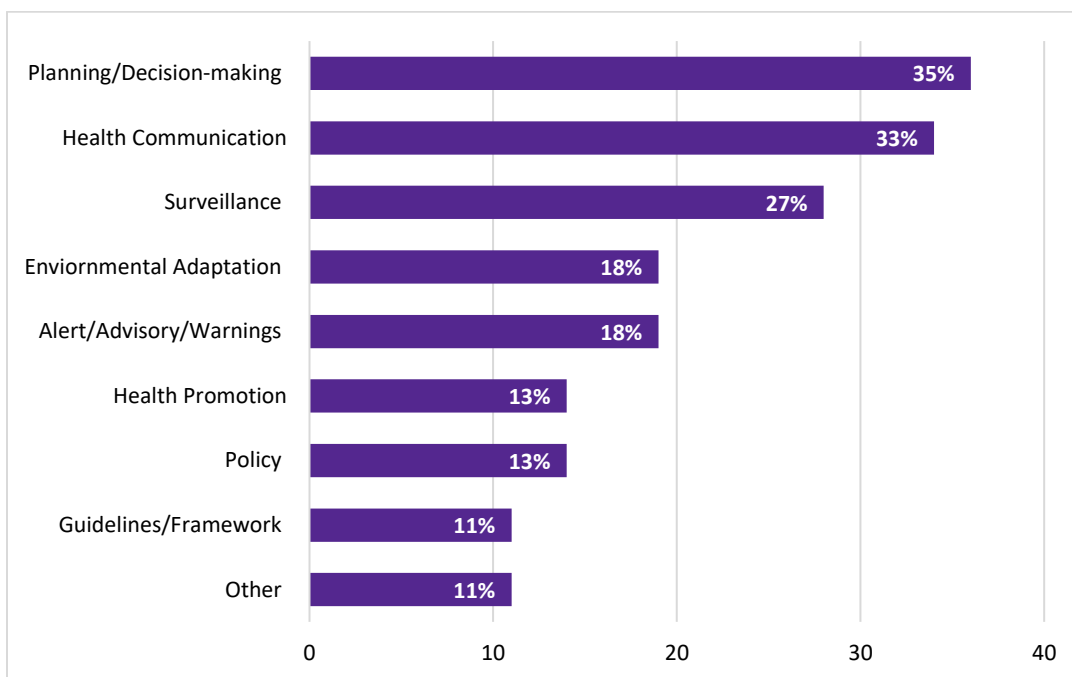
^a Articles may include more than one climate-sensitive category, so values for n may not add up to the total number of articles published each year (N). Percentages likewise may not sum to 100%.

4.4 Trends by Intervention Types

4.4.1 Distribution of Articles by Intervention Type

Figure 8 displays the frequency in which each intervention type were included in relevant literature (for alternative format see **Appendix E**). When looking at all relevant literature, the public health intervention type identified most frequently was planning/decision making (35%; n=35), a strategic intervention⁴ to address climate-health outcomes. The second most common intervention type identified was health communication (33%; n=34), a more applied approach⁵ to adaptation. The least common intervention types addressed were guidelines/framework (11%; n=11).

Figure 8: Distribution of Articles by Public Health Intervention Type (N=104)



Articles may include more than one public health intervention type, so values are > 104. Likewise percentages will not equal 100%.

⁴ Strategic interventions are strategies that identify how to address an issue, or achieve an objective, and plans actions and resources to do so over some time.

⁵ Applied interventions are strategies that apply knowledge, theory and/or techniques into actions that address an identified issue, often tailored to a particular situation and target audience.

Table 6 presents the distribution of articles that features each public health intervention type by the main climate-sensitive category. Vector-borne disease was the most frequently addressed main climate-sensitive category among articles that included health communication, health promotion, surveillance, and ‘other’ intervention categories, accounting for 44% (n=15), 43% (n=6), 79% (n=22), and 73% (n=8) of articles respectively. Among articles that included environmental adaptation, planning/decision-making, guidelines/framework, and alerts/advisory/warning interventions types, the most frequently addressed main climate-sensitive category was extreme temperature attributing 84% (n=16), 44% (n=16), 27% (n=3), and 58% (n=11) of articles respectively. In articles that captured guidelines/framework interventions, extreme weather and extreme temperature were most frequently identified (27%; n=3). Air quality was most frequently addressed within articles that applied alerts/advisories/warnings (58%; n=11) and policy (50%; n=7) intervention types.

Table 6: Summary of the Main Climate-sensitive Categories Addressed in Articles that use Each Public Health Intervention Type

Climate-sensitive Category	Public Health Intervention Type																	
	Health Communication		Health Promotion		Environmental Adaptations		Policy		Planning / Decision-making		Surveillance		Guidelines / Frameworks		Alerts / Advisories / Warnings		Other	
	(N=34)		(N=14)		(N=19)		(N=14)		(N=36)		(N=28)		(N=11)		(N=19)		(N=11)	
	n ^a	% ^a	n ^a	% ^a	n ^a	% ^a	n ^a	% ^a	n ^a	% ^a	n ^a	% ^a	n ^a	% ^a	n ^a	% ^a	n ^a	% ^a
Extreme Weather	10	29%	5	36%	8	42%	6	43%	10	28%	7	25%	3	27%	5	26%	4	36%
Extreme Temperature	11	32%	5	36%	16	84%	6	43%	16	44%	9	32%	3	27%	11	58%	4	36%
Air Quality	11	32%	3	21%	8	42%	7	50%	8	22%	6	21%	1	9%	11	58%	3	27%
Vector-borne Disease	15	44%	6	43%	8	42%	3	21%	15	42%	22	79%	2	18%	5	26%	8	73%

Ultraviolet Radiation	1	3%	4	29%	1	5%	1	7%	1	3%	0	0%	0	0%	0	0%	1	9%
Food and Water	8	24%	4	29%	8	42%	5	36%	7	19%	7	25%	2	18%	5	26%	5	45%

^a Articles may include more than one public health intervention type category and climate-sensitive category, so numbers are > N, and percentages will not equal 100%.

Articles that include health communication and health promotion interventions address a variety of difference climate-sensitive categories. In contrast, articles that include certain intervention types, such as surveillance, alerts/advisories/warnings, and 'other', mainly address one or two climate-sensitive categories.

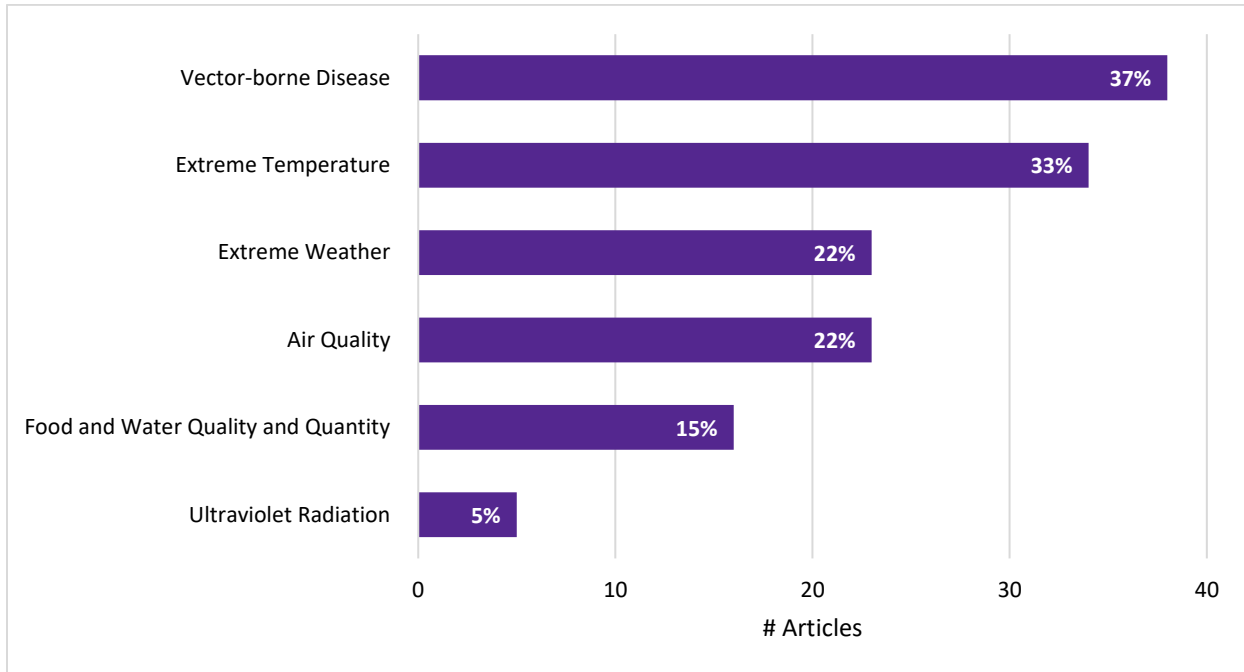
As less than 5% of all collected literature identified, the main climate-sensitive category ultraviolet radiation, unsurprisingly was among the least commonly addressed climate-sensitive category by most intervention types.

4.5 Trends by Climate-sensitive Categories

4.5.1 Distribution of Articles by Main Climate-sensitive Category

The frequency in which articles included the main climate-sensitive categories are displayed in **Figure 9** (for alternative format see **Appendix F**). The most frequently reported climate-sensitive category was vector-borne (37%; n=38), followed by extreme temperature (33%; n=34). Ultraviolet radiation was identified least often (5%; n=5).

Figure 9: Distribution of Articles by Main Climate-sensitive Category

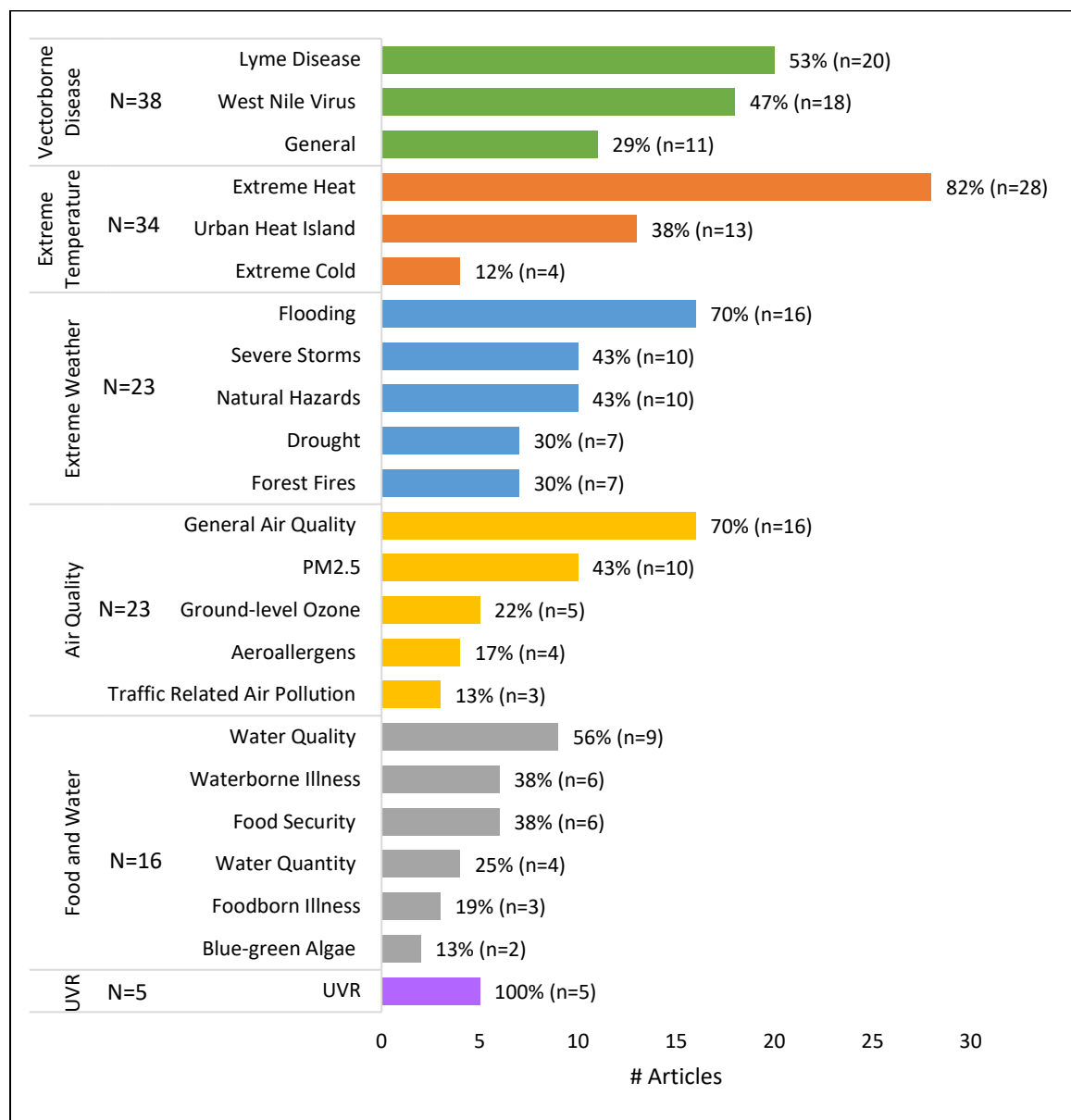


Articles may include more than one main climate-sensitive category, so numbers are >104. Likewise percentages will not equal 100%.

