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Municipal Heat Response Planning in British Columbia, Canada

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Thank you to the health authority and municipal respondents to the survey upon which this report is based.

Introduction

As reported by the Intergovernmental Panel on Climate Change (IPCC) in 2007, the surface temperature of the Earth is increasing, with average temperatures projected to be between 1.8 and 4 degrees higher than 1900 by the end of the century [2]. This temperature rise is likely to be accompanied by more frequent and intense extreme weather events, including multi-day episodes of extreme heat [2]. The World Health Organization (WHO) estimates that high temperatures represent the largest contribution to weather-related global mortality [3]. Climate change models predict, by 2050, very hot days (above 30^{o}C) may occur across Canada approximately four-times as frequently as they do today [4, 5]. In south-central Canada, Cheng *et al.* project heat-related mortality may increase by 100% by 2050, and 200% by 2080 compared to current levels [6]. Health authorities and municipalities across Canada have taken to planning responses to extreme heat in order to mitigate its impact on health [7-12].

Rationale

British Columbia is expected to experience increases in average temperature faster than the global average and, since 2009, has encountered extreme heat events associated with increased mortality [1, 13, 14]; however, BC's historically temperate climate may have altered the perception of the risk posed by heat when compared to the rest of Canada. In order to effectively address the risks posed by climate change and increasing temperatures in BC, it will be important to assess the current perceptions and level of preparedness of health authorities and municipalities.

Objectives

This review aims to describe the interest in and approaches to addressing the risks associated with extreme heat by health authorities and municipalities in BC. From these findings, gaps in knowledge will be shown and recommendations made to advance heat response planning in BC.

Heat-related Human Health Impacts

The association between extreme heat events and increased mortality/morbidity is well known. Extreme heat is the leading cause of weather-related death in the US and has been associated with increased mortality in BC and other Canadian jurisdictions [1, 13, 15, 16].

Various factors modify the degree of risk posed by extreme heat. Higher relative humidity affects the body's ability to cool by evaporation and thus may exacerbate the effects of heat alone [17]. Mortality and morbidly may be greater for extreme heat events which occur early in the season, due to the acclimatization to heat which occurs over the summer [17]. Air pollution may also exacerbate heat-related illness, with mortality during extreme heat peaking on days with high concentrations of particulate matter (PM_{10}) [18, 19].

Risk may also be elevated for those living or residing in proximity to urban heat islands (UHI). These UHIs occur where large buildings, as well as large concrete surfaces, absorb and emit solar radiation, creating locally elevated temperatures. This effect may also be coupled with other anthropogenic heat sources [20]. In China, the UHI effect has been associated with higher heat-related mortality rates in the city centre of Shanghai, as compared to surrounding areas. [21]. A study in Montreal also demonstrated differential mortality across the city related to micro-urban heat island effects [22].

Vulnerable Populations

Heat-related health impacts disproportionately affect vulnerable populations. As such, it is important to understand who is at particular risk in order to effectively target extreme heat response interventions.

Seniors tend to be at greatest risk for heat-related mortality, given age-related, physiological changes that increase heat susceptibility, as well as a greater likelihood of medical co-morbidities [23]. Persons of older age often have diminished cardiac output, which limits the efficiency of rapid heat dissipation [24]. Over a lifetime, ultraviolet and other environmental exposures reduce the number of sweat glands and the capacity to lose heat through perspiration [25]. Aging is also associated with pre-existing chronic conditions, lower levels of physical fitness, and social vulnerability factors, such as social isolation and poverty [26] .

Studies have demonstrated inconsistent evidence as to heat-related susceptibility among men as compared to women. Greater heat-related impacts have been observed in men in meta-analyses from the US and Europe [27, 28], while studies from Australia, Italy and France indicate that women, especially older women, may be more susceptible [29-31]. During the 2003 heatwave in France, heat-related mortality was greater for persons who were widowed, divorced, or single [30]. This finding is supported by evidence indicating excess heat-related vulnerability for those who are social isolated [30, 32-35].

Social isolation may also increase risk of heat-related mortality. Case-control studies investigating the 1995 and 1999 Chicago heat waves found that persons who lived alone and did not leave their homes daily were at great risk of heat-related death [36, 37]; however, studies from Italy, England and Wales [32, 37, 38] did not demonstrate this vulnerability. This difference may be due to differing contextual factors or to confounders, such as social networks.

Children may also be more susceptible to heat-related illnesses, although the degree of excess risk is less clear than that experienced by seniors. Excess risk in children may relate to a higher surface area to body mass ratio and production of more metabolic heat than adults, as well as increased levels of physical activity; however, the evidence related to pediatric physiological susceptibility to heat on a population basis is inconsistent [39]. Children are at risk of heat related mortality if left in cars alone, as temperatures in vehicles can increase rapidly, especially when parked in direct sunlight [40]. Furthermore, infants may have higher risk of heat-related due to their higher metabolic rates and inability to remove excess clothing and blankets [41].

Low socioeconomic status may also increase vulnerability to heat-related illness. In the United States, studies have shown greater mortality of those living in poverty compared to those with higher socioeconomic status; however, studies from Europe and Latin America did not demonstrate this association [42-45]. The etiology of this elevated risk is complex and multifactorial; however, there is some speculation that this may be associated with a lack of awareness, means, or opportunity to take preventive measures [42-45]. In the United Sates, there is strong evidence that lack of air conditioning and poor quality housing may be factors in heat-related mortality [37, 46]. It is also possible that those who live in poverty may be less likely to open their doors/windows or use screen doors during heat events due to their perception that they live in neighbourhoods which are unsafe [47]. Furthermore, those living in poverty are more likely to have medical risk factors, such as chronic disease, which may make them particularly susceptible to heat-related illness [46].

Risk factors for morbidity and/or mortality due to extreme heat can be associated with the use of certain medications and substances, which can interfere with thirst, volume control and temperature regulation [48]. A study of patients over the age of 70 during the 2003 heat waves in France showed a number of drug categories associated with adverse reactions, most frequently diuretics, angiotensin converting enzyme (ACE) inhibitors, antidepressants (mainly selective serotonin reuptake inhibitors), proton pump inhibitors, digoxin, benzodiazepines, oral hypoglycaemic, angiotensin receptor blockers (ARBs), calcium antagonists and beta-blockers [49]. Various drugs of dependence are also associated with increased risk of heat-related morbidity/ mortality. Sympathomimetic drugs, such as amphetamines and amphetamine-like substances (e.g.: methamphetamines, cocaine, and MDMA) trigger vasoconstriction and increase muscular activity through agitation, leading to increased body temperature [50].

Municipal Heat Response Planning in Canada

Increasing average temperatures and an increased frequency of extreme heat events have brought attention to the importance of developing heat response plans by and for Canadian communities. Various Canadian municipalities have developed their own extreme heat response plans. These differ in complexity and composition depending on the availability of resources, perceived level of risk and other local factors.

Health Canada Best Practices

Health Canada has collated best practices and supports municipalities in the development of their own plans. So far, Health Canada has not been directly involved in the development of heat alert and response systems (HARS) for BC.

The Health Canada Best Practices document outlines several activities municipalities should take in order to plan and prepare for response to extreme heat events [51]. The document describes five main components of HARS: alert protocol, community response plan, communication plan, evaluation plan, and community mobilization and engagement, the last of which should occur at all stages of the HARS (See Figure 1). For the purpose of assessing planning and response activities in BC, HARS will be looked at in three sections: planning and preparation, emergency response, and long-term strategies. The components of these sections are described in further detail in Appendix A1.

