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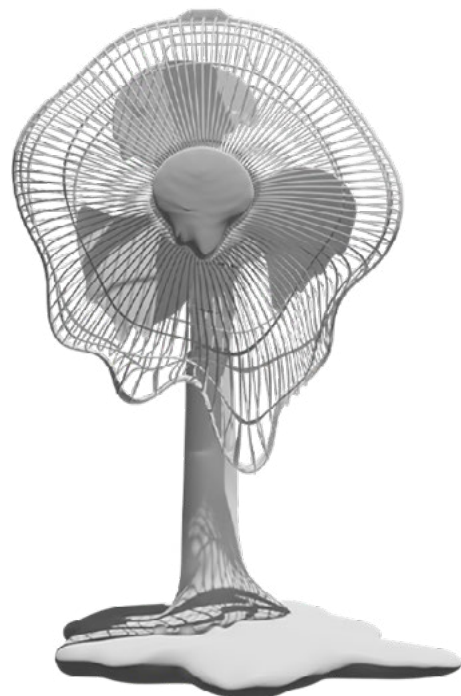
Technical Report



# British Columbia heatwave

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2021/2022



Interconnected

Disaster

Risks

# Table of Contents

<b>1. Introduction</b>	<b>03</b>
<b>2. Impacts</b>	<b>03</b>
2.1 Loss of life	03
2.2 Health impacts	04
2.3 Ecosystem damage and biodiversity loss	05
2.4 Livelihood loss	06
2.5 Infrastructure damage	06
<b>3. Drivers</b>	<b>07</b>
3.1 Heat dome	07
3.2 Unpreparedness	09
3.3 Low heat risk perception	09
<b>4. Root causes</b>	<b>10</b>
4.1 Human-induced greenhouse gas emissions	10
4.2 Insufficient risk governance	10
<b>5. Big picture</b>	<b>11</b>
<b>6. Solutions</b>	<b>12</b>
6.1 Innovate	12
6.2 Strengthen governance	13
6.3 Boost early warning	14
6.4 Work together	14
6.5 Conclusion	14
<b>7. References</b>	<b>15</b>

# 1. Introduction

In the summer of 2021, western Canada suffered an intense heatwave as a heat dome settled over the Pacific Northwest, affecting portions of Oregon and Washington, USA. On 29 June, the town of Lytton, Province of British Columbia, Canada set an all-time high temperature in the country at 49.6°C before being destroyed by a wildfire the next day (Philip and others, 2021). The heatwave quickly became one of the deadliest weather events in Canadian history, with more than 570 deaths during the hottest week (Silberner, 2021; British Columbia Coroners Service (BCCS), 2022).

The extreme heat was also closely linked to wildfire risks (Philip and others, 2021). Because of the smoke generated by the fires, households were advised to keep their windows closed, which may have reinforced the intensity of the indoor heat, considering that only 34 per cent of homes in British Columbia have some form of air conditioning (BBC, 2021; Philip and others, 2021; Henderson and others, 2022). Additionally, as these fires destroyed vegetation and scorched the ground, susceptibility to landslides and floods increased as damaged roots could not stabilize soil. The charred ground became impermeable and unable to soak up rainwater. The effects were devastating when, on 13 November, a rainstorm dropped around 250mm of rain in 48 hours over central British Columbia, with highways and bridges washed away. Landslides buried cars, and damaged rail lines, oil pipelines ceased