4.5.2 Distribution of Articles by Specific Climate-sensitive Categories

The distribution of articles by specific climate-sensitive category related to each main climate-sensitive category is displayed in **Figure 10**. (For alternative format see **Appendix G**).

Figure 10: Frequency of the Specific Climate-sensitive Categories Related to Each Main Climate-sensitive Category



Articles may include more than one category so the sum is > N and percentages will not equal 100%.

4.5.3 Intervention Types that Address Vector-borne Disease

Table 7 summarizes the public health intervention types applied in articles that addressed the main climate-sensitive category vector-borne disease and the related specific climate-sensitive categories. Surveillance was the most frequent intervention type captured among literature that addressed vector-borne disease (58%; n=22) and the related categories Lyme disease (50%; n=10), West Nile Virus (72%; n=13), and general vector-borne disease (73%; n=8). Health communication and planning/decision-making interventions were also common in the literature that addressed vector-borne disease and all related specific climate-sensitive categories.

Table 7: Summary of Public Health Intervention Types Used in Articles that Address Vector-borne Disease and Related Specific Climate-sensitive Categories

Public Health Intervention Type	Main Climate-sensitive Category		Specific Climate-sensitive Categories Related to Vector-borne Disease					
	Vector-borne Disease		Lyme Disease		West Nile Virus		General	
	(N=38)		(N=20)		(N=18)		(N=11)	
	n ^a	% ^a	n ^a	% ^a	n ^z	% ^a	n ^z	% ^a
Health Communication	15	39%	9	45%	8	44%	6	55%
Health Promotion	6	16%	5	25%	2	11%	3	27%
Environmental Adaptations	8	21%	6	30%	4	22%	4	36%
Policy	3	8%	2	10%	3	17%	1	9%
Planning / Decision-making	15	39%	8	40%	9	50%	5	45%
Surveillance	22	58%	10	50%	13	72%	8	73%
Guidelines / Frameworks	2	5%	1	5%	1	6%	-	-
Alerts / Advisories / Warnings	5	13%	2	10%	3	17%	3	27%
Other	8	21%	5	25%	3	17%	4	36%

^a Articles may include more than one category so the sum is > N, and percentages will not equal 100%.

4.5.4 Intervention Types that Address Extreme Temperature

The frequency in which intervention types were used in captured literature that addresses the main climate-sensitive category extreme temperature and related specific climate-sensitive categories is illustrated in **Table 8**. Environmental adaptation and planning/decision-making interventions were the two most frequently applied intervention types in the literature that

addresses extreme temperature and the related categories extreme heat and urban heat island. Among articles that address extreme cold, planning/decision-making, and alerts/advisories/warnings, intervention types were most frequently captured (75%; n=3). Policy was also frequently identified in the literature that addresses urban heat islands (31%; n=4).

Table 8: Summary of Public Health Intervention Types Used in Articles that Address Extreme Temperature and Related Specific Climate-sensitive Categories

Public Health Intervention Type	Main Climate-sensitive Category		Specific Climate-sensitive Category Related to Extreme Temperature					
	Extreme Temperature		Extreme Heat		Urban Heat Island		Extreme Cold	
	(N=34)		(N=28)		(N=13)		(N=4)	
	n ^a	% ^a	n ^a	% ^a	n ^a	% ^a	n ^a	% ^a
Health Communication	11	32%	10	36%	3	23%	1	25%
Health Promotion	5	15%	5	18%	0	0%	0	0%
Environmental Adaptations	16	47%	13	46%	12	92%	1	25%
Policy	6	18%	5	18%	4	31%	2	50%
Planning / Decision-making	16	47%	14	50%	5	38%	3	75%
Surveillance	9	26%	9	32%	2	15%	1	25%
Guidelines / Frameworks	3	9%	3	11%	-	-	-	-
Alerts / Advisories / Warnings	11	32%	9	32%	2	15%	3	75%
Other	4	12%	4	14%	2	15%	1	25%

^a Articles may include more than one category, so the sum is > N and percentages will not equal 100%.

4.5.5 Intervention Types that Address Extreme Weather

The distribution of public health intervention types applied in articles that address the main climate sensitive-category extreme weather and related specific climate-sensitive categories are identified in **Table 9**. Health communication was the most frequently applied intervention type among all articles that addressed extreme weather and all related specific climate-sensitive categories. For all literature that addressed extreme weather, flooding and forest fires, planning/decision-making interventions were also most frequently addressed and were included in 43% (n=10), 50% (n=8), and 57% (n=4) of associated articles respectively. Environmental adaptation interventions were the second most commonly used intervention among 4 of the 5 specific climate-sensitive categories related to extreme weather. Guidelines/framework

interventions were among the least commonly used in all articles that address extreme weather and related specific climate-sensitive category related to extreme weather.

Table 9: Summary of Public Health Interventions Used in Articles that Address Extreme Weather and Related Specific Climate-sensitive Categories

Public Health Intervention Type	Main Climate-sensitive Category		Specific Climate-sensitive Category Related to Extreme Temperature									
	Extreme Weather		Severe Storms		Drought		Flooding		Natural Hazards		Forest Fires	
	(N=23)		(N=10)		(N=7)		(N=16)		(N=10)		(N=7)	
	n ^a	% ^a	n ^a	% ^a	n ^a	% ^a	n ^a	% ^a	n ^a	% ^a	n ^a	% ^a
Health Communication	10	43%	6	60%	5	71%	8	50%	7	70%	4	57%
Health Promotion	5	22%	2	20%	4	57%	4	25%	3	30%	3	43%
Environmental Adaptations	8	35%	4	40%	4	57%	7	44%	4	40%	4	57%
Policy	6	26%	3	30%	2	29%	5	31%	2	20%	3	43%
Planning / Decision-making	10	43%	2	20%	4	57%	8	50%	3	30%	4	57%
Surveillance	7	30%	4	40%	5	71%	5	31%	3	30%	4	57%
Guidelines / Frameworks	3	13%	2	20%	1	14%	2	13%	2	20%	-	-
Alerts / Advisories / Warnings	5	22%	3	30%	3	43%	4	25%	2	20%	4	57%
Other	4	17%	2	20%	2	29%	4	25%	1	10%	3	43%

^a Articles may include more than one category, so the sum is > N and percentages will not equal 100%.

4.5.6 Intervention Types that Address Air Quality

Table 10 summarizes the frequency in which public health intervention types were applied in articles that address air quality and related specific climate-sensitive categories. Health communication was the most frequently applied intervention type among all articles that address air quality (48%; n=11) and all the related specific climate-sensitive categories except for traffic-related air pollution. The intervention type alerts/advisories/warnings was the most frequently used intervention type among articles that addressed the main climate-sensitive category air quality (48%; n=11), and 3 of the 5 related specific categories. Among articles that targeted

aeroallergens, planning/decision-making interventions were also most frequently addressed. Policy was the most common intervention type identified in articles that addressed traffic-related air pollution. In articles that addressed air quality, only one applied a guidelines/framework intervention which was included in an article targeting traffic-related air pollution. Among articles that target the specific climate-sensitive category traffic-related air pollution, the most common intervention type addressed was policy (67%; n=2).

The majority of articles captured more than one specific climate-sensitive category related to air quality including general air quality. Therefore targeting general air quality can address several other specific climate-sensitive category related to air quality.

Table 10: Summary of Public Health Interventions Used in Articles that Address Air Quality and Related Specific Climate-sensitive Categories

Public Health Intervention Type	Main Climate-sensitive Category		Specific Climate-sensitive Category Related to Extreme Temperature									
	Air Quality		PM2.5		Ground-Level Ozone		Traffic Related Air Pollution		General Air Quality		Aeroallergens	
	(N=23)		(N=10)		(N=5)		(N=3)		(N=16)		(N=4)	
	n ^a	% ^a	n ^a	% ^a	n ^a	% ^a	n ^a	% ^a	n ^a	% ^a	n ^a	% ^a
Health Communication	11	48%	6	60%	5	100%	1	33%	8	50%	3	75%
Health Promotion	3	13%	1	10%	2	40%	1	33%	2	13%	2	50%
Environmental Adaptations	8	35%	2	20%	3	60%	1	33%	7	44%	2	50%
Policy	7	30%	4	40%	2	40%	2	67%	4	25%	1	25%
Planning / Decision-making	8	35%	3	30%	2	40%	-	-	5	31%	3	75%
Surveillance	6	26%	2	20%	3	60%	1	33%	5	31%	2	50%
Guidelines / Frameworks	1	4%	-	-	-	-	1	33%	-	-	-	-
Alerts / Advisories / Warnings	11	48%	6	60%	3	60%	1	33%	8	50%	3	75%
Other	3	13%	-	-	-	-	-	-	3	19%	-	-

^a Articles may include more than one category so the sum is > N and percentages will not equal 100%.

4.5.7 Intervention Types that Address Food and Water

A summary of public health interventions included in articles that address the main climate-sensitive category food and water and related specific climate-sensitive categories is presented in **Table 11**.

Table 11: Summary of Public Health Interventions Used in Articles that Address Food and Water Safety and Security and Related Specific Climate-sensitive Categories

Public Health Intervention Type	Main Climate-sensitive Category		Specific Climate-sensitive Category Related to Extreme Temperature											
	Food / Water		Waterborne Illness		Foodborne Illness		Blue-Green Algae		Food Security		Water Quality		Water Quality	
	(N=16)		(N=6)		(N=3)		(N=2)		(N=6)		(N=9)		(N=4)	
	n ^a	% ^a	n ^a	% ^a	n ^a	% ^a	n ^a	% ^a	n ^a	% ^a	n ^a	% ^a	n ^a	% ^a
Health Communication	8	50%	4	67%	2	67%	2	100%	3	50%	8	89%	2	50%
Health Promotion	4	25%	3	50%	2	67%	2	100%	1	17%	4	44%	2	50%
Environmental Adaptations	8	50%	3	50%	1	33%	2	100%	4	67%	5	56%	2	50%
Policy	5	31%	2	33%	-	-	1	50%	2	33%	4	44%	-	-
Planning / Decision-making	7	44%	3	50%	2	67%	1	50%	3	50%	6	67%	3	75%
Surveillance	7	44%	5	83%	3	100%	2	100%	3	50%	6	67%	2	50%
Guidelines / Frameworks	2	13%	1	17%	-	-	-	-	1	17%	-	-	-	-
Alerts / Advisories / Warnings	5	31%	3	50%	1	33%	1	50%	2	33%	4	44%	-	-
Other	5	31%	2	33%	1	33%	1	50%	4	67%	2	22%	1	25%

^a Articles may include more than one category, so the sum is > N and percentages will not equal 100%.

In articles that identify the main climate-sensitive category food and water the most common intervention types highlighted were health communication (50%; n=8) and environmental adaptation (50%; n=8). Each specific climate-sensitive category related to food and water exhibited a different distribution of intervention types.