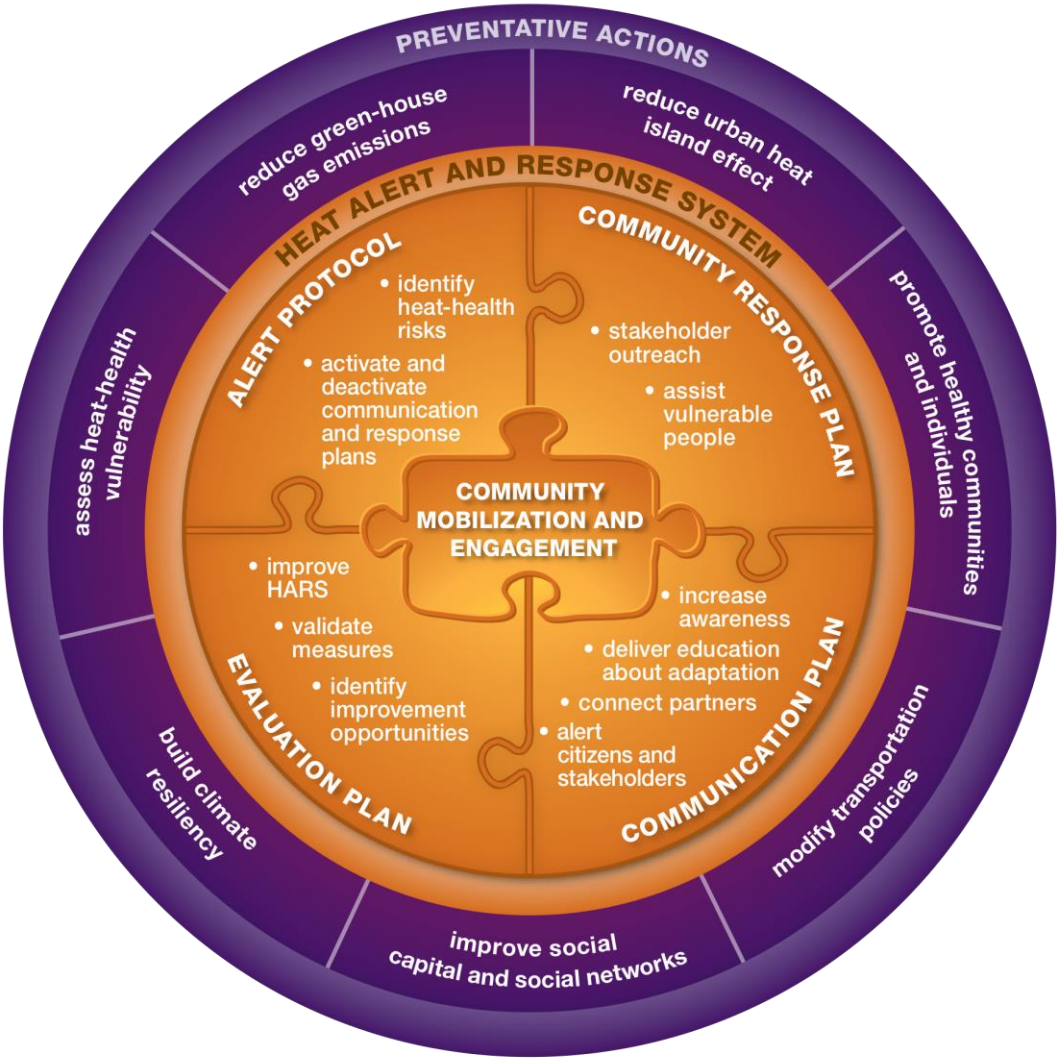

Figure 1. Components of community HARS as outlined by Health Canada (2012)

Municipal Heat Response Strategies in BC

The BC Context

HEAT RISK AND HOT WEATHER IN BC

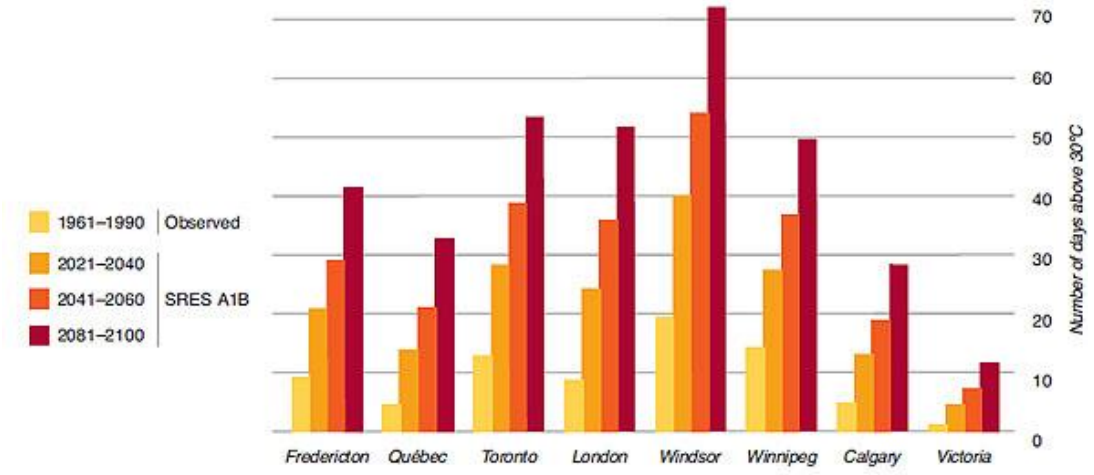

Figure 2. Comparison of number of days above 30 degrees Celsius among various Canadian municipalities over time [52]

The number of days with elevated temperatures has increased across Canada and is expected to keep rising according to current climate models [52, 53]. In 2016, various jurisdictions in BC experienced considerably elevated temperatures, including 32.2 ^{o}C in Pitt Meadows, 36.5 ^{o}C in Squamish, 35.5 ^{o}C in Port Alberni, and 36 ^{o}C in Kamloops [54, 55]. These temperatures compare with the hottest days in Toronto, ON [56]. Research indicates that the average annual temperature across BC may increase by 1.7 ^{o}C to 4.5 ^{o}C by the end of the 21st century relative to 1990. Currently, summer temperatures across the province have warmed since 1900 by between 0.6 ^{o}C to 1.6 ^{o}C , with the greatest warming occurring in the north [57].

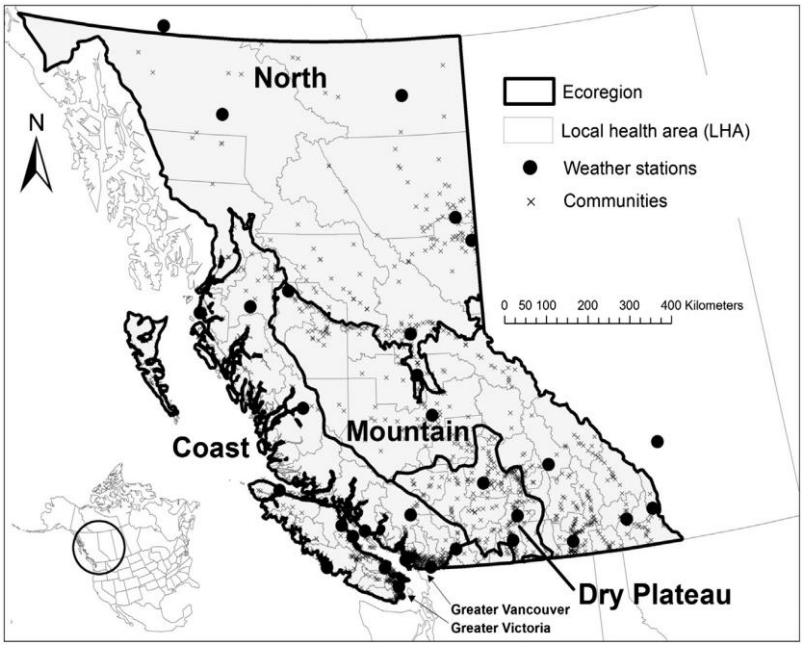

Figure 3. Ecoregions of BC [1]

BC has been defined as having four ecoregions with differing geography (Figure 3), very different population structures, and quite different heat vulnerabilities [1]. The Coast ecoregion has an average mean temperature of 19.9^{o}C, reaching maximum temperatures on particularly hot days of approximately

35.5°C. The Dry Plateau region of BC has average temperatures of approximately 24.2 °C and maximum heat of 38.4 °C. The Mountain ecoregion has average temperatures of 21.0 °C and maximum temperatures of 33.5 °C. North Ecoregion has average temperatures of 18.6 °C and maximum temperatures of 33.1 °C. The potentially vulnerable elderly populations (over 75 years of age) for the Coast, Dry Plateau, Mountain, and North Ecoregion are approximately 6.6, 8.5, 6.8, and 4.3 percent, respectively [1]. According to Statistics Canada (2011), the national average percentage of people over 75 is approximately 10.2% and is projected to increase until at least 2041 [58, 59].

To investigate differences in heat-related mortality in BC, Henderson *et al.* analysed temperature versus mortality in the four ecoregions of BC between 1986 and 2010 [1]. Though the highest absolute mortality in the province occurs in the most densely populated areas in the lower mainland, the relative impact was highest in the North ecoregion where hot days are generally rare. The Coast ecoregion had a similar trend to the North, with comparatively higher increases in mortality compared to other regions, potentially indicating that BC's Coastal and Northern populations are relatively less acclimatized to extreme heat [1]. In the Dry Plateau region, populations experience consistently hot summers and lower than expected mortality, potentially due to people being well-adapted to heat and/or most private homes having air-conditioning [1].

PUBLIC HEALTH AND MUNICIPAL COLLABORATION

Although public health departments in BC were relocated from municipalities to health authorities over a decade ago, public health officials often retain strong municipal relationships. These manifest through consultations on municipal plans/policies regarding transportation and planning, monitoring of and reporting on community health, and engagement on health-related municipal services[60]. In addition, medical health officers have a legislated responsibility under the BC Public Health Act to advise local governments on the public health aspects of municipal policies and practices [61].