Among articles that target the specific climate-sensitive category food security (n=6), the most common intervention types identified were environmental adaptation (67%, n=4) and 'other' interventions (67%; n=4).

4.5.8 Intervention Types that Address Ultraviolet Radiation

The distribution of public health intervention types applied in articles that address the main climate-sensitive category ultraviolet radiation is displayed in **Table 12**. Health promotion was the most frequently applied intervention type captured within the literature that addresses ultraviolet radiation (80%; n=4). Surveillance, alerts/advisories/warnings and guideline/framework interventions were not identified among articles that addressed ultraviolet radiation.

Table 12: Summary of Public Health Interventions Among Literature that Addresses Ultraviolet Radiation (N=5)

Public Health Intervention Type	Ultraviolet Radiation (N=5)	
	n ^a	% ^a
Health Communication	1	20%
Health Promotion	4	80%
Environmental Adaptations	1	20%
Policy	1	20%
Planning/Decision-making	1	20%
Surveillance	0	0%
Guidelines/Frameworks	0	0%
Alerts/Advisories/Warnings	0	0%
Other	1	20%

^a Articles may include more than one public health intervention type category, so the sum is > N and percentages will not equal 100%.

4.6 Interventions that Address Multiple Main Climate-sensitive Categories

Among all relevant literature, approximately 8% (n=8) identified a public health intervention that could address multiple climate-sensitive categories. **Table 13** briefly summarizes key characteristics of the interventions identified in that addressed multiple main climate-sensitive categories.

The most common combination of climate-sensitive categories addressed by one intervention include:

- Extreme Temperature & Extreme Weather
- Extreme Weather & Food/Water
- Extreme Weather & Air Quality
- Extreme Temperature & Air Quality
- Extreme Temperature & Food/Water
- Air Quality & Food/Water

Figure 11: Chord graph showing inter-relation in climate-health adaptation literature across climate-sensitive categories. Increasing chord thickness indicates more articles addressing both climate-sensitive categories.

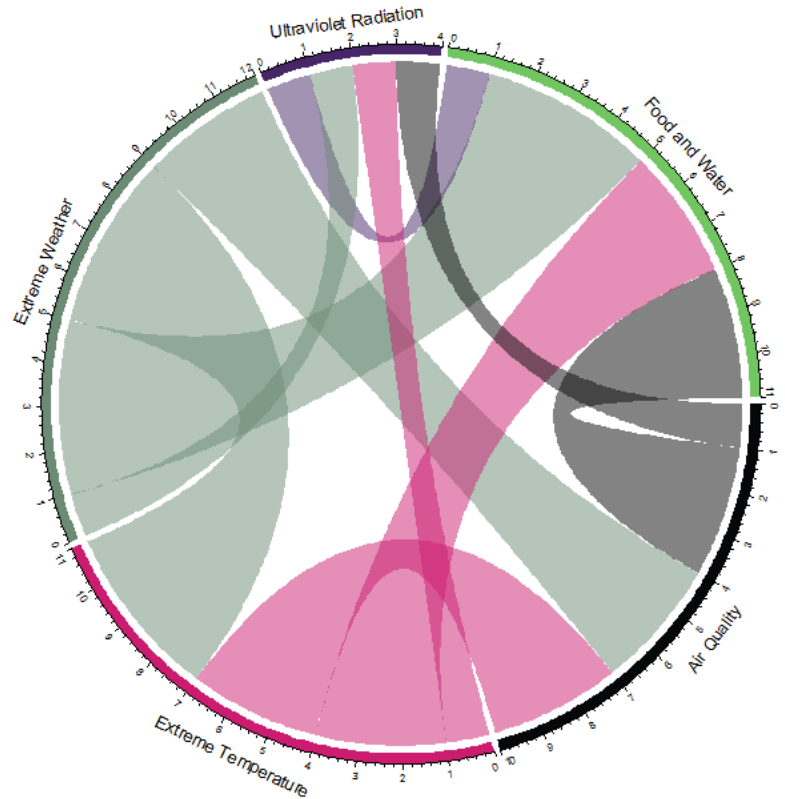


Figure 11 shows the inter-relation of climate-sensitive categories addressed by one intervention type. No intervention that addressed vector-borne disease addressed another climate-sensitive category.

Among the articles that included an intervention that was able to address multiple main climate-sensitive categories, the intervention types most often identified were environmental adaptation and planning/decision-making.

Table 13: Articles that Highlight One Intervention that Addresses Multiple Climate-sensitive Categories

Primary Intervention Type	Intervention Description	Climate-sensitive Categories Addressed	Article
Planning / Decision-making	Contingency plan for public health emergencies in relation to drought.	Extreme Weather (drought) Food and Water (waterborne illness, foodborne illness, water quality, water quantity)	Grigoletto, Cabral. 2016 (82)
	Smoke forecasting model predicts moving plumes and air pollutants	Air Quality (PM2.5) Extreme Weather (forest fires)	Rappold, Fann. 2014 (83)

	to support public health decision-making.		
	Planning guidance to support water sensitive urban design as a component of integrated urban water management.		<u>Sharma, Pezzaniti. 2016 (84)</u>
Environmental Adaptations	Overview of environmental adaptations needed to reduce extreme heat and urban heat island to improve health outcomes.	Extreme Weather (natural hazard) Extreme Temperature (extreme heat, urban heat island)	<u>Endlicher. 2017 (85)</u>
	Examples of green space intervention.	Extreme Weather (severe storms, flooding) Extreme Temperature (extreme heat, urban heat island) Air Quality (general) UVR Food/Water (food security)	<u>Kingsley and EcoHealth. 2019 (61)</u>
	Green Roofs.	Extreme Temperature (urban heat island) Air Quality (general) Food/Water (water quantity)	<u>Semeraro, Aretano. 86)</u>
	Examples of green space interventions and cases studies.	Extreme Temperature (extreme heat, urban heat island) Extreme Weather (flooding) Air Quality (general) Food/Water (water quality) Highlight mental health benefits	<u>World Health Organization Regional Office for Europe. 2017 (87)</u>
Surveillance	Emergency Room Syndromic Surveillance	Extreme Temperature (extreme heat) Extreme Weather (severe storms)	<u>Lall, Abdelnabi. 2017 (88)</u>

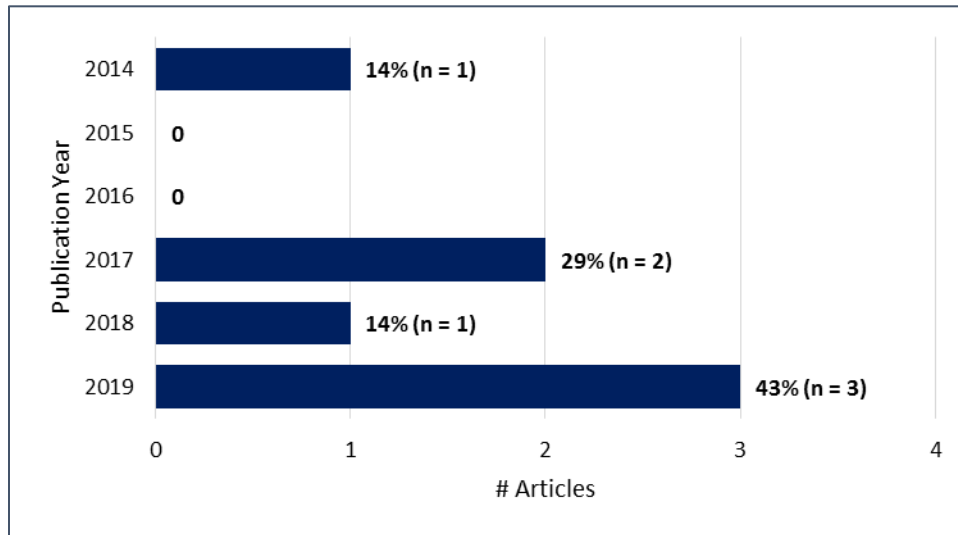
4.7 Articles that Addressed Mental Health

Less than 7%, (n=7) of the collected literature specifically addressed mental health outcomes associated with climate change.

4.7.1 Time Trends and Mental Health

The majority of articles that specifically address mental health were published in 2019 (43%; n=3). The review found only a small increase in the number of public health interventions that specifically address climate-related mental health outcomes (**Figure 12**).

Figure 12: Summary of Articles that Address Mental Health by Publication Year



4.7.2 Geographic Trends and Mental Health

The majority of articles that address mental health are derived from North America (86%; n=6), specifically Canada (57%; n=4) and USA (29%; n=2). The other region which addressed mental health was Europe (14%; n=1). No other literature collected from other geographical regions addressed mental health.

4.7.3 Intervention Types that Address Mental Health

All articles that addressed mental health identified multiple interventions pertaining to one or more climate-health risks. A deeper dive into the literature that identified climate-mental health outcomes was required to distinguish key characteristics of the related climate-health adaptation interventions. A range of intervention types that could address climate-mental health effects were identified (Table 14).

4.7.4 Common Climate-sensitive Categories Identified

Interventions that aimed to address climate related mental health impacts focused on the following climate-sensitive categories:

- Extreme Weather
 - Flooding, Severe Storms, Natural Hazards, Drought, Fires
- Extreme Temperature
 - Extreme Heat
- Food and Water
 - Water Quality
 - Food Security

Table 14: Literature that Highlights Climate-related Mental Health Outcomes

Article that addressed mental health	Intervention Type *	Associated Climate-sensitive Category
American Public Health. 2018 (89)	<ul style="list-style-type: none"> • Health Communication 	Extreme Weather Extreme Temperature
Anderson, Brown. 2017 (90)	<ul style="list-style-type: none"> • School-based Interventions • Children-based Interventions • Cognitive-based Interventions • Group-based Interventions • Crisis Counselling Programs • Psychological First Aid • Eye Movement Desensitization And Reprocessing • Psychological Debriefing • Exposure Therapy • Psychodynamic Psychotherapy • Pharmacotherapeutics • Health Promotion (Mental Health Promotion Campaign) 	Extreme Weather
	<ul style="list-style-type: none"> • Alerts/Advisories/Warnings • Health Communication • Planning/Decision-making • Suicide Prevention Programs • Environmental Adaptation (Green Space) • Health Promotion (Peer-networks, Behaviours) 	Extreme Temperature
Berry, Clark. 2014 (24)	<ul style="list-style-type: none"> • School-based Programs • Early Identification of Mental Health Challenges 	Food & Water
	<ul style="list-style-type: none"> • Environmental Adaptations • Alerts/Advisories/Warnings • Planning/Decision-making • Health Communication • Health Promotion • Disaster Mental Health Services • Surveillance • Immediate Family Reunion and Support • Psychological First Aid • Early Post-Disaster Psychological Interventions 	Extreme Weather
(CAPE). 2019 (91)	<ul style="list-style-type: none"> • Environmental Adaptations 	Extreme Temperature
	<ul style="list-style-type: none"> • Environmental Adaptations • Planning/Decision-making • Policies • Mental Health Services • Recovery Plan for Addiction and Mental Health 	Extreme Weather
Kingsley and EcoHealth. 2019 (61)	<ul style="list-style-type: none"> • Environmental Adaptations 	Extreme Weather Extreme Temperature Air Quality

		Ultraviolet radiation Food & Water
Schnitter and Berry. 2019 (92)	• Guidelines/Frameworks	Food & Water
World Health Organization Regional Office for Europe. 2017 (87)	• Environmental Adaptations	Extreme Weather Extreme Temperature Air Quality Food & Water

**Intervention Types identified may differ from categories applied in scoping review and may not be public health specific.*

5 DISCUSSION

This scoping review maps out the range and characteristics of existing literature on climate-health adaptation interventions applicable to Ontario. In complement to the results section, key concepts and general trends are summarized in **section 5.1**, followed by knowledge gaps in **section 5.2**. Recommendations for public health practice and research are expressed in **section 5.3**.