ROLE OF PROVINCIAL AND FEDERAL AGENCIES

Following an excessively hot summer in 2009 associated with elevated mortality in the lower mainland, the BC Center for Disease Control worked with federal and health authority partners to develop temperature-related triggers for emergency response [62]. Alert triggers were determined through comparison of days with excess mortality and a combination of real and forecast elevated temperatures at two regional airport weather stations in the lower mainland, with subsequent validation. The triggers developed through this process were subsequently adopted by Fraser Health Authority and Vancouver Coastal Health, and were incorporated into several municipal heat response plans.

Municipal and Health Authority Consultations

A semi-structured consultation process was adopted in order to better characterize the nature and degree of municipal and health authority planning around extreme heat, as well as organizational preparedness and emergency response capacity.

METHODS

Ethics review was not obtained given the low risk of the consultations. Nonetheless, written consent was obtained from all participants.

Participants

Participants were recruited through convenience and snowball sampling, with recruitment of municipal staff involved in emergency response, climate adaptation, or heat response, as well as health authority medical health officers, environmental health officers, or other staff involved in emergency response.

Questions

Semi-structured expert consultations were conducted by phone and in-person, utilizing a standard set of questions specific to municipal- or health authority-associated participants. Twelve questions (some with conditional sub-questions) were divided into eight categories: Participant information, health effects of extreme heat, current state of heat response planning, collaboration, data and surveillance capacity, use of Health Canada resources, other useful resources, and other additional comments.

Consultation notes were collated and analyzed through qualitative content analysis, whereby themes were extracted and compared.

RESULTS

Health authority/organization participants represented 3 health regions and included 3 medical health officers, as well as a manager from a provincial emergency management organization. Municipal participants represented 7 municipalities in the interior and lower mainland of BC and included 6 staff involved in climate adaptation, sustainability and emergency management. These municipalities were located in the Coastal and Dry Plateau ecoregions, ranging in population size from less than 5000 to over 500,000.

Prioritization of Extreme Heat Planning

Municipalities

Risk of extreme heat is generally not considered a priority among municipalities, although it was prioritized in one municipality following publicized mortality events during an extreme heat event. Some participants also noted that heat response may be “on the radar” of staff and fire services, but not politicians. Climate change adaptation plans addressing heat risks are considered higher priority among several municipalities, and have either been implemented or are under development.

Municipal participants reported various reasons for the lack of prioritization of extreme heat planning within their communities. In general, the risk of extreme heat was considered low, particularly given the temperate climate within the Coastal ecoregion. In the interior region, lower risk was attributed to the adaptation of the population to heat. Other reasons for lower prioritization included competing agendas and the perception that response to the health risks of heat is outside of municipal jurisdiction. One

participant reported heat as a higher priority given that heatwaves are expected to arrive earlier in the season due to the effects of climate change.

Health Authorities

Extreme heat was not considered a priority by any of the health authority participants, although was considered “on their radar”. Participants noted that the issue received minimal attention from their respective organizations. This was primarily associated with the low perceived risk associated with extreme heat in their communities given the historically temperate conditions.

Current State of Heat Response Planning

Municipalities

Of the municipalities interviewed, response and adaptation plans for extreme heat, as well as climate change, ranged from extremely detailed to absent. Only one large municipality in the Coast ecoregion has a detailed heat plan following interest from Mayor and Council. The mayor and council of another large participant city saw heat as a medium risk, therefore not a priority. Two midsized municipalities in the Coast ecoregion also had formalized heat plans mainly at the behest of emergency planners. In the warmer ecoregion of Dry Plateau no municipality interviewed has a formalized heat plan, although one reported that heat was considered in their municipality’s all-hazards plan. Staff identified that extreme heat was a low priority, with one municipality stating that their population was acclimatized. For most of the participants, the plans involved health information outreach prior to the hot season with plans to direct the public to cool public spaces (libraries, malls, pools) and/or implement cooling shelters.

Though all participants had plans to reduce greenhouse gas emissions to combat climate change, formalized climate adaptation plans were most common in large cities in the Coast ecoregion. Smaller municipalities in the Coast ecoregion primarily incorporated climate adaption activities into other bylaws and practices concerning adaptation, such as expansion of tree canopies or storm water management. In the Dry Plateau ecoregion, no participant could relay a formalized climate change adaptation strategy, although one confirmed mitigation efforts were underway and that the council was in the process of developing a plan. Some of the participants addressed that human resources and lack of personnel were factors in not having a formal heat or climate adaptation plan, including having enough staff to organize cooling shelters.

Health Authorities

Description of the degree to which health authorities have pursued heat response and preparation activities differed among participants. Medical health officers from two urban health authorities described HA involvement in heat response algorithm development and surveillance of temperatures during summer months in partnership with the British Columbia Center for Disease Control and Environment Canada. Health authority and emergency management respondents described the development of heat response procedures for residential care facilities. These included protocols for cooling rooms (putting up drapes etc.) and relocating people when their rooms become too hot. An MHO reported that their more rural health authority had few activities around heat response, noting that the risk to the region appeared low given the temperate climate, with very few extreme heat events. They noted that no plan was

currently in place; however, the MHOs would lead a response if it were to become a larger concern, possibly with some support from environmental health officers (public health inspectors).

Collaboration

Municipalities

Participants generally described ongoing relationships with regional public health officials, although the degree of contact depended on their position within the organization. Public health involvement was described as consultations during policy development, as well as presentations by medical health officers on various health-related topics. Formalized partnerships with health authorities on various municipal initiatives were also described. Many participants articulated that they would like consistent messaging or collaboration between municipalities. Some participants stated that they had used BC Centre for Disease Control materials in the development of their plans.

Health Authorities

Health authorities generally maintained relationships with municipalities; however, their level of involvement in heat response and climate change adaptation planning varied. Two HA participants reported generally supportive involvement in municipal heat response planning, which included educating municipalities about risk, vulnerable populations, and most effective measures; however, this level of involvement was not constant amongst all municipalities in their regions. Another HA participant reported no recent MHO consultations on municipal emergency response plans. Minimal involvement in climate change adaptation planning was reported, with two participants noting informal conversations.

The main barrier encountered by health authority participants when engaging with municipalities on heat-related issues involved the low perceived risk of extreme heat within communities. Limited municipal and health authority resources were also reported as a barrier.

Data and Surveillance Capacity

Municipalities

Although only a fraction of the municipalities reported formalized heat response plans, most provided examples of municipal programs or activities that could support identification of vulnerable individuals. These included a senior's contact program, whereby the municipal program maintains a list of vulnerable seniors who are contacted once a week in order to check on their wellbeing. Some of the large municipalities were able to do formal heat and climate vulnerability studies to understand their risk of UHI effect and where their most vulnerable populations were, though there were various collaborations used to do this mapping, with one instance of contracting out of Canada, implying that not all municipalities are aware of local resources. Others would rely on census data. Participants also suggested that non-governmental organizations or city staff within their communities may maintain lists of vulnerable individuals that could be accessed in an emergency.

None of the municipal participants described formalized plans for evaluation of heat-related activities or response plans. One participant noted that they converse with the local ambulance centre and HA to

determine if there was more a strain of health resources during a heatwave or not. Another participant reported that debriefing and continuous improvement is incorporated into their all-hazards plan.

Health Authorities

Although some HA participants believed their organizations may have the capacity to identify those vulnerable to heat related illness within their jurisdictions, they reported that this had not been done, partly due to focus on other priorities. Other respondents felt that they did not have the means to identify socially isolated or vulnerable populations. Some HA participants believed they had the analytic capacity to evaluate the health effects of extreme heat events, while others believed that information would have to come from other sources, such as Environment Canada or the BCCDC. The participant from the emergency management organization noted that their organization's focus was on internal infrastructure and that it relies on public health to consider vulnerabilities.

Potential data sources included electronic health records (regional and provincial), Emergency Department admissions, and census data. One HA participant also described an initiative to develop a case management system for those identified as frail. HA participants also described access to heat mapping data from BCCDC, as well as data provided through other academic partnerships.

Health Canada Resources

Municipalities

The majority of municipal participants were not aware of the heat response planning resources developed by Health Canada.

Health Authorities

Although all participants were aware of the Health Canada resources for heat response planning, their use was limited. One MHO reported that they primarily used HC resources to inform public messaging on heat. Participants reported potential limitations of the resources including document length, lack of applicability to local contexts, and the need to be familiar with background research in order to maximize their use (primarily related to the best practices document). Participants were conflicted on their utility for municipalities, as one said the resources were of value for municipalities, while another disagreed.

Useful Resources

Municipalities

Municipal participants requested resources to better characterize risk and identify those within their communities who are vulnerable to heat and other effects of climate change. Public messaging resources were also requested, which could be shared across regional areas. One participant requested business-case examples or information on return on investment for heat mitigation and adaptation measures. Others cited the need for more guidance on best practices, including more specifics on what type of policy tools are required, as well as a province-wide protocol.