5.1 Summary of the range and characteristics of literature on climate-health adaptation interventions

Key trends related to time and geography, intervention type, and climate-sensitive categories can help public health authorities' source examples and lessons learned from climate-health adaptation interventions to identify, modify, and implement interventions.

5.1.1 Time Trends

Analysis of the captured articles by publication year suggests that in recent years climate-health adaptation interventions, applicable to Ontario, are increasingly implemented and published. The increase in published articles captured since 2015 aligns with the adoption of the Paris Agreement in 2016 and the associated shift in discourse towards greater emphasis on climate change adaptation strategies (93, 94). The release of the IPCC AR5 in 2014 (1) may have influenced the higher number of articles captured in 2014. However, it is unclear why the literature review identified a drop in publications between 2014 and 2015.

The analysis demonstrates that climate-sensitive categories addressed in captured literature evolved throughout the period of the review (2014-2019) as identified in **section 4.2.3**. Changes in the frequency of climate-sensitive categories captured across publication year reflect an increasing occurrence and awareness of climate-related events and associated health risks in addition to growing empirical knowledge of the complex linkages between climate change and related health risks.

For example, 2017 experienced the highest number of articles that address extreme temperature. This pattern aligns with the global context of extreme heat events in that 2016 was, to date, the hottest year on record and extended into 2017, which at the time was the warmest year on record without an El Niño event (95-97). Moreover, anthropogenic global warming reached approximately 1°C in 2017 (98). The experience of extreme heat in 2016 and 2017 may have stimulated a surge in the literature that was published in 2017. This 2017 peak may also be reflective of the time taken to complete research initiated since the AR5 report. Among relevant literature, the number highlighting extreme temperature has decreased since 2017. This trend is also aligned with global temperature patterns; 2018 was cooler than 2017 and 2016 (97, 99). However, 2019 was to date, the second warmest year on record after 2016 and was only 0.04°C cooler than 2016 (97, 99, 100).

The increase in the literature that addressed vector-borne disease captured in the review aligns with a growing evidence base of the relationship between climate change and vector-borne diseases and awareness of increasing health outcomes (i.e. more cases of Lyme disease in North America) (101-106). Similarly, air quality was identified much more frequently in the captured literature published since 2018. This increase may have been influenced by a growing recognition of associated health impacts, and particularly by the attention received and concern raised by the Lancet Commission on air pollution and health, published in 2017 (107-109).

Time trends by climate-sensitive category indicate that more climate-health adaptation interventions are likely to be designed and published as the recognition of climate-sensitive categories and associated health impacts become increased. While this is unsurprising, it is also troublesome that climate-health adaptation interventions may be applied in reaction to, rather than preparation for, climate-related events and that empirical uncertainty may hinder intervention development. This interpretation reinforces the importance of using a climate-health lens for health risks associated with climate change and the continued need for empirical studies that link climate change to health outcomes. These actions may reduce the amount of uncertainty and promote adaptation actions sooner.

The distribution of public health intervention types used in captured articles has also changed across publication years, as identified in **section 4.2.2**. These changes are likely guided in part by the changes in climate-sensitive categories being addressed. The review captured an increase in the number of publications that highlight all intervention types except for health promotion. This potential knowledge gap is explored further in **section 5.2**.

Furthermore, a small increase in the number of articles that explicitly addressed mental health was identified between 2014 and 2019. This finding is explored further in **section 5.2**.

5.1.2 Geographic Trends

The experience of other regions can help local authorities predict what will happen in their communities and provide a learning opportunity that can be applied to plan effective adaptation

interventions locally. This reinforces the value of engaging in knowledge translation activities to advance climate adaptation actions. Geographic trends identified by this review can help public health authorities' source relevant examples and experiences to support adaptation planning.

The geographic distribution of included literature (**section 4.3**) is likely influenced by the inclusion criteria's emphasis on climate-sensitive categories relevant to the Ontario context. Geographic regions with more similarities to Ontario's climate-health risks would be more frequently captured. The geographic distribution findings suggest that when public health authorities in Ontario plan to implement public health interventions that address climate-health impacts, examples from North America (particularly Canada and USA) and Europe are most likely to be applicable.

The specific geographic region most frequently identified was Canada. The distribution of intervention types and climate-sensitive categories included in articles derived from Canada suggests Canadian authorities are engaged in implementing a variety of climate-health adaptation interventions. Among articles from Canada, the four most commonly identified climate-sensitive categories (vector-borne disease, extreme temperature, extreme weather, and air quality) aligns with the frequency climate-health risks being addressed by public health authorities in Canada as identified in the Health Canada, *Climate Change and Health Resilience Survey* conducted in 2018 (110). This scoping review did not assess the distribution of articles across Canadian provinces, although Austin et al. found that adaptation varied across Canadian provinces/territories and while most were in early stages of adaptation, Québec was engaged in a high level of adaptation (66). Potential gaps in Canadian climate-health interventions are outlined in **section 5.2**.

There are variations in the distribution of particular climate-sensitive categories and intervention types across geographic areas. Overall, geographic patterns illustrate that climate-health interventions reflect climate-context of a specific region. When local public health authorities seek to address a particular climate-sensitive category, areas with practice managing similar health risks can be useful for local adaptation planning. For example, Australia has high levels of ultraviolet radiation and high rates of skin cancer (111-113) and thus is more likely to have public health interventions in place to address associated health risks. This region is likely to have interventions that address ultraviolet radiation that can be used to support adaptation planning in Ontario.

Similarly, the findings display that specific regions more frequently apply different intervention types. Articles from North America most frequently identified eight intervention types. Europe, notably the United Kingdom, captured the most examples of policy interventions. This suggests the policy interventions from the United Kingdom may provide a foundation to support the development of policy interventions for the Ontario context. The distribution of policy interventions is considered in greater detail in **section 5.2**.

Another potential influence on the geographic distribution of included articles is the restriction of the search strategy to English and French articles, with only English key terms used in the search strategy. Thus if regions produce a smaller amount of articles published in English, they would be captured less frequently by the review. As such, this review may not have identified relevant examples of climate-health adaptation due to language of publication.

5.1.3 Key Characteristics of Existing Climate-health Adaptation Interventions

5.1.3.1 Intervention Types

An assortment of public health intervention types was identified in this review (**Figure 8**). The most common intervention type identified, planning/decision-making, is a strategic intervention⁶ to address climate-health outcomes. The second most common intervention type identified, health communication, is a more applied approach⁷ to adaptation. Both strategic and practical strategies can be used to address climate-health risks and should be included in public health climate change adaptation planning. The least frequently identified intervention type categories are explored in **section 5.2**.

5.1.3.2 Climate-sensitive Categories

The distribution of the main climate-sensitive categories captured in this review (**Figure 9**) also aligns with the most frequent health-risks being addressed by public health authorities identified by the *Climate Change and Health Resilience Survey* (110). In both studies, vector-borne disease, extreme weather, extreme temperature, and air quality were among the most frequently identified climate-health risks.

The search terms used in the literature search may have influenced the distribution of main and specific climate-sensitive categories. The search strategy intentionally excluded explicit terms for food and water and ultraviolet radiation to reduce the number of irrelevant articles identified. While the term water was used in combination with vector, food was not included in search terms nor was blue-green algae.

Articles that captured ultraviolet radiation and food and water were obtained using other relevant search terms like climate change and public health interventions. They may also have been captured in literature that identified more than one climate-adaptation intervention. Climate-

⁶ Strategic interventions are strategies that identify how to address an issue, or achieve an objective, and plans actions and resources to do so over some time.

⁷ Applied interventions are strategies that apply knowledge, theory and/or techniques into actions that address an identified issue, often tailored to a particular situation and target audience.

health adaptation interventions that address these climate-sensitive categories may not have been captured in this review if a robust public health and climate change lens was not applied.

Both ultraviolet radiation and food and water categories were captured less frequently in the review. In comparison, food and water categories were also less often targeted by public health authorities as identified in the *Climate Change and Health Resilience Survey* (110). Ultraviolet radiation was not assessed in the survey study (110). The similarity between the two studies indicates that despite confines of the scoping review search strategy, it is likely that ultraviolet radiation and food and water health-risks are less frequently addressed climate-sensitive categories. This potential gap in explored further in **section 5.2**.

The frequency of specific climate-sensitive categories related to a particular main climate-sensitive category provides valuable information on the climate health-risks being targeted. Many of the most frequently identified main and specific climate-sensitive categories reflect the level of awareness of climate-health risks in Ontario (i.e. extreme heat, flooding). Level of awareness is often greater for health-risks associated with climate-sensitive categories that occur more frequently, or have more severe outcomes. Climate-sensitive categories that are often less recognized were included in fewer articles (i.e. blue-green algae, extreme cold, ultraviolet radiation).

Several potential gaps in knowledge and practice related to the distribution climate-sensitive categories and related specific climate-sensitive categories are discussed in **section 5.2**.

5.1.3.3 *Cross Analysis of Intervention Types and Climate-sensitive Categories*

Cross analysis of intervention types and climate-sensitive categories provides insight into what intervention types are likely used to address a particular climate-sensitive category and specific climate-sensitive categories where applicable. **Section 5.3** specifies the application of these results for public health practice. Several stand out findings relevant to public health adaptation planning were discovered, and are presented here.

A range of intervention types were found to be useful to address one or more climate-health outcomes. Some intervention types, like health communication and health promotion can address a variety of different climate-sensitive categories. In contrast, some intervention types, such as surveillance and alerts/advisories/warnings mainly address one or two climate-sensitive categories, suggesting they are most applicable to a smaller selection of climate-health risks.

Findings regarding the intervention types that address vector-borne disease were particularly interesting. The review suggests surveillance is the most frequently applied intervention type to address vector-borne disease. In articles that address vector-borne disease, health promotion was one of the least commonly used intervention types (**Table 7**). Conversely, among the literature that applied health promotion interventions, vector-borne disease was the most frequently addressed climate-sensitive category (**Table 6**). Engaging in protective behaviours is

considered the best way to prevent Lyme disease and West-Nile Virus (114, 115). Preventative behaviours align with health promotion intervention type. These findings suggest that health promotion is a promising intervention type to address vector-borne disease.

The intervention type category 'other' was also most frequently captured in articles that addressed vector-borne disease. Intervention categorized under 'other' may reflect space for innovative public health interventions, such as citizen science. It may also indicate the application of specialized public health interventions explicitly tailored to the health outcome, like vaccine development. On the contrary, the higher frequency of 'other' intervention types that address vector-borne disease may have occurred because vector-borne disease was the most frequently captured climate-sensitive category in this study.

Among all articles that addressed ultraviolet radiation, the majority applied health promotion interventions, despite health promotion being one of the least commonly identified intervention types in the review. Interventions that would be expected to address ultraviolet radiation such as environmental adaptation (i.e. shade structures) and advisories were not readily identified in this review.

Cross analysis of intervention types and specific climate-sensitive categories provides some indication of which intervention types are most fitting to address a particular climate-sensitive category. Comparing findings between specific climate-sensitive categories and the related main climate-sensitive categories can identify similarities, differences, or exceptions that can be informative for public health practice.

While some specific climate-sensitive categories share a similar distribution of intervention types as the related main climate-sensitive categories, others follow different patterns. For example, the distribution of intervention types that address vector-borne disease is similar to those that target both Lyme disease and West Nile Virus. In comparison, while the specific climate-sensitive categories extreme heat and urban health island follow a similar distribution of intervention types to the central climate-sensitive category extreme temperature, articles that include extreme cold followed a different distribution of intervention types. This information can be useful to determine which intervention types are likely most applicable to health risks and whether a particular intervention type can be tailored to address multiple specific climate-sensitive categories related to one main climate-health risks.

A distinguishing finding regarding the distribution of intervention types in articles that address air quality and related specific climate-sensitive categories, revealed that addressing individual components related to air quality (PM2.5 and ground-level ozone) together (general air quality) may be more useful than addressing either component separately. Conversely, separate interventions are likely required to target the specific category aeroallergens. Likewise, different interventions may be needed to target specific climate-sensitive categories related to the main

category food and water. This is likely because these specific categories are quite distinct from each other.