Health Authorities

Health Authority participants requested additional resources, primarily to support risk assessment and guide municipalities in heat response planning. Participants requested more government support, particularly for risk assessment at the local level. They reported a need for local data, as well as the capacity to compare local risk from heat to other environmental hazards in order to support prioritization. Participants also described a need for mapping capacity in order to identify at risk areas. Further guidance was requested for managing concurrent emergencies, such as extreme heat and poor air quality. One participant also requested recommendations for heat response planning be stratified based on the availability of municipal resources. An additional suggestion involved support for the addition of heat safety messaging to heat-sensitizing medications that are prescribed during the summer months. Finally, a request was made that resources for heat response & mitigation be part of a broader resource or set of tools for climate change mitigation/adaptation rather than creating separate resources for every topic: municipalities get bombarded with tools on highly specific topics.

Review of Municipal Heat Response Plans in BC

As is evident from the interviews, many municipalities in British Columbia have taken steps to mitigate the risks of increased frequency and intensity extreme heat events due to climate change. While some have developed comprehensive plans addressing both adaptation measures and emergency response, others have focused on more limited interventions. Several heat plans were described during the consultations; however, plans were also obtained from municipalities which did not participate in the consultation process.

In order to expand on information gathered through consultations, documentation was reviewed for several municipalities outlining extreme heat response plans, as well as climate adaptation strategies.

METHODS

The jurisdictional scan for municipal heat response plans was accomplished through online searches, as well as communication with regional public health officials and municipal staff. Medical health officers within each health authority were contacted and asked whether they were aware of any municipalities within their region that had developed or were in the process of developing extreme heat response plans. If not publically available online, municipalities identified through this process were subsequently contacted to obtain their heat response plans.

In addition to direct communication with select municipalities, a general search of grey literature was performed. Initially, the Google search engine was used to broadly identify additional municipalities with heat plans. Search terms were linked using Boolean operators and included the following: “British Columbia”, “heat”, “plan”, and/or “climate change adaptation”. Following this general search, the public websites for major municipalities in British Columbia were searched using the terms “heat” and/or “climate change adaptation”.

RESULTS

Surrey

Planning and Preparation

Surrey began the planning process for its Climate Adaptation Strategy[1] in 2011, using a five-milestone approach facilitated by the International Council for Local Environmental Initiatives (ICLEI): initiate, research, plan, implement and monitor [63]. The strategy was developed through consultation with an "adaptation team" comprised of representatives from City Departments. Following research into potential climate impacts and risk stratification, municipal actions were categorized based on type of impact (Ex. infrastructure, ecosystems, human health and safety etc.).

To address human health and safety concerns, the Strategy outlined actions to support collaboration with key partners to improve population health. These actions included collaboration with community organizations and health/service agencies to improve socioeconomic conditions and health outcomes of vulnerable populations, and identify needs related to climate-specific health risks. Surrey would also work with these partners to integrate climate change messaging into communication materials related to public health and safety.

Emergency Response

The Climate Adaptation Strategy recommended actions to improve emergency preparedness capacity, including development of community capacity, reviewing/supporting implementation of the Surrey-White Rock Extreme Heat Response Plan and identification of gaps in existing emergency plans.

The Surrey-White Rock Extreme Weather Response Plan was developed for 2015/2016 with the purpose of facilitating access to temporary shelter resources for homeless individuals during extreme weather events; however, according to the municipal participant involved in the consultation process, this plan was never formally adopted by council [64]. Although the Climate Adaptation Strategy refers to the Surrey-White Rock Extreme **Heat** Response Plan, the 2015/2016 Extreme **Weather** Response Plan does not mention heat; rather, it focuses on low temperatures, snow, rain and windstorms.

Long-term Strategies

Long-term strategies formed the core actions proposed in the Climate Adaptation Strategy. In particular, infrastructure improvements were recommended to address the urban heat effect. This included increasing capacity for shade trees, promoting passive building design features to keep buildings cool, increasing green space, exploring opportunities to incorporate green roofs, connecting vulnerable neighbourhoods with heat-mitigation programs (energy retrofit programs, tree planting, water fountain installations etc.), increasing canopy coverage and alternative paving surfaces in parking lots, and using high albedo surfaces for buildings and pavement.

[1] http://www.surrey.ca/files/(13365)_Climate_Adaption_Strategy_-_FINAL_WEB.pdf

Vancouver

Planning and Preparation

The City of Vancouver developed a comprehensive strategy to prepare for and respond to extreme weather events in response to a publicized hot weather death in 2009 [65]. This strategy was guided by an Extreme Hot Weather Committee, comprised of representatives from City departments, as well as Vancouver Coastal Health, BC Housing, the Greater Vancouver Shelter Strategy and the Coroner's Office. The development process produced a set of Initial Response Guidelines (IRG), most recently updated in March 2016 [66]. These IRGs include both preparedness activities prior to the heat season, as well as an emergency protocol to be triggered in response to extreme heat.

Although various initiatives to map vulnerable populations within Vancouver were described during the consultation process, these were not articulated in the IRG document; however, a general description of individuals at higher risk included *"seniors (particularly those homebound); small children; people who work or exercise outdoors; and those with health problems (addiction problems, breathing difficulties, heart conditions, and/or mental illness)"*. An older document from 2010 outlined initial steps in the development of the IRGs and included the identification of vulnerable populations and evaluation of potential impacts of extreme heat events [65]. This would involve partnership with researchers on community assessments, including mapping of heat impacts and vulnerable populations. A unique approach to community assessment would also involve the collection of neighbourhood level weather information by members of the homeless community.

Two alert trigger levels were outlined in the IRG document. A Special Weather Statement for Hot Weather from Environment Canada and Hot Weather News Release from Vancouver Coastal Health would be triggered: *"when temperatures ≥ 32^{o}C are expected for at least two consecutive days at Abbotsford, Hope or Pitt Meadows weather stations"*. A heat warning and heat health warning will be released by Environment Canada and VCH respectively when: *"the average of today's 14:05h temperature and tomorrow's forecasted high is ≥ 34℃ at Abbotsford or ≥ 29℃ at Vancouver"*.

While triggers are described, there is no reference to a deactivation protocol.

Various pre-season preparation and communication activities were also outlined. These included reconvening the Extreme Heat Planning Committee, increasing access to portable water fountains, and updating public messaging materials. In order to increase access to portable water fountains, the IRG includes pre-season identification of locations and installation, as well as updating and sharing water fountain mapping data (VanMap and Metro Van water apps, Google Maps). Updates to public messaging materials include cooling center hours, website/media materials and pre-authorized statements.

Heat mitigation and adaptation strategies were further described in the City of Vancouver Climate Change Adaptation Strategy[2]. This was developed as part of the ICLEI Adaptation Initiative using a similar approach to Surrey's Climate Adaptation Strategy.

[2] http://vancouver.ca/files/cov/Vancouver-Climate-Change-Adaptation-Strategy-2012-11-07.pdf

Emergency Response

The IRG outlines a comprehensive set of communication activities following trigger of an alert. Internal communications include convening the Extreme Heat Planning Committee and ensuring the CMO, Mayor and Council, and other stakeholders remain informed. Health/safety messaging and heat warnings would also be distributed to city staff.

External communications would be distributed through various media (websites, stakeholder communications, posters etc.) focusing on health/safety messaging and providing information on extended cooling center hours, as well as the location of cooling centers and water fountains. Messaging would also recommend that residents *"look out for each other and obtain assistance for people exhibiting signs of heat related illness when required"*.

Other community response activities included increasing access to drinking water, opening cooling centers, monitoring both outdoor spaces and city-owned single room occupancy hotels for those with symptoms of heat-related illness.

Actions were also recommended in the Climate Adaptation Strategy to improved emergency response to heat events. These included broadening the "Team Vancouver Emergency Response" volunteer urban search and rescue program to include heat alert patrols and other extreme event responses.

Long-term Strategies

No evaluation activities were described in the City of Vancouver IRG.

Several long-term actions were also described in the Climate Adaptation Strategy. In order to prevent water shortages during heat events, the City proposed actions to reduce per capita water consumption by 33% below 2006 levels, while also expanding public access to drinking water. The strategy also emphasized completion of Phase 2 actions, as well as expanded hot weather preparedness to include targeting green space and trees to hot areas, developing capacity for cooling refuges in civic facilities ad assessing the potential for cooling rooms in non-market housing. The strategy also recommended exploring options to transport vulnerable individuals to cooling refuges during extreme heat events.

Pitt Meadows

Planning and Preparation

The 2011 Hot Weather Response Plan[3] did not describe the planning process.

The Hot Weather Response Plan outlined an iterative process that would guide the City's response to extreme heat events [67]. The City partnered with Fraser Health Authority, which, with the BC Center for Disease Control, monitors temperature forecasts provided by Environment Canada and declares a heat advisory if an extreme heat event is predicted. This would trigger public messaging from the City for residents to "keep cool, keep wet (drink and splash) and check in on others".