5.1.3.4 Climate-health Adaptation Interventions that Address Multiple Climate-health Risks

The review revealed that certain intervention types can address more than one main climate-sensitive category in a single intervention, and may be a good investment to address climate-health risks. Environmental adaptation and planning/decision-making interventions are most likely able to address multiple climate-sensitive categories.

Environmental adaptation interventions affecting green space were able to address two or more main climate-sensitive types. The most common climate-sensitive categories addressed by green space interventions were extreme weather, extreme temperature, air quality, and food and water. Some articles addressed ultraviolet radiation.

Planning/decision-making interventions provided a strategic approach to address multiple climate-health impacts. These interventions commonly outlined how and when to implement other more applied interventions such as health communication, surveillance, health promotion, and alerts to support an overall goal.

No intervention that addresses vector-borne disease addressed another climate-sensitive category. This finding suggests that interventions designed to tackle vector-borne disease are specific and associated health-impacts are unlikely related to another climate-sensitive category.

5.1.3.5 Climate-health Adaptation Interventions that Address Mental Health Outcomes

Several articles captured by this review explicitly addressed the mental health outcomes of climate change. Of these, not one article solely identified one climate-health adaptation intervention that focused only on climate-mental health outcomes. As such, a deeper dive into these articles was required to identify key characteristics.

The scope of this research project explicitly stated that health impacts addressed by adaptation interventions included both physical and mental health outcomes directly or indirectly caused by climate change would be relevant. However, the search strategy did not explicitly include search terms for particular health outcomes, including mental health outcomes. Consequently, relevant literature that highlights public health interventions that specifically address climate-related mental health outcomes may not be captured by this review.

Analysis of the relevant articles proposes that a variety of intervention types can be used to target climate-mental health outcomes. Some articles that addressed other climate-health risks described benefits to mental health. By reducing exposure, sensitivity, and enhancing adaptive capacity to climate change through adaptation interventions broadly, individuals and communities can better cope with climate change, simultaneously improving psychosocial health risk of climate change (12). This approach to addressing climate-mental health is more

integrated and reflects a primary and secondary approach to prevention. Other literature identified interventions that focused specifically on preventing mental illness influenced by climate change. These interventions included crisis counselling, cognitive interventions, and suicide prevention.

The most common climate-sensitive categories associated with interventions targeting climate-mental health risk were extreme weather (flooding, severe storms, drought, and fire), extreme temperature (extreme heat), and food and water (water quality and food security). Emerging evidence indicates that the psychological impacts of climate change are widespread (116). Potential gaps associated with climate-health interventions that address mental health outcomes are identified in **section 5.2**.

5.1.3.6 Additional Observations

Only one article (117), written from an Indigenous standpoint, was captured in this study. This was influenced by the fact that the review was not designed with an explicit aim to capture climate-health adaptation interventions specific to the context of Indigenous peoples. Thus the search terms applied did not include language reflective of Indigenous perspectives.

The methodological omission was identified in this study because experts external to the research team were consulted on the study protocol and early findings. This flagged the lack of literature reflective of Indigenous contexts and knowledge which motivated the research team to reflect on the cause of this and the unintended consequences of the project scope. The experience highlights an advantage of collaboration and consultation between experts when conducting research.

Several interventions identified from this source did not *'fit'* under the definitions of the intervention type categories used in the review. They were consequently captured under the 'other' intervention type category. This illustrates that some interventions that address climate-health risks of Indigenous people likely do not match western conceptualization of interventions that are predominantly used. Further interpretation and ramifications of this matter are considered in **sections 5.2, 5.3, and 6.2**.

5.2 Gaps in Knowledge and Practice

The analysis revealed several potential shortcomings regarding existing climate-health adaptation interventions. Recognizing these gaps in practice and knowledge presents an opportunity for public health authorities to modify activities and develop a research agenda that will contribute to the evidentiary base for climate-health adaptation initiatives, and sequentially support population health and wellbeing.

1. Some public health intervention types may be under-utilized.

The distribution of intervention types (**Figure 8**), illustrates that health promotion, policy and guideline/framework interventions may be under-utilized compared to other intervention types identified in this study.

Despite being a core public health activity (32), health promotion interventions were among the less frequently captured intervention type in this review. This study applied a definition of health promotion that focused on behaviours as opposed to broader systems change during intervention type categorization and thus may have influenced the number of captured health promotion interventions. However, unlike all other intervention types identified, the number of publications that emphasized health promotion did not increase over time.

Despite the low frequency, findings illustrate that health promotion interventions can be applied to a variety of climate-sensitive categories and may be particularly useful for targeting certain health risks such as vector-borne disease and ultraviolet radiation. Overall, the findings represent an opportunity for further research into the utility of health promotion interventions for a variety of climate-health risks and investing in implementation of promising interventions.

Policy and guideline/framework interventions were also less frequently applied intervention types. This may be influenced by how they were conceptualized in the review. This study defined policy and guideline/framework interventions independently; however, in practice, there is a fine line between the conceptualization of these two intervention types. As such, the separation of these intervention types in this review may have contributed to the observed low frequency.

The geographic region North America most frequently identified all intervention types except for policy. This may indicate a gap in the implementation of policy interventions to address climate-health outcomes in North American, including Canada. However, this may also be reflective of a potential difference in the defining characteristics of policy interventions implemented across geographic regions where these interventions were captured under a different, related intervention type such as guidelines/framework.

2. Some main and specific climate-sensitive categories may warrant greater attention.

The study displays that some climate-sensitive categories are less commonly addressed within climate-health adaptation intervention literature. As previously described in **section 5.1** the distribution of climate-sensitive categories could be influenced by the choice of search terms applied in this study. Regardless, this is a potential gap in practice that warrants further attention.

The distribution of climate-sensitive categories indicates (**section 4.5.1**) that few interventions target ultraviolet radiation. Moreover, geographic trends indicate ultraviolet radiation is infrequently addressed in most included geographic regions except for Australia/New Zealand

(section 4.3.3). These findings suggest a disparity in climate-health adaptation interventions that address ultraviolet radiation, including in Canada. This idea is reinforced by the fact that ultraviolet radiation was not assessed in the Health Canada survey (110), despite being recognized as a current and increasing climate-health risk within Canada (24, 112).

Several specific climate-sensitive categories were also identified infrequently among the included literature **(section 4.5.2)**. The specific climate-sensitive categories related to food and water, blue-green algae, and foodborne illness were not often addressed in captured literature despite evidence that they are current and growing climate-health risks (23, 24, 29, 110). Similarly, interventions that address winter storms were not captured under severe storms or natural hazards related to extreme weather although this is particularly relevant to the Ontario context (23, 24). Likewise, there were fewer interventions targeting extreme cold than extreme heat under the main climate-sensitive category extreme temperature. These specific climate-sensitive categories are increasingly a health issue due to climate change, and the fact they were less commonly captured within this review suggests it is a potential gap that public health authorities should consider.

3. Climate-mental health outcomes are insufficiently addressed.

The results suggest that few interventions address climate-mental health outcomes, and only a small increase was identified between 2014 and 2019. Moreover, among articles that addressed mental health, none exclusively identified one intervention that solely targeted mental health outcomes related to a particular climate-sensitive category.

These trends align with other literature which identified that mental health impacts associated with climate change are not well understood and often overlooked, despite evidence that shows rising psychological health effects of climate change (116, 118). Hayes et al. identified that literature on psychosocial adaptation to climate change is missing in literature globally (12).

Several interventions identified in the literature addressed mental health by explicitly expressing how a climate-health adaptation intervention supports mental health and wellbeing. For example, green space interventions that targeted several climate-health risks made an explicit reference to how the intervention could benefit mental wellbeing. In comparison, some articles that did not address climate-mental health outcomes displayed similar interventions to those that explicitly described mental health benefits, and would likely have mental health benefits that were not expressed. This illustrates that climate-mental health outcomes are not always considered. Public health authorities and researchers should make these connections in climate-health work to strengthen evidentiary bases for climate-health adaptation interventions regarding mental health and wellbeing.

Emerging literature on climate change and mental health demonstrate that the climate-sensitive categories extreme weather, extreme temperature, and vector-borne disease can have direct mental health impacts (116). Moreover, climate change's influence on the determinants of

health can have psychosocial effects (119, 120). Furthermore, general concern and worry over climate change, referred to as ecological grief and anxiety, has increasingly been acknowledged as a concern for mental wellbeing (116, 118). The captured interventions that targeted mental health did not address two of these better-known sources of mental health outcomes related to climate change, vector-borne disease, and ecological grief and anxiety.

4. Authorities may not regularly apply a climate-health lens to all interventions that address climate-health risks and may not be publishing their experiences on climate-health adaptation interventions.

The interpretation of the results suggests that public health interventions that address a climate-health risk, may not explicitly identify or communicate a climate-health lens and/or interventions with a climate-health lens may not be consistently published. Public health work often targets health risks that are associated with climate change without directly acknowledging.

Furthermore, Public Health Authorities may lack resource capacity to publish related work.

This was exemplified by the fact that traffic-related air pollution was the least targeted specific climate-sensitive category related to air quality in the review, suggesting it is less frequently addressed than other related specific climate-sensitive categories. However, traffic-related air pollution is commonly addressed by public health authorities in different contexts (121-124). Since the review did not capture this work, it suggests a climate-health lens is not being applied to traffic-related air pollution.

Since health promotion is a core public health function, the low frequency of publication of health promotion interventions was unexpected. This intervention type may have been captured less frequently in this study because those implementing such interventions are not publishing their experiences or are not explicitly communicating a climate-health lens within publications.

Furthermore, although search terms for ultraviolet radiation were not included in this study, literature that included a clear climate-health lens should have been captured by the search strategy. This indicates that an explicit climate-health lens is not commonly being applied to climate-health interventions targeting ultraviolet radiation, and potentially other climate-health risks.

The most frequently addressed climate-sensitive categories by adaptation interventions captured in this review are those most commonly recognized as climate-health risks (i.e. flooding, extreme heat, Lyme disease). This suggests that strengthening the application of a climate-health lens, and increasingly disseminating related knowledge may result in more public health adaptation interventions that address a variety of climate-sensitive categories.

5. Public health authorities need to make stronger efforts to include Indigenous voices in climate-health adaptation strategies.

The review did not capture a reasonable number of articles that meaningfully incorporated Indigenous perspectives and knowledge into climate-health adaptation planning. This does *not* mean that there is a gap in climate-health adaptation interventions that take into account Indigenous contexts and perspectives. Indigenous peoples and communities are at the forefront of climate change action and have led and developed adaptation strategies themselves (33, 34, 44, 125-129). Additionally, more funding has become available to support these actions by government agencies (130-132).

More accurately, the results reflect a probable disparity in meaningful efforts to include Indigenous voices in climate-health adaptation and Indigenous research methods in public health practice. This review exemplified an unacceptable yet common ‘mistake’ in public health practice. Indigenous voices were unintentionally excluded because the review did not explicitly aim to capture or make space for Indigenous perspectives, as described in **sections 3.8 and 5.1.3.6**. In other words, because the review did not purposefully make space for Indigenous perspectives or Indigenous research methods, Indigenous knowledge and ways of knowing and doing were actually blocked from being captured.

This interpretation is supported by literature on Indigenous and decolonizing methodologies and approaches (45, 125). Research conducted through western knowledge systems and understanding cannot adequately capture Indigenous experiences and perceptions due to contrasting values, epistemologies, and power dynamics (43-45). Existing Indigenous climate change studies have highlighted a need for assessments of risk and adaptation strategies that are rooted in the understanding of Indigenous experiences and worldviews in order to effectively utilize and strengthen adaptive capacity of Indigenous peoples to promote health and wellbeing in the face of climate change. (34, 43, 133, 134). Strategies applied to address an issue are dictated by how the issue is framed; therefore neglecting Indigenous worldviews in assessments and research may restrict the development of adaptive capacity (33, 43, 133).

In an attempt to support future public health efforts, a complementary project captured critical concepts of Indigenous perspectives and knowledge that need to be understood and meaningfully integrated into adaptation planning. Additional suggestions are highlighted in **sections 5.3 and 6.2**.