[3] http://www.pittmeadows.bc.ca/assets/Emergency~Preparedness/Hot_Weather_Response_Plan.pdf

A heat alert would be declared by Fraser Health Authority the day before a forecasted extreme heat event, triggering municipal emergency response measures. The following criteria were set for triggering a heat alert:

> "A heat health emergency will be called 20 hours in advance for the entire Lower Mainland when the average of today's measured high at 14:00 hours and tomorrow's forecasted high equals or exceeds 34 degrees Celsius in Abbotsford."

No specific strategies were included in the protocol to prepare for extreme heat events (aside from developing the emergency response). Pitt Meadows provides recommendations on their public facing website for measures that can be taken by the public to prevent heat-related harms.

Emergency Response

Following the heat alert, the City would release public messaging encouraging the public to use air conditioned facilities within the community. The City would also establish cooling centres within public community centres. If necessary, emergency social services may also become involved.

Long-term Strategies

No evaluation or long-term strategies were described in the Pitt Meadows Hot Weather Response Plan.

North Shore Municipalities

Planning and Preparation

North Shore Emergency Management (NSEM) is an inter-municipal agency shared between the City of North Vancouver, District of North Vancouver and District of West Vancouver that provides emergency management services [68]. The 2016 North Shore Extreme Heat Initial Response Guideline (IRG) developed by the agency did not describe the planning process [69].

The North Shore Extreme Heat IRG is primarily focused on informing emergency response activities within the first 4-6 hours following alert of an extreme heat event. The protocol will be triggered on request of a medical health officer, likely following a Heat Health Warning from the health authority occurring "when the average of the day's 2pm temperature and the next day's high is greater than or equal to 34C at Abbotsford or 29C at YVR".

The IRG provides example recommendations for measures that can be taken by the public to prevent heat-related harms that can be displayed on partner municipality websites (District of North Vancouver website used as example). The document also provides a "toolkit" listing contacts, physical assets (fountains, spray parks, cooling locations, Fire Rescue Rehabilitation Trailer and Portable water wagon) and other resources.

Emergency Response

The response activities are divided into five categories: initial notification, impact assessment, life safety, information and de-activation.

Following initiation of the protocol, NSEM would provide initial notification to CAOs, corporate communications, function leads and members of the NSEM distribution list, with subsequent dissemination to other municipal departments. NSEM would also facilitate meetings to assess potential impacts and required resources, as well as review specific response functions.

Community messaging would provide information on recognizing heat distress and available municipal resources, as well as recommendations for residents to "look out for each other". Outdoor municipal workers would also monitor outdoor spaces for people experiencing heat-related illnesses. Notifications would also be sent out to media outlets and internal staff.

Various community response activities were described. As part of the impact assessment, record management systems would be monitored for increased volume of emergency calls regarding heat-related illness. The life safety category included organization of cooling centres and increased access to drinking water (portable water stations, existing fountains in libraries and community centres).

Long-term Strategies

NSEM included a brief description of evaluation activities in their IRG. Upon deactivation of the heat response protocol, individual municipal departments would review response activities, in addition to debriefing with Function Leads facilitated by NSEM.

No long-term strategies were described in the North Shore Extreme Heat IRG; however, several long-term actions were described in the City of North Vancouver's Climate Adaptation Plan[4] [70]. These included identifying populations vulnerable to climate change impacts and working to improve access to drinking water, cooling stations and temporary shelters. The Plan described actions to reduce urban heat island effects through targeted use of parks and trees, as well as changes to zoning and building bylaws.

Maple Ridge

Planning and Preparation

The 2016 Hot Weather Response Plan did not describe the planning process, nor did it discuss specific approaches to mapping vulnerable populations within the community; however, general vulnerable groups were identified, including socially isolated seniors, people with chronic and pre-existing illnesses, children and people who are marginally housed or homeless [71].

The plan outlines the municipal response using two levels of activation set by Environment Canada and Fraser Health Authority. Level 1 would involve Initial preparatory and preventive actions that would be taken following a Special Weather Statement by Environment Canada when temperatures ≥ 32^{o}C are expected for at least two consecutive days at Abbotsford, Hope or Pitt Meadows weather stations. Level 2 is triggered by the issuance of a Heat Health Warning by Fraser Health Authority when the average of the day's 14:05h temperature and subsequent day's forecasted high is ≥ 34℃ at Abbotsford or ≥ 29℃ at Vancouver involves more emergent responses and would involve more emergent actions to mitigate the potential health effects.

[4] http://www.cnv.org//-/media/city-of-north-vancouver/documents/climate-change-adaptation/city-of-north-vancouver-climate-change-adaptation-plan.PDF

Limited strategies were included in the protocol to prepare for extreme heat events (aside from developing the emergency response and the preparatory actions triggered at Level 1). Similar to other plans, an inventory of drinking water and cooling centre assets is included, as well as template public messaging statements. The document also describes the Metro Vancouver TapMap App, which provides information on the locations of public drinking fountains and taps (available on iTunes, the Google Play Store and at www.metrovancouver.org). Maple Ridge also provides recommendations on their public facing website for measures that can be taken by the public to prevent heat-related harms [72].

Emergency Response

The response activities in the hot weather protocol are divided by trigger level. Following a level 1 trigger (Special Weather Statement released by Environment Canada), Fraser Health Authority would issue a Hot Weather Statement distributed to HEMBC and subsequently local authorities. The Maple Ridge Emergency Program Coordinator would then notify relevant municipal and emergency staff of level 1 activation, with subsequent notification of community partners and residents. The municipal Information Officer may disseminate information and safety tips to the public through various media, including the City website, social media, and physical advertising. The management team would also review the potential impacts and consider the need for further advanced planning.

Upon activation of level 2, the EOC Director would consider convening the EOC. Several response measures would also be considered, including opening of cooling centres, extending hours of operation of public swims at community pools, distribution of bottled water and/or fans, transport of highly vulnerable individuals to cooling centres, and requesting local utility companies halt service cancellations while the heat health warning is in effect. Additionally, municipal staff and emergency responders would monitor for and assist residents showing signs of heat-related illness. Further public communications would also be initiated, including recommendations that residents “look out for each other”.

Although the specific criteria are not defined in the plan, deactivation processes and notification steps are described for both levels.

Long-term Strategies

Maple Ridge included a brief description of evaluation activities in their hot weather response plan. Upon deactivation of the heat response protocol, the municipality would review the effectiveness plan in coordination with Fraser Health Authority and make any revisions deemed necessary. This would occur following activation of the plan or annually if not activated during the season.

No long-term preventive measures were included in the plan.

Comparative Analysis of Municipal Heat Response Plans in BC

Relatively few municipalities in British Columbia were found to have formalized extreme heat response plans. Those municipalities with plans were located within the coastal ecoregion, specifically the lower mainland. No municipalities with heat plans were identified in Northern Health, Interior Health Authority or Island Health. A summary of the findings is displayed in Appendix A2.

Planning and Preparation

Description of the planning activities involved in the development of heat response plans and adaptation strategies varied considerably across jurisdictions in BC.

The heat response plan developed by the City of Vancouver was the only document to outline the steps involved in planning and development. The steps generally paralleled those recommended by the Health Canada HARS Best Practices, whereby the City identified a coordinating agency, engaged a broad array of stakeholders to assist with development, mobilized the community and implemented pre-heat season preparations.

In contrast to the heat plans, several municipalities (Surrey, North Vancouver and City of Vancouver) described the planning processes for development of their climate adaptation strategies. These followed the five-milestone approach recommended by the International Council for Local Environmental Initiatives (ICLEI): initiate, research, plan, implement, and monitor.

Most protocols described populations susceptible to heat-related illness; however, many of these documents included no description of vulnerability mapping used to targeting interventions. Vancouver outlined various vulnerability mapping initiatives in their initial heat response planning document, including an initiative whereby homeless individuals would collect neighbourhood-level weather data. During the consultations, participants from larger jurisdictions described partnerships with researchers to pursue vulnerability and heat mapping projects, including surface temperature readings. Many participants also referred to the heat mapping work published by the BCCDC. Several municipal participants described various sources that could be used to identify vulnerable individuals, including municipal programs or non-governmental organizations that keep lists of susceptible people within the community.

Although the terminology and use of weather stations differed slightly (Table 2), the meteorological triggers remained relatively constant among those municipalities with published heat response plans, relying solely on temperature forecasts (as opposed to metrics that include air pollution, humidity etc.). These triggers were predominantly based on those developed by the BCCDC, Environment Canada and several regional health authorities. The municipalities with heat plans were split between the jurisdictions of two health authority (Vancouver Coastal Health/Fraser Health Authority) that use the same heat trigger algorithms for all alerts (irrespective of the differences noted in the municipality-specific documents).

Table 1. Comparison of heat alert triggers among municipalities with heat response plans in British Columbia

Trigger Level	City of Vancouver	Pitt Meadows	North Shore Municipalities	Maple Ridge
Level 1	*Description:* **Special Weather Statement**	*No level 1 trigger described*	*Description:* **Special Weather Statement**	*Description:* **Special Weather Statement**
	Trigger: when temperatures ≥ 32°C are expected for at least two consecutive days at Abbotsford, Hope or Pitt Meadows weather stations		Trigger: when temperatures reach 32°C for at least two days at specific Lower Mainland weather stations	*Trigger:* when temperatures ≥ 32°C are expected for at least two consecutive days at Abbotsford, Hope or Pitt Meadows weather stations
Level 2	*Description:* **Heat**	*Description:* **Heat**	*Description:* **Heat**	*Description:* **Heat**

	Warning/Heat Health Warning	Alert	Health Warning	Health Warning
	Trigger: when the average of today's 14:05h temperature and tomorrow's forecasted high is ≥ 34℃ at Abbotsford or ≥ 29℃ at Vancouver	*Trigger:* when the average of today's measured high at 14:00 hours and tomorrow's forecasted high equals or exceeds 34 degrees Celsius in Abbotsford.	*Trigger:* when the average of the day's 2pm temperature and the next day's high is greater than or equal to 34^{o}C at Abbotsford or 29^{o}C at YVR	*Trigger:* when the average of today's 14:05h temperature and tomorrow's forecasted high is ≥ 34℃ at Abbotsford or ≥ 29℃ at Vancouver

Several municipalities implemented pre-season measures in preparation for extreme heat events. For example, Pitt Meadows, Maple Ridge, and the North Shore Municipalities included descriptions on their public websites of preventive measures that can be taken by the public to prevent heat-related harms. The City of Vancouver documented a comprehensive approach to pre-season preparations, including reconvening the Extreme Heat Planning Committee, increasing access to portable water fountains, and updating public messaging materials. The Vancouver, Maple Ridge, and North Shore plans also developed a detailed inventory of assets that could be accessed in response to a heat event, including portable water stations, cooling centers, and other emergency resources.

Emergency Response

Although Pitt Meadows included the basic components of a HARS, the City of Vancouver, Maple Ridge, and North Shore Emergency Management protocols were the most comprehensive, outlining an array of clear protocols related to communication (internal and public) and community response.

Internal mechanisms of communication were explicitly described in the City of Vancouver, Maple Ridge, and NSEM protocols, including initial notification of city staff and stakeholders, as well as provision of health and safety messaging.

External (public) communications formed the core components of all three protocols, although were described in varying levels of detail. Pitt Meadows provided the least detail, indicating only that the city would encourage community members to use cooling facilities. The NESM, Maple Ridge, and City of Vancouver IRGs provided considerable detail on the mechanisms and types of messaging, as well as target audiences, including vulnerable populations (residents of single room occupancy hotels etc.).

Community responses varied although focused on accessibility of cooling facilities and drinking water. Pitt Meadows' primary response involved opening cooling facilities (libraries, community centres etc.) and extending their hours, which was also included in the other municipal protocols. The City of Vancouver, Maple Ridge, and NSEM provided a greater array of responses, as outlined in Table 2.

Table 2. Comparison of community responses following trigger of heat alert among municipalities with published heat response plans

Community Response	City of Vancouver	North Shore Municipalities	Pitt Meadows*	Maple Ridge
Extend cooling center operating hours	√	√	√	√

Extend wading pool and spray park hours of operations	√			
Cooling rooms in single-room occupancy hotels	√			
Deploy portable water stations	√	√		
Provide public access to drinking water (fountains, washrooms) at libraries, community centers and Park Board Facilities	√	√		√
Work with non-profits to identify and implement additional actions (e.g. bottled water distribution)	√			√
Distribution of fans				√
Open additional arenas with an ice rink	√			
Activate volunteer groups to assist with cooling centers and drinking water stations	√			√
City staff (particularly outside workers/ seniors or socially isolated people) to monitor and respond to people suffering heat related illness	√	√		√
Monitor Emergency Call Volumes		√		
Request local utility companies halt service cancellations during extreme heat event				√

*Residents of Pitt Meadows, a smaller municipality, often use facilities of the larger and adjacent Maple Ridge.

Long-term Strategies

The plans developed by NSEM and Maple Ridge were the only documents (aside from an early plan developed by Vancouver) to include evaluation protocols, although they were limited to various debriefing

activities and general calls for evaluation. Although few municipalities published formal heat response plans, others described the need to advocate for evaluation and improvement of emergency planning around heat as part of their climate adaption strategies.

The majority of municipalities had either adopted or were in the process of developing climate change adaptation plans. The development of climate adaptation strategies was not mandatory; rather, the municipalities described the planning process as aligned with their broader goals and mandates. The development of these strategies also align with the commitments to address the impacts of climate change outlined in the BC Climate Action Charter, which was signed by the Province of British Columbia, the Union of BC Municipalities and 183 local governments in 2013 [73].

All three municipalities with climate adaptation strategies were voluntary members of the Building Adaptive & Resilient Communities (BARC) Program and followed the five milestone ICLEI approach. The Guide and Workbook for Municipal Climate Adaptation[74][5] describes an outline of the ICLEI planning process and references extreme heat as an example area for adaptation and mitigation; however, all three strategies described heat mitigation strategies. These plans were therefore the primary platforms for publication of long-term, extreme heat mitigation and adaptation strategies.

Long-term initiatives varied among municipalities and included research, updates to emergency protocols, changes to municipal policies and bylaws, and infrastructure improvements. Climate change adaptation policies described the need for research in order to better characterize vulnerable populations within communities. This was supported by activities described during municipal consultations, including vulnerability and heat mapping initiatives.

Each climate adaptation strategy also included reference to the need adapt existing emergency protocols to include climate related emergencies, such as extreme heat.

Changes to the built environment were also emphasized in these strategies, including alterations to zoning/bylaws and improved infrastructure. Infrastructure improvements included increased green space (green roofs, tree planting, increased canopy coverage, parks), installation of water fountains, alternative paving surfaces and the use of high albedo surfaces for buildings and pavement.

Conclusion

Limitations

There were considerable limitations to the jurisdictional scan and associated consultation process. Although we attempted to recruit a diverse sample of participants from municipalities with and without heat response plans, our sample was not representative of all municipalities and health authorities in BC. Also, not all municipalities invited to take part responded to our invitations. Nevertheless, we did interview a wide variety of municipalities and HAs representing an array of population sizes and climates. The semi-structured interview process was also relatively informal and may have been strengthened through more rigorous data collection methodologies. Finally, the review of municipal heat plans was limited to those that were available online or provided to us through internal channels. Our review may therefore have missed internal documents that were not identified through this process.

[5] http://www.icleicanada.org/images/icleicanada/pdfs/GuideWorkbookInfoAnnexes_WebsiteCombo.pdf

Current Gaps

Through this jurisdictional scan it became evident that limited extreme heat response planning has occurred among BC municipalities and health authorities. Only six municipalities, all of which are located in the coastal ecoregion, were reported to have formalized heat response plans, three of which were reviewed.

Although consultations suggested this may be the result of the low perception of risk posed by heat and subsequent lack of prioritization, participants also described a lack of local data for risk assessments and absence of contextually appropriate and accessible best practice guidelines.

Next Steps

In partnership with Environment Canada, Health Canada, and the BC health authorities, the BC Center for Disease Control may consider the following next steps:

- Develop a brief version of best practices that prioritizes components of HARS and outlines their implementation based on availability of municipal and health authority resources.
- Given that the Metro Vancouver HARS was simple, data-driven and collaborative, the current version and its implementation by many Metro Vancouver municipalities could be used to inform the setting of HARS triggers, best heat responses, and municipal heat response planning throughout BC.
- Explore the benefits and disadvantages of incorporating heat response plans into pre-existing all-hazards plans.
- Support development of a data-driven approach to assessing vulnerability at regional and local levels with subsequent validation. This could be extended to support all-hazards planning.
- Explore the availability of local health data and support local risk assessment activities to better characterize municipal vulnerabilities to extreme heat and inform risk prioritization. Continue to build partnerships between health authorities and municipalities to develop effective HARS.
- Develop guidance for the creation of an inventory of heat-related response assets by BC municipalities.
- Continue to provide accessible resources for heat-related public messaging
- Provide guidance and messaging for management of concurrent emergencies, such as extreme heat and poor air quality
- Consider development of protocols that may be used by multiple municipalities, possibly at the regional or provincial level

References

1. Henderson SB, Wan V, Kosatsky T: **Differences in heat-related mortality across four ecological regions with diverse urban, rural, and remote populations in British Columbia, Canada**. *Health Place* 2013, **23**:48-53.

2. Parry M, Canziani O, Palutikof J, van der Linden P, Hanson C: **Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change**. In.; 2007.

3. Organization WH: **Improving Public Health Responses to Extreme Weather Heat-Waves EuroHEAT.** . In. Copenhagen:WHO; 2009.

4. Kharin VV, Zwiers FW, Zhang X, Hegerl GC: **Changes in temperature and precipitation extremes in the IPCC ensemble of global coupled model simulations**. *Journal of Climate* 2007, **20**(8):1419-1444.