5.3 Recommendations for Practice and Research

5.3.1 Applying Results to Climate Change and Public Health Adaptation Planning

Public health authorities are encouraged to use the results of this scoping review to inform local public health climate change adaptation planning. This section proposes how public health authorities can operationalize these results to address local climate-health risks in Ontario.

1. Geographic trends can support public health authorities to source relevant examples of climate-health adaptation interventions.

Ontario public health authorities can learn from the experiences of other regions facing similar climate-health risks to inform local adaptation planning. Geographic trends identified by this study can support public health authorities to find relevant examples of climate-health adaptation interventions from a variety of regions by intervention types and climate-sensitive categories. Examples and lessons learned from other regions can be tailored and applied to the local context.

2. Characteristics of existing climate-health interventions can support public health authorities to compile an inventory of possible climate-health interventions that can be adapted to implement locally.

Cross analysis of intervention types and climate-sensitive categories display a range of existing public health intervention types and the climate-sensitive categories that they are likely to target. Public health authorities can use this collection of knowledge on the characteristics of existing interventions to compile an inventory of possible measures that can be adapted and implemented locally.

Compiling an inventory list of possible climate-health adaptation interventions is endorsed by the *Ontario Climate Change and Health Vulnerability and Adaptation Assessment Guideline* as an initial step in adaptation planning (23).

3. Interventions that address multiple climate-sensitive categories can help public health authorities plan climate-health adaptation interventions that may provide a greater return on investment.

Characteristics of interventions that can address multiple climate-sensitive categories can help authorities plan for interventions that can support climate change adaptation and address expected health outcomes related to several climate-sensitive categories. Implementing one intervention that can address multiple climate-health risks may provide a greater return on investment.

This review identified several examples of public health interventions capable of addressing multiple health risks. Moreover, key characteristics of these interventions reveal related climate-sensitive categories that are likely to be addressed simultaneously if interventions are designed to do so.

4. Interpretation of the results reveal several key considerations that can support public health climate change adaptation planning.

The results and interpretation of this scoping review have identified several important considerations for public health practice. When developing local public health climate change adaptation plans, public health authorities should consider the following:

- Health communication and health promotion intervention types are likely versatile and can be tailored to tackle a variety of climate-sensitive categories.
- Some intervention types, like surveillance and alerts/advisory/warnings, predominantly address one or two climate-sensitive categories.
- The intervention type ‘other’ captured by this review often indicates space for innovative or distinctive approaches to address particular climate-health risks, sometimes for specific populations (e.g. Indigenous).
- Both strategic and practical approaches can be applied to address local climate health risks.
- Public health interventions that aim to address air quality broadly can effectively address multiple components of air pollution such as PM2.5, ground-level ozone and traffic-related air pollution. There may be less opportunity for overlap between pollution-related interventions and those addressing aeroallergens.
- Existing mental health supports and services can support mental wellbeing and prevent mental illness related to climate change. Identifying and mapping out local mental health services and supports can contribute to climate-health adaptation planning.
- Reflect on how interventions can address both physical and mental health consequences of climate-sensitive categories.
- Consider whether existing public health interventions could benefit from incorporating a climate-health lens. Existing interventions may function as a climate-health adaptation intervention.
- Public health authorities may be able to identify promising intervention types that address climate-sensitive categories by comparing the proportion of intervention types that address climate-sensitive categories and vice-versa.

5.3.2 *Applying Results to Advance Public Health Practice and Knowledge*

In light of several potential gaps in practice and knowledge revealed by the scoping review and supporting literature, several actions are suggested for public health authorities and researchers. Engaging in these suggested activities can contribute to advancing public health practice and the evidentiary base regarding public health and climate change adaptation interventions.

1. Increase knowledge translation activities.

The public health community will benefit from knowledge exchange activities from authorities that develop, implement, and evaluate climate-health adaptation interventions. This may be particularly beneficial for climate-health adaptation interventions that include intervention types and climate-sensitive categories that were identified less frequently in the review. Knowledge translation products should provide information about the processes and outcomes of interventions to inform other public health authorities and the research community.

Public Health Authorities may lack the resources required to engage in knowledge translation activities, such as publishing. Other public health authorities and stakeholders can support knowledge translation activities on climate-health adaptation interventions by providing or sharing required resources.

2. Explicitly integrate a climate-health lens.

Public health activities may address climate-related health risks without explicitly acknowledging or applying a climate-health lens. Public health authorities should consider and explicitly state how a climate-health lens can be incorporated into existing interventions that support climate change adaptation and address expected climate-health outcomes. The inclusion of a climate-health lens can enhance knowledge on how climate change is connected with health outcomes already being addressed and build the evidentiary basis. It can increase recognition for climate-health risks and therefore lead to the development of climate-health adaptation interventions. Moreover, applying a climate-health lens may identify additional health benefits that can further rationalize public health activities to stakeholders.

3. Invest in climate-health interventions.

Public health authorities and researchers should invest in developing, piloting, implementing, and evaluating climate-health interventions. The scoping review findings can help authorities develop a research agenda. The review identifies promising intervention types to address specific climate-sensitive categories, including multiple health-risks that can be advanced. Identified gaps regarding intervention types and climate-sensitive categories should also be targeted.

4. Continue to build understanding of climate-health risks.

The review identified that climate-sensitive categories that are more recognizable and understood are more likely to be addressed by climate-health adaptation interventions. Thus, advancing empirical evidence on health-risks may lead to more interventions. Climate-sensitive categories less often captured in this review should be prioritized.

Additionally, climate-mental health outcomes must be prioritized by public health authorities and researchers. Mental health must be included in climate change and health vulnerability and adaptation assessments to better understand current and projected climate-related mental health outcomes and potential adaptation strategies. Further recommendations regarding incorporating mental health indicators into climate change and health vulnerability adaptation assessments are highlighted in Hayes & Poland (2019).

Indigenous values, ways of knowing and doing and experiences must be rooted in assessments of climate-health risks for Indigenous peoples and communities, in order to strengthen adaptation capacity effectively.

5. Public health authorities have a moral responsibility to become educated on how to support Indigenous climate-health adaptation.

The complementary project (Module Two), identifies Indigenous perspectives and the importance of including these perspectives into climate-adaptation, as well as strategies to assist public health authorities in doing so. It is important that public health authorities understand and meaningfully apply these perspectives to work with and learn from Indigenous peoples regarding climate-health adaptation planning and implementation.

Public health authorities are encouraged to use this document as an *introduction* to critical concepts that should be further explored, built-on, and applied to develop respectful, reciprocal relationships with Indigenous communities and work towards appropriate adaptation strategies that take into account Indigenous contexts and worldviews. Public health authorities must become educated on the influence that colonization has on climate-health vulnerability, Indigenous conceptualizations of health and wellbeing, and the importance of land as a key determinants of Indigenous health. Moreover, public health authorities must learn how to promote decolonizing methodologies.

6 CONCLUSION

The scoping review synthesized knowledge on the range and characteristics of public health interventions that support climate change adaptation and address expected health impacts associated with climate-sensitive categories within Ontario. The review adopted a broad focus on interventions that had public health relevance published within the last 5 years (2014-2019).

The findings of this review are a starting point to advance public health practice and knowledge on climate-health adaptation interventions. Key themes that were analysed include time trends, geographic trends, climate sensitive categories, intervention types, interventions that target multiple climate-sensitive categories, and whether mental health impacts were addressed were identified.

Literature published on interventions that address a variety of climate-health risks that have public health relevance in Ontario is increasing. Certain intervention types are more commonly applied to certain climate-sensitive categories, while some can address multiple health risks which may provide a good investment. Mental health was not commonly addressed. This, as well as several other areas, require further investment to establish a stronger evidence base to support public health climate change adaptation planning.

This report has highlighted ways in which public health authorities can use this information to support local public health and climate change adaptation plans. It also provides key areas of future research and activities that would further support this field of knowledge and practice.

This project was possible because of the collaboration between the Simcoe Muskoka District Health Unit, the Public Health Agency of Canada Ontario Region, and Cambium Indigenous Professional Services.

6.1 Strengths and Limitations

The review addresses a practical need for local public health authorities in Ontario. *The Ontario Public Health Standards* require Public Health Authorities to conduct climate change and health vulnerability and adaptation assessments (32, 135). The logical next step, following vulnerability assessments, is to plan and implement climate-health adaptation interventions to promote and protect health and wellbeing. Moreover, public health authorities have a moral and ethical imperative to apply a climate-health lens because of the significant public health risk that climate change poses.

The scoping review applied a methodological rigour while allowing for rapid synthesis of the literature to address the knowledge gap as health units in Ontario work to complete vulnerability assessments and identify climate change adaptation interventions.

As such, this review presents a timely and practice evidentiary basis, done with rigour, to respond to the Ontario public health authorities' needs, created by the Ontario Public Health Standards and moral obligation. The review provides information on key characteristics of climate-health interventions which can help public health authorities identify and prioritize climate-health adaptation interventions. It also offers insight into potential gaps in public health practice and knowledge. The review is practical, in that it determines how public health authorities can use critical findings to support climate change adaptation, planning, and advance public health activities and practice to respond to potential gaps identified.

This scoping review project was deliberately broadly scoped to seek information on existing climate change related interventions that may be of relevance in the Ontario context. This was a strength of the review. By maintaining a breadth, the study was able to capture and identify gaps in the North American context. For example, by including geographic regions outside of Canada, the review was able to capture ultraviolet radiation interventions from Australia and Policy interventions from the United Kingdom. Furthermore, the breadth of the study can help public health authority's forecast, so as climate shifts, authorities can pull examples from areas with more experience with a particular climate-sensitive category or intervention type.

While this review has several strengths, there are also some limitations to be acknowledged. The scope of this review makes it possible that not all relevant literature was identified. The research team made decisions regarding the scope of the project to make the study feasible. These decisions and their potential impacts on the study has been reported on throughout the methods (**section 3**) and discussion (**section 5**) of this report. Reporting on these decisions and their potential impact maintains transparency of this review.

The data collection and analysis processes limited the ability to discern which intervention types and climate-sensitive categories were associated with a particular intervention within one article. A deeper dive into the literature was applied to make this distinction for interventions that addressed mental health and those that addressed multiple climate-sensitive categories.

A shortcoming of the review was that it did not commonly capture adaptation interventions that took into account Indigenous peoples context and ways of knowing and doing. The authors recognize that this is because the scoping review was not designed with the explicit aim to capture this information. Thus, search terms did not include language reflective of Indigenous ways of knowing and doing. This shortcoming is unfortunately often cited in public health work and can perpetuate colonial systems of knowledge and practice. In response to this issue, Cambium Indigenous Professional Services was contracted to complete an associated project that focused explicitly on adaptation to climate change as it relates to Indigenous-specific ways of knowing and doing. This complementary project will hopefully help Public Health Authorities avoid this mistake in the future.

6.2 Next Steps to Enhance the Findings of this Scoping Review

This scoping review lays the groundwork for better understanding of the range and characteristics of public health interventions that address associated health risks across climate-sensitive categories relevant to Ontario. Several next steps are recommended to specifically address limitations of this scoping review, and advance this body of work beyond the scope of this research project. Recommendations and the rationale for each are as follows:

- Future research on existing climate-health interventions should capture the intervention implementation bodies to highlight the interdisciplinary intersectional collaboration needed to deliver an intervention. This could help public health audiences see the type of collaborative actions needed to support climate change adaptation efforts.
- Forthcoming investigations should identify specific health outcomes that the climate-health adaptation interventions are targeting as opposed to climate-sensitive categories. This information is useful to increase the understanding of which health issues are being addressed by interventions and can help public health authorities integrate climate adaptation work into existing activities that address specific health outcomes.
- Capturing the target populations in future assessments would help to identify whether specific vulnerable populations are targeted by the interventions. This can help identify if and how health equity considerations are, or are not, being taken into account within interventions. It can also help public health authorities understand which groups are being targeted and who's adaptation needs are being considered.
- Future reviews should capture characteristics of barriers and opportunities for adaptation interventions, including if and how literature on climate-health adaptation interventions document or discuss them. This would be useful information to inform adaptation

planning and implementation of similar climate-health adaptation interventions. It could also identify success factors or implementation tools that could help with the application of interventions in Ontario.