5. Hoffmann B, Hertel S, Boes T, Weiland D, Jöckel K-H: **Increased Cause-Specific Mortality Associated with 2003 Heat Wave in Essen, Germany**. *Journal of Toxicology & Environmental Health: Part A* 2008, **71**(11/12):759-765.

6. Cheng CS, Campbell M, Li Q, Li G, Auld H, Day N, Pengelly D, Gingrich S, Klaassen J, MacIver D: **Differential and combined impacts of extreme temperatures and air pollution on human mortality in south–central Canada. Part II: future estimates**. *Air Quality, Atmosphere & Health* 2008, **1**(4):223-235.

7. Meadows CoP: **Hot Weather Response Plan**. In.; 2011.

8. Montreal Co: **Climate Change Adaptation Plan for the Agglomeration of Montreal 2015-2020**. In. Montreal, QC; 2015.

9. Mathewson A: **Building Resilience to Climate Change: Surrey's Climate Adaptation Strategy**. In. Surey, BC; 2014.

10. Toronto Co: **Resilient City: Preparing for Extreme Weather Events**. In. Toronto, ON; 2013.

11. Damiano H, Umberger M, Monitz G, Friedman J, Hariri M, Tehranifar R, Grassi C, Lindsey E: **NYC's Risk Landscape: A Guide to Hazard Mitigation**. In. New York, NY; 2014.

12. De Carolis L: **The Urban Heat Island Effect in Windsor, ON: An Assessment of Vulnerability and Mitigation Strategies**. In. Windsor, ON; 2012.

13. Kosatsky T, Henderson SB, Pollock SL: **Shifts in mortality during a hot weather event in Vancouver, British Columbia: Rapid assessment with case-only analysis**. *Am J Public Health* 2012, **102**(12):2367-2371.

14. Ho HC, Knudby A, Walker BB, Henderson SB: **Delineation of Spatial Variability in the Temperature-Mortality Relationship on Extremely Hot Days in Greater Vancouver, Canada**. *Environ Health Perspect* 2017, **125**(1):66-75.

15. Wheeler K, Lane K, Walters S, Matte T: **Heat illness and deaths - new york city, 2000-2011**. *MMWR: Morbidity & Mortality Weekly Report* 2013, **62**(31):617-621.

16. Kosatsky T, Henry B, N K: **How Toronto and Montreal (Canada) respond to heat**. In: *Extreme weather events and public health responses.* Edited by Kirch W, Menne B, Bertollini R. New York: Springer Verlag; 2005: 167-171.

17. Agency. USEP: **Heat island effect. U.S. Environmental Protection Agency.** In.; 2005.

18. Analitis A, Katsouyanni K: **Short-term effects of temperature and air pollution on health: the EuroHEAT analysis. In: Matthies F, Menne B, eds. Preparedness and response to heatwaves in Europe, from evidence to action. Public health response to extreme weather events.** . In. Copenhagen, WHO Regional Office for Europe. .

19. Kosatsky T: **Short-term effects of temperature and air pollution on health: a review of the evidence. In: Matthies F, Menne B, eds. Preparedness and response to heat-waves in Europe, from evidence to action**. In. Copenhagen, WHO Regional Office for Europe.

20. Rizwan AM, Dennis LYC, Liu C: **A review on the generation, determination and mitigation of Urban Heat Island**. *Journal of Environmental Sciences* 2008, **20**(1):120-128.

21. Tan J, Zheng Y, Tang X, Guo C, Li L, Song G, Zhen X, Yuan D, Kalkstein AJ, Li F: **The urban heat island and its impact on heat waves and human health in Shanghai**. *Int J Biometeorol* 2010, **54**(1):75-84.

22. Smargiassi A, Goldberg MS, Plante C, Fournier M, Baudouin Y, Kosatsky T: **Variation of daily warm season mortality as a function of micro-urban heat islands**. *J Epidemiol Community Health* 2009, **63**(8):659-664.

23. Basu R: **High ambient temperature and mortality: a review of epidemiologic studies from 2001 to 2008**. *Environ Health* 2009, **8**:40-52.

24. Weiss M, Milman B, Rosen B, Eisenstein Z, Zimlichman R: **Analysis of the diminished skin perfusion in elderly people by laser Doppler flowmetry**. *Age Ageing* 1992, **21**(4):237-241.

25. Worfolk JB: **Heat waves: Their impact on the health of elders**. *Geriatr Nurs* 2000, **21**(2):70-77.

26. Schifano P, Cappai G, De Sario M, Michelozzi P, Marino C, Bargagli AM, Perucci CA: **Susceptibility to heat wave-related mortality: a follow-up study of a cohort of elderly in Rome**. *Environ Health* 2009, **8**:50-50.

27. Robine JM, Michel JP, Herrmann FR: **Excess male mortality and age-specific mortality trajectories under different mortality conditions: A lesson from the heat wave of summer 2003**. *Mech Ageing Dev* 2012.

28. Centers for Disease Control: **Heat--related illnesses and deaths-United States, 1994-1995**. *MMWR Morb Mortal Wkly Rep* 1995, **44**(25):465-468.

29. Wang XY, Guo Y, FitzGerald G, Aitken P, Tippett V, Chen D, Wang X, Tong S: **The impacts of heatwaves on mortality differ with different study periods: a multi-city time series investigation**. *PLoS ONE* 2015, **10**(7):e0134233.

30. Fouillet A, Rey G, Laurent F, Pavillon G, Bellec S, Guihenneuc-Jouyaux C, Clavel J, Jougla E, Hemon D: **Excess mortality related to the August 2003 heat wave in France**. *Int Arch Occup Environ Health* 2006, **80**(1):16-24.

31. Michelozzi P, De' Donato F, Accetta G, Forastiere F, D'Ovidio M, Perucci C, Kalkstein L: **Impact of heat waves on mortality—Rome, Italy, June-August 2003**. *JAMA* 2004, **291**(21):2537-2538.

32. Naughton MP, Henderson A, Mirabelli MC, Kaiser R, Wilhelm JL, Kieszak SM, Rubin CH, McGeehin MA: **Heat-related mortality during a 1999 heat wave in Chicago**. *Am J Prev Med* 2002, **22**(4):221-227.

33. Poumadere M, Mays C, Le Mer S, Blong R: **The 2003 heat wave in France: dangerous climate change here and now**. *Risk Anal* 2005, **25**(6):1483-1494.

34. Basu R, Ostro BD: **A multicounty analysis identifying the populations vulnerable to mortality associated with high ambient temperature in California**. *Am J Epidemiol* 2008, **168**(6):632-637.

35. Kovats RS, Kristie LE: **Heatwaves and public health in Europe**. *Eur J Public Health* 2006, **16**(6):592-599.

36. Rey G, Fouillet A, Bessemoulin P, Frayssinet P, Dufour A, Jougla E, Hémon D: **Heat exposure and socio-economic vulnerability as synergistic factors in heat-wave-related mortality**. *Eur J Epidemiol* 2009, **24**(9):495-502.

37. Semenza JC, Rubin CH, Falter KH, Selanikio JD, Flanders WD, Howe HL, Wilhelm JL: **Heat-related deaths during the July 1995 heat wave in Chicago**. *N Engl J Med* 1996, **335**(2):84-90.

38. Foroni M, Salvioli G, Rielli R, Goldoni CA, Orlandi G, Zauli Sajani S, Guerzoni A, Maccaferri C, Daya G, Mussi C: **A retrospective study on heat-related mortality in an elderly population during the 2003 heat wave in Modena, Italy: the Argento Project**. *J Gerontol A Biol Sci Med Sci* 2007, **62**(6):647-651.

39. Bytomski JR, Squire DL: **Heat illness in children**. *Curr Sports Med Rep* 2003, **2**(6):320-324.

40. McLaren C, Null J, Quinn J: **Heat stress from enclosed vehicles: moderate ambient temperatures cause significant temperature rise in enclosed vehicles**. *Pediatrics* 2005, **116**(1):e109-e112.

41. Krous HF, Nadeau JM, Fukumoto RI, Blackbourne BD, Byard RW: **Environmental hyperthermic infant and early childhood death: circumstances, pathologic changes, and manner of death**. *Am J Forensic Med Pathol* 2001, **22**(4):374-382.

42. Bell ML, O'Neill MS, Ranjit N, Borja-Aburto VH, Cifuentes LA, Gouveia NC: **Vulnerability to heat-related mortality in Latin America: a case-crossover study in Sao Paulo, Brazil, Santiago, Chile and Mexico City, Mexico**. *Int J Epidemiol* 2008, **37**(4):796-804.

43. Borrell C, Marí-Dell'Olmo M, Rodríguez-Sanz M, Garcia-Olalla P, Caylà JA, Benach J, Muntaner C: **Socioeconomic position and excess mortality during the heat wave of 2003 in Barcelona**. *Eur J Epidemiol* 2006, **21**(9):633-640.