- Knowledge synthesis on the characteristics of existing capacity building strategies for the implementation of adaptation interventions could be beneficial. This information can help public health authorities identify how to build capacity and readiness within a public health authority or community to implement adaptation activities more efficaciously.
- A study should exclusively capture the range and characteristics of adaptation strategies that address climate-health impacts for Indigenous populations within Ontario.
- Lastly empirical evidence on the quality and effectiveness of existing interventions would be extremely informative to public health authorities. This information can help authorities prioritize different interventions and provide insights into which interventions would be the best investment for health.

Capturing this information in future projects will build the evidentiary base for local climate change adaptation and sequentially further support public health authorities in the adaptation planning processes and implementation.

APPENDICES

Appendix A: Distribution of Public Health Interventions Types across Publication Years

Public Health Intervention Type	Publication Year											
	2014 (N=14)		2015 (N=9)		2016 (N=11)		2017 (N=15)		2018 (N=15)		2019 (N=30)	
	n ^a	% ^a	n	%	n	%	n	%	n	%	n	%
Health Communication	4	29%	5	56%	5	45%	3	20%	7	28%	10	33%
Health Promotion	2	14%	3	33%	1	9%	3	20%	3	12%	2	7%
Environmental Adaptations	1	7%	2	22%	1	9%	6	40%	2	8%	7	23%
Policy	-	-	3	33%	1	9%	2	13%	3	12%	5	17%
Planning / Decision-making	4	29%	3	33%	7	64%	6	40%	9	36%	7	23%
Surveillance	4	29%	5	56%	2	18%	4	27%	5	20%	8	27%
Guidelines / Frameworks	2	14%	1	11%	-	-	2	13%	2	8%	4	13%
Alerts / Advisories / Warnings	3	21%	2	22%	3	27%	1	7%	5	20%	5	17%
Other	1	7%	-	-	1	9%	1	7%	2	8%	6	20%

^a Articles may include more than one public health intervention type, so values for n may not add up to the total number of articles published each year (N). Percentages likewise may not sum to 100%.

Appendix B: Distribution of Main Climate-sensitive Categories by Publication Year

Main Climate-Sensitive Category	Publication Year											
	2014 (N=14)		2015 (N=9)		2016 (N=11)		2017 (N=15)		2018 (N=25)		2019 (N=30)	
	n ^a	% ^a	n ^a	% ^a	n ^a	% ^a	n ^a	% ^a	n ^a	% ^a	n ^a	% ^a
Extreme Weather	5	36%	1	11%	2	18%	5	33%	4	16%	6	20%
Extreme Temperature	5	36%	3	33%	3	27%	10	67%	7	28%	6	20%
Air Quality	2	14%	2	22%	2	18%	2	13%	7	28%	8	27%
Vector-borne Disease	4	29%	5	56%	3	27%	4	27%	10	40%	12	40%
Ultraviolet Radiation	1	7%	1	11%	0	0%	0	0%	0	0%	3	10%
Food and Water	2	14%	1	11%	3	27%	2	13%	3	12%	6	20%

^a Articles may include more than one main climate-sensitive category, so values for n may not add up to the total number of articles published each year (N). Percentages likewise may not sum to 100%.

Appendix C: Distribution of Articles by Main Geographic Region (N=104)

Main Geographic Region	n	% Total
North America	59	57%
Europe	29	28%
South America	2	2%
Australia, New Zealand	8	8%
Non-Defined	6	6%

Appendix D: Distribution of Articles by Specific Geographic Region (N=104)

Specific Geographic Region	n	% Total ^a	% Associated Main Geographic Region ^b
Canada	30	29%	51%
USA	28	27%	47%
Mexico	1	1%	2%
United Kingdom	10	10%	34%
Central Europe	7	7%	24%
General Europe	4	4%	14%
Eastern Europe	1	1%	3%
Southern Europe (Mediterranean)	7	7%	24%

^a The % of the total number of articles (N=104).

^b The % associated with main geographic region for Canada, USA and Mexico is North America (N=59); The % associated with the main geographic region for United Kingdom, Central Europe, General Europe, Eastern Europe, Southern Europe is Europe (N=29).

Appendix E: Distribution of Articles by Public Health Intervention Type (N=104)

Public Health Intervention Type	n ^a	% ^a
Planning / Decision-making	36	35%
Health Communication	34	33%
Surveillance	28	27%
Environmental Adaptations	19	18%
Alerts / Advisories / Warnings	19	18%
Health Promotion	14	13%
Policy	14	13%
Guidelines / Frameworks	11	11%
Other	11	11%

^a Articles may include more than one public health intervention type, so values are >104. Likewise percentages will not equal 100%.

Appendix F: Distribution of Articles by Main Climate-sensitive Category (N=104)

Main Climate-Sensitive Category	n ^a	% ^a
Vector-borne Disease	38	37%
Extreme Temperature	34	33%
Extreme Weather	23	22%
Air Quality	23	22%
Food and Water	16	15%
Ultraviolet Radiation	5	5%

^a Articles may include more than one main climate-sensitive category, so values are >104. Likewise percentages will not equal 100%.

Appendix G: Frequency of the Specific Climate-sensitive Categories Related to Each Main Climate-sensitive Category

Main Climate-sensitive Category	N ^a	Specific Climate-sensitive Category	n ^a	% ^a
Vector-borne Disease	38	Lyme Disease	20	53%
		West Nile Virus	18	47%
		General	11	29%
Extreme Temperature	34	Extreme Heat	28	82%
		Urban Heat Island	13	38%
		Extreme Cold	4	12%
Extreme Weather	23	Flooding	16	70%
		Severe Storms	10	43%
		Natural Hazards	10	43%
		Drought	7	30%
		Forest Fires	7	30%
Air Quality	23	General Air Quality	16	70%
		PM2.5	10	43%
		Ground-level Ozone	5	22%

		Aeroallergens	4	17%
		Traffic Related Air Pollution	3	13%
Food and Water	16	Water Quality	9	56%
		Waterborne Illness	6	38%
		Food Security	6	38%
		Water Quantity	4	25%
		Foodborne Illness	3	19%
		Blue-green Algae	2	13%
UVR	5	UVR	5	100%

^a Articles may include more than one category, so sum is greater than N, and percentages will not equal 100%.

Appendix H: Captured Articles that Address the Main Climate-sensitive Category Vector-borne Disease

Article	Specific Climate-sensitive Category Related to Vector-borne Disease	Public Health Intervention(s)
Aenishaenslin, Gern. 2015 (136)	Lyme Disease	Planning/Decision-making
American Public Health. 2018 (89)	Vector-borne Disease General	Health Communication Health Promotion Environmental Adaptations Planning/Decision-making Surveillance Alerts/Advisories/Warnings
Anderson, Brown. 2017 (90)	West Nile Virus Lyme Disease Vector-borne Disease General	Health Communication Health Promotion Environmental Adaptations Policy Surveillance Alerts/Advisories/Warnings
Antonise-Kamp, Beaujean. 2017 (137)	Lyme Disease	Health Communication Health Promotion
Barker. 2019 (138)	West Nile Virus	Planning/Decision-making Surveillance
Bartumeus, Oltra. 2018 (139)	West Nile Virus Vector-borne Disease General	Health Communication Planning/Decision-making Surveillance
Bateman, Cook. 2018 (140)	Lyme Disease	Guidelines/Frameworks

Berry, Clark. 2014 (24)	West Nile Virus Lyme Disease Vector-borne Disease General	Health Communication Health Promotion Environmental Adaptations Planning/Decision-making Surveillance Other
Bonnet and Richardson. 2018 (141)	Lyme Disease Vector-borne Disease General	Planning/Decision-making Other
Bouchard, Aenishaenslin. 2018 (142)	Lyme Disease	Planning/Decision-making
Bouchard, Aenishaenslin. 2018 (142)	Lyme Disease	Health Communication Environmental Adaptations Surveillance
California Department of Public. 2017 (143)	West Nile Virus	Surveillance Guidelines/Frameworks
(CAPE). 2019 (91)	West Nile Virus Lyme Disease	Health Communication Environmental Adaptations Policy Planning/Decision-making Surveillance Alerts/Advisories/Warnings
Chiari, Prosperi. 2015 (144)	West Nile Virus	Surveillance
Clow, Ogden. 2018 (145)	Lyme Disease	Planning/Decision-making
DeFelice, Birger. 2019 (146)	West Nile Virus	Planning/Decision-making Surveillance
Dubey, Amritphale. 2014 (147)	West Nile Virus	Health Communication
Fischhoff, Keesing. 2019 (148)	Lyme Disease	Environmental Adaptations
Germain, Simon. 2019 (149)	West Nile Virus Lyme Disease Vector-borne Disease General	Health Communication Planning/Decision-making Surveillance
Hinckley, Meek. 2016 (150)	Lyme Disease	Other
Hines and Sibbald. 2015 (151)	Lyme Disease	Health Communication Health Promotion Surveillance
Hongoh, Campagna. 2016 (152)	West Nile Virus	Planning/Decision-making

Jourdain, Samy. 2019 (153)	West Nile Virus Vector-borne Disease General	Surveillance
Koffi, Savage. 2017 (154)	Lyme Disease	Surveillance
Lewis, Boudreau. 2018 (155)	Lyme Disease	Health Communication Health Promotion Surveillance
Martin, Borucki. 2019 (156)	West Nile Virus Vector-borne Disease General	Surveillance
Napoli, Iannetti. 2015 (157)	West Nile Virus	Surveillance
Nasci and Mutebi. 2019 (158)	West Nile Virus	Other
Nichols, Andersson. 2014 (159)	Vector-borne Disease General	Surveillance Alerts/Advisories/Warnings
Ogden, Koffi. 2014 (160)	Lyme Disease	Surveillance
Pamela and Nation Government. 2018 (117)	Vector-borne Disease General	Other
Potter, Jardine. 2019 (161)	West Nile Virus	Health Communication
Ripoche, Gasmi. 2018 (162)	Lyme Disease	Surveillance
Rochlin, Ninivaggi. 2019 (163)	Lyme Disease Vector-borne Disease General	Health Communication Environmental Adaptations Other
Soucy, Slatculescu. 2018 (164)	Lyme Disease	Planning/Decision-making
Tarter, Levy. 2019 (165)	West-Nile Virus	Health Communication Surveillance Other
Varnado and Goddard. 2016 (166)	West Nile Virus	Planning/Decision-making
Watts, Adger. 2015 (55)	West Nile Virus	Health Communication Environmental Adaptations Policy Planning/Decision-making Surveillance Alerts/Advisories/Warnings

Appendix I: Captured Articles that Address the Main Climate-sensitive Category
Extreme Temperature

Article	Specific Climate-sensitive Category Related to Extreme Temperature	Public Health Intervention(s)
Alavipanah, Wegmann. 2015 (167)	Extreme Heat Urban Heat Island	Environmental Adaptations
American Public Health. 2018 (89)	Extreme Heat	Health Communication Health Promotion Environmental Adaptations Planning/Decision-making Surveillance Alerts/Advisories/Warnings
Anderson, Brown. 2017 (90)	Extreme Heat	Health Communication Health Promotion Environmental Adaptations Policy Surveillance Alerts/Advisories/Warnings
Anderson. 2016 (168)	Extreme Heat	Health Communication Planning/Decision-making Alerts/Advisories/Warnings
Beaudoin and Gosselin. 2016 (169)	Urban Heat Island	Health Communication Environmental Adaptations
Benmarhnia, Zhao. 2019 (170)	Extreme Cold	Policy Planning/Decision-making Alerts/Advisories/Warnings
Berisha, Hondula. 2017 (171)	Extreme Heat	Health Promotion
Berry, Clark. 2014 (24)	Extreme Heat	Health Communication Health Promotion Environmental Adaptations Planning/Decision-making Surveillance Other
Bittner, Matthies. 2014 (172)	Extreme Heat	Planning/Decision-making
Boyson, Taylor. 2014 (173)	Extreme Heat	Planning/Decision-making
(CAPE). 2019 (91)	Extreme Heat Urban Heat Island Extreme Cold	Health Communication Environmental Adaptations Policy Planning/Decision-making Surveillance Alerts/Advisories/Warnings Other
Carmona, Linares. 2017 (174)	Extreme Heat	Planning/Decision-making
Center for Climate Energy Solutions. 2017 (175)	Extreme Heat Urban Heat Island	Environmental Adaptations Planning/Decision-making

Chiu, Vagi. 2014 (176)	Extreme Cold	Alerts/Advisories/Warnings
Elliot, Bone. 2014 (177)	Extreme Heat	Surveillance
Endlicher. 2017 (85)	Extreme Heat Urban Heat Island	Environmental Adaptations
Graham, Vanos. 2017 (178)	Extreme Heat	Environmental Adaptations Planning/Decision-making
Grothmann, Leitner. 2017 (179)	Extreme Heat	Health Communication Guidelines/Frameworks
Hatvani-Kovacs, Bush. 2018 (180)	Extreme Heat Urban Heat Island	Policy
Katiyo, Dorey. 2018 (181)	Extreme Cold	Planning/Decision-making
Kingsley and EcoHealth. 2019 (61)	Extreme Heat Urban Heat Island	Environmental Adaptations Other
Lall, Abdelnabi. 2017 (88)	Extreme Heat	Surveillance
Lee, Voogt. 2018 (182)	Extreme Heat Urban Heat Island	Environmental Adaptations
MacIntyre, Khanna. 2019 (183)	Extreme Heat	Health Communication Guidelines/Frameworks
Marando, Salvatori. 2019 (184)	Urban Heat Island	Environmental Adaptations
Martin. 2016 (185)	Extreme Heat	Health Communication Planning/Decision-making Surveillance Alerts/Advisories/Warnings
McGregor, Bessemoulin. 2015 (186)	Extreme Heat	Health Communication Health Promotion Surveillance Guidelines/Frameworks Alerts/Advisories/Warnings
National Health Service. 2018 (187)	Extreme Heat	Planning/Decision-making
Semeraro, Aretano. 86)	Urban Heat Island	Environmental Adaptations
Watts, Adger. 2015 (55)	Extreme Heat Urban Heat Island	Health Communication Environmental Adaptations Policy Planning/Decision-making Surveillance Alerts/Advisories/Warnings
Weinberger, Zanobetti. 2018 (188)	Extreme Heat	Alerts/Advisories/Warnings
Williams, Hanson-Easey. 2018 (189)	Extreme Heat	Alerts/Advisories/Warnings

World Health Organization Regional Office for Europe. 2017 (87)	Extreme Heat Urban Heat Island	Environmental Adaptations Policy Planning/Decision-making
Zhang, Murray. 2017 (190)	Extreme Heat Urban Heat Island	Environmental Adaptations Planning/Decision-making

Appendix J: Captured Articles that Address the Main Climate-sensitive Category
Extreme Weather

Article	Specific Climate-sensitive Category Related to Extreme Weather	Public Health Intervention(s)
American Public Health. 2018 (89)	Severe storms Drought Flooding Natural Hazards Forest Fire	Health Communication Health Promotion Environmental Adaptations Planning/Decision-making Surveillance Alerts/Advisories/Warnings
Anderson, Brown. 2017 (90)	Severe storms Drought Flooding Forest Fire	Health Communication Health Promotion Environmental Adaptations Policy Surveillance Alerts/Advisories/Warnings
Appuhamilage, Barbir. 2019 (191)	Severe storms Flooding Natural Hazards	Policy Guidelines/Frameworks
Berry, Clark. 2014 (24)	Drought Flooding Natural Hazards Forest Fire	Health Communication Health Promotion Environmental Adaptations Planning/Decision-making Surveillance Other
(CAPE). 2019 (91)	Flooding Forest Fire	Health Communication Environmental Adaptations Policy Planning/Decision-making Surveillance Alerts/Advisories/Warnings Other
Endlicher. 2017 (85)	Natural Hazards	Environmental Adaptations
Gainey, Brown. 2018 (192)	Flooding Natural Hazards	Health Promotion
Genes, Chary. 2014 (193)	Severe storms Natural Hazards	Health Communication
Grigoletto, Cabral. 2016 (82)	Drought	Health Communication Health Promotion Planning/Decision-making Surveillance
Kingsley and EcoHealth. 2019 (61)	Severe storms Flooding	Environmental Adaptations Other

Lall, Abdelnabi. 2017 (88)	Severe storms	Surveillance
Levy, Jenkins. 2014 (194)	Severe storms Flooding Natural Hazards	Health Communication
MacIntyre, Khanna. 2019 (183)	Severe storms Flooding Natural Hazards	Health Communication Guidelines/Frameworks
Pamela and Nation Government. 2018 (117)	Severe storms Drought Flooding Forest Fire	Other
Rappold, Fann. 2014 (83)	Forest Fire	Planning/Decision-making Alerts/Advisories/Warnings
Scott and Errett. 2018 (195)	Flooding Natural Hazards	Health Communication
Sena, Barcellos. 2014 (196)	Drought	Guidelines/Frameworks
Sharma, Pezzaniti. 2016 (84)	Flooding	Planning/Decision-making
Valois, Caron. 2019 (197)	Flooding	Planning/Decision-making
Watts, Adger. 2015 (55)	Severe storms Drought Flooding Natural Hazards	Health Communication Environmental Adaptations Policy Planning/Decision-making Surveillance Alerts/Advisories/Warnings
Westcott, Ronan. 2019 (198)	Forest Fire	Policy
World Health Organization Regional Office for Europe. 2017 (87)	Flooding	Environmental Adaptations Policy Planning/Decision-making
World Health Organization Regional Office for Europe. 2017 (199)	Flooding	Planning/Decision-making

**Climate-sensitive categories and public health intervention categories are not mutually exclusive. One article may highlight multiple climate-sensitive categories and/or intervention types*

.Appendix K: Captured Articles that Address the Main Climate-sensitive Category Air Quality

Article	Specific Climate-sensitive Category Related to Air Quality	Public Health Intervention(s)
American Public Health. 2018 (89)	Ground-level Ozone Air Quality General Aeroallergens	Health Communication Health Promotion Environmental Adaptations Planning/Decision-making

		Surveillance Alerts/Advisories/Warnings
Anderson, Brown. 2017 (90)	PM 2.5 Ground-level Ozone Traffic Related Air Pollutants Aeroallergens	Health Communication Health Promotion Environmental Adaptations Policy Surveillance Alerts/Advisories/Warnings
Berry, Clark. 2014 (24)	Air Quality General	Health Communication Health Promotion Environmental Adaptations Planning/Decision-making Surveillance Other
Borbet, Gladson. 2018 (200)	PM 2.5 Ground-level Ozone Air Quality General	Health Communication
Brunt, Barnes. 2018 (201)	Air Quality General	Policy
(CAPE). 2019 (91)	Air Quality General	Health Communication Environmental Adaptations Policy Planning/Decision-making Surveillance Alerts/Advisories/Warnings Other
Chen, Li. 2018 (202)	PM 2.5 Air Quality General	Alerts/Advisories/Warnings
Glazener and Khreis. 2019 (203)	PM 2.5 Traffic Related Air Pollutants	Policy
Goix, Petrovic. 2018 (204)	Air Quality General	Surveillance
Johnston, Wheeler. 2018 (205)	PM 2.5 Aeroallergens	Health Communication Planning/Decision-making Alerts/Advisories/Warnings
Kingsley and EcoHealth. 2019 (61)	Air Quality General	Environmental Adaptations Other
Lyons, Rodgers. 2016 (206)	Air Quality General	Alerts/Advisories/Warnings
Masselot, Chebana. 2019 (207)	PM 2.5 Air Quality General	Alerts/Advisories/Warnings
Mehiriz and Gosselin. 2019 (208)	Air Quality General	Health Communication Alerts/Advisories/Warnings
Morishita, Thompson. 2015 (209)	PM 2.5	Health Communication Policy
Patella, Florio. 2019 (210)	Aeroallergens	Planning/Decision-making
Pennington, Sircar. 2019 (211)	Air Quality General	Health Communication Alerts/Advisories/Warnings

Radisic and Newbold. 2016 (212)	PM 2.5 Ground-level Ozone Air Quality General	Health Communication
Rappold, Fann. 2014 (83)	PM 2.5	Planning/Decision-making Alerts/Advisories/Warnings
Semeraro, Aretano. 86)	Air Quality General	Environmental Adaptations
Vardoulakis, Kettle. 2018 (213)	Traffic Related Air Pollutants	Guidelines/Frameworks
Watts, Adger. 2015 (55)	PM 2.5 Ground-level Ozone Air Quality General	Health Communication Environmental Adaptations Policy Planning/Decision-making Surveillance Alerts/Advisories/Warnings
World Health Organization Regional Office for Europe. 2017 (87)	Air Quality General	Environmental Adaptations Policy Planning/Decision-making

Appendix L: Captured Articles that Address the Main Climate-sensitive Category Food and Water

Articles	Specific Climate-sensitive Category Related to Food and Water	Public Health Intervention(s)
American Public Health. 2018 (89)	Water Quality	Health Communication Health Promotion Environmental Adaptations Planning/Decision-making Surveillance Alerts/Advisories/Warnings
Anderson, Brown. 2017 (90)	Waterborne Illness Blue-green Algae Water Quality	Health Communication Health Promotion Environmental Adaptations Policy Surveillance Alerts/Advisories/Warnings
Berry, Clark. 2014 (24)	Waterborne Illness Foodborne Illness Blue-green Algae Food Security Water Quality Water Quantity	Health Communication Health Promotion Environmental Adaptations Planning/Decision-making Surveillance Other
(CAPE). 2019 (91)	Food Security Water Quality	Health Communication Environmental Adaptations Policy Planning/Decision-making Surveillance Alerts/Advisories/Warnings Other
Grigoletto, Cabral. 2016 (82)	Waterborne Illness Foodborne Illness	Health Communication Health Promotion

	Water Quality Water Quantity	Planning/Decision-making Surveillance
Hynds, Naughton. 2018 (214)	Water Quality	Health Communication Policy
Kingsley and EcoHealth. 2019 (61)	Food Security	Environmental Adaptations Other
Nichols, Andersson. 2014 (159)	Waterborne Illness Foodborne Illness	Surveillance Alerts/Advisories/Warnings
O'Brien and Xagorarakis. 2019 (215)	Waterborne Illness	Guidelines/Frameworks Other
Pamela and Nation Government. 2018 (117)	Food Security	Other
Schnitter and Berry. 2019 (92)	Food Security	Guidelines/Frameworks
Semeraro, Aretano. 86)	Water Quantity	Environmental Adaptations
Sharma, Chandramouli. 216)	Water Quality	Health Communication
Sharma, Pezzaniti. 2016 (84)	Water Quality Water Quantity	Planning/Decision-making
Watts, Adger. 2015 (55)	Waterborne Illness Food Security Water Quality	Health Communication Environmental Adaptations Policy Planning/Decision-making Surveillance Alerts/Advisories/Warnings

Appendix M: Captured Articles that Address the Main Climate-sensitive Category Ultraviolet Radiation

Article	Specific Climate-sensitive Category Related to Ultraviolet Radiation	Public Health Intervention(s)
Victoria Cancer Council. 2019 (217)	Ultraviolet Radiation	Health Promotion
Garcia-Romero, Geller. 2015 (218)	Ultraviolet Radiation	Health Communication Health Promotion Policy Planning/Decision-making
Hacker, Horsham. 2019 (219)	Ultraviolet Radiation	Health Promotion

Kingsley and EcoHealth. 2019 (61)	Ultraviolet Radiation	Environmental Adaptations Other
Oyebanjo and Bushell. 2014 (220)	Ultraviolet Radiation	Health Promotion

Appendix N: Captured Articles that Address the Main Climate-sensitive Category General Climate Change

Article	Specific Climate-sensitive Category Related to General Climate Change	Public Health Intervention
Marinucci, Luber. 2014 (221)	General Climate Change	Guidelines/frameworks

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