44. Gouveia N, Hajat S, Armstrong B: **Socioeconomic differentials in the temperature-mortality relationship in São Paulo, Brazil**. *Int J Epidemiol* 2003, **32**(3):390-397.

45. Stafoggia M, Forastiere F, Agostini D, Biggeri A, Bisanti L, Cadum E, Caranci N, deDonato F, De Lisio S, De Maria M *et al*: **Vulnerability to heat-related mortality. A multicity, population-based, case-crossover analysis**. *Epidemiol* 2006, **17**(3):315-323.

46. Kovats RS, Hajat S: **Heat stress and public health: A critical review**. *Annu Rev Public Health* 2008, **29**:41-55.

47. Klinenberg E: **Heat wave: A social autopsy of disaster in Chicago**. Chicago, IL: University of Chicago Press; 2002.

48. Vanakoski J, Seppälä T: **Heat Exposure and Drugs**. *Clin Pharmacokinet* 1998, **34**(4):311-322.

49. Michenot F, Sommet A, Bagheri H, Lapeyre-Mestre M, Montastruc JL: **Adverse drug reactions in patients older than 70 years during the heat wave occurred in France in summer 2003: A study from the French PharmacoVigilance Database**. *Pharmacoepidemiol Drug Saf* 2006, **15**(10):735-740.

50. Cusack L, de Crespigny C, Athanasos P: **Heatwaves and their impact on people with alcohol, drug and mental health conditions: a discussion paper on clinical practice considerations**. *J Adv Nurs* 2011, **67**(4):915-922.

51. Health Canada, Water Air and Climate Change Bureau - Healthy Environments and Consumer Safety Branch: **Heat alert and response systems to protect health: Best practices guidebook**. In. Otttawa, ON: Health Canada; 2012.

52. Health Canada: **Communicating the Health Risks of Extreme Heat Events**. In. Ottawa, ON; 2011.

53. Austin S, Biesbroek R, Berrang-Ford L, Ford J, Parker S, Fleury M: **Public health adaptation to climate change in OECD countries**. *Int J Environ Res Public Health* 2016, **13**(9):889.

54. Slattery J: **17 temperature records broken across B.C. on Thursday**. In: *Global News.* Vancouver, BC; 2016.

55. Lindsay B: **Scorching Sunday sees 16 temperature records set across B.C.** In: *Vancouver Sun,.* Vancouver, BC; 2016.

56. Switzer J: **Toronto breaks weather record as temperatures top 36°C**. In: *Globe and Mail.* Toronto, ON; 2016.

57. Ministry of Environment: **Indicators of Climate Change for British Columbia**. In. Victoria, BC: Government of British Columbia; 2015.

58. **2011 Census of Canada: Topic-based tabulations** [http://www12.statcan.gc.ca/census-recensement/2011/dp-pd/tbt-tt/Rp-eng.cfm?LANG=E&APATH=3&DETAIL=0&DIM=0&FL=A&FREE=0&GC=0&GID=0&GK=0&GRP=1&PID=102011&PRID=10&PTYPE=101955&S=0&SHOWALL=0&SUB=0&Temporal=2011&THEME=88&VID=0&VNAMEE=&VNAMEF=]

59. **A Portrait of Seniors in Canada** [http://www.statcan.gc.ca/pub/89-519-x/2006001/4122092-eng.htm]

60. BC Healthy Built Environment Council: **Public Health Guide to Planning with Local Governments**. In. Vancouver, BC; 2015.

61. Columbia GoB: **Public Health Act**. In. Victoria, BC: Queen's Printer; 2008.

62. Henderson SB, Kosatsky T: **A data-driven approach to setting trigger temperatures for heat health emergencies**. *Can J Public Health* 2012, **103**(3):227-230.

63. Surrey: **Climate Adaptation Strategy**. In. Surrey, BC: City of Surrey; 2011.

64. Surrey: **Surrey/White Rock Extreme Weather Response 2015/2016**. In. Surrey, BC: City of Surrey; 2015.

65. Vancouver Co: **Review of Preparedness and Response Services During Extreme Weather**. In.; 2010.

66. Vancouver: **Extreme Heat Initial Response Guideline**. In. Vancouver, BC: Office of Emergency Management 2016.

67. Pitt Meadows: **Hot Weather Response Plan**. In. Pitt Meadows, BC; 2011.

68. **About North Shore Emergency Management** [http://nsem.info/about-nsem]

69. Management NSE: **North Shore Extreme Heat Initial Response Guideline (IRG)**. In.; 2016.

70. Vancouver CoN: **City of North Vancouver Climate Change Adaptation Plan**. In.; 2013.

71. Cullen P: **Hot Weather Response Plan**. In. Maple Ridge, BC; 2016.

72. **Extreme Heat** [http://www.mapleridge.ca/1229/Extreme-Heat]

73. British Columbia Ministry of Community SaCDaRfT: **THE BRITISH COLUMBIA CLIMATE ACTION CHARTER**. In. Victoria, BC; 2013.

74. ICLEI Local Governments for Sustainability: **Changing Climate, Changing Communities: Guide and Workbook for Municipal Climate Adaptation**. In.; 2010.

Appendix

A1. Review of HARS Components from Health Canada Best Practices Guide

PLANNING AND PREPARATION

Community mobilization and engagement was identified as a core component of HARS. It is recommended that municipalities undertake stakeholder engagement, including community planners, environmental/sustainability officers, and emergency management officials, as well as officials from Environment Canada and the regional Health Authorities. Community partners may include fire officials, the Canadian Red Cross, Meals on Wheels, staff at seniors' residences, as well as staff that work with the homeless.

It is recommended that municipalities perform a **vulnerability assessment**, identifying those within the community who may be most susceptible to heat-related illnesses. Some larger municipalities are resourced to fund heat studies of where vulnerable populations and areas of the municipalities are. However, if the resources for mapping are not available, community groups and Health Authorities may be able to fill in gaps.

Once communities have engaged stakeholders and assessed vulnerabilities, a **heat alert activation/deactivation protocol** should be established. A variety of techniques have been used to generate trigger points for calling and deactivating heat alerts. In Canada, all are based on weather-mortality relationships. Some jurisdictions use complex, others simpler meteorological data. Some are based on the analysis of mortality as a function of historical weather records, while others use historical weather forecasts, to take precision of forecast data into account. Finally, a set of weather triggers is established and based on Environment Canada forecasts, heat alerts are called and deactivated. Some jurisdictions add emergency respondent call outs and recent numbers of deaths to weather forecast information as triggers for heat alerts.

EMERGENCY RESPONSE

In addition to pre-season communications strategies described previously, municipalities should plan for **communications following the declaration of a heat alert**. Health Canada recommends that, once an alert is called, the lead agency should send out an alert via local media, email, websites, and/or social media, as well as interagency communications and community stakeholders. Partners could then reach out and monitor vulnerable populations including the homeless, the elderly and outdoor workers. In

addition to communication, examples of outreach assistance strategies could include ensuring access to cooling shelters and drinking water, as well as surveillance of heat-related morbidity/mortality.

LONG-TERM STRATEGIES

Health Canada recommends that municipalities develop the capacity for formal evaluation following deactivation of the protocol in the event of an extreme heat event. These results should then be shared with stakeholders in order to improve planning for future events. Additionally, Health Canada also recommends long-term planning to strengthen resiliency in communities, minimize the urban heat island effect, and reduce greenhouse gas emissions.

A2. Comparison of BC Municipal HARS using Health Canada framework

Comparison and evaluation of the heat alert and response systems (HARS) and adaption in 4 Canadian municipalities

Activity	Surrey	Vancouver	Pitt Meadows	North Shore	Maple Ridge
Community mobilization and engagement					
Identifying a principal coordinating agency	√	√	√	√	√
Engage broad stakeholders	√	√		√	
Organize and develop HARS		√	√	√	√
Mobilize Community		√		√	
Lead pre-heat season preparations		√		√	√
Alert protocol					
Establish formal alert protocol		√	√	√	√
Reflect local weather conditions		√	√	√	√
Reflect heat-health vulnerabilities	√	√	√	√	√
Include activation protocol			√	√	√
Include deactivation protocol				√	√
Community response plan					
Establish formal community response plan		√	√	√	√

Included measures tailored to the needs of vulnerable populations		√	√	√	√
Stakeholder driven		√		√	√
Communications plan					
Establish formal communications plan				√	√
Develop pre-season education and awareness campaign					
Identify and plan to address contradictory messages					
Included audience-specific health-health messages and outreach strategies		Unclear		√	
Evaluation plan					
Establish formal evaluation plan				√	√
Implement real-time health surveillance					
Hold end-of-season evaluation					
Preventive Action – Reducing Urban Heat					
Investigate the urban heat island effect	√	√			
Plan long-term (eg. Implement urban heat island mitigation measure)	√	√		(North Van has climate adaptation plan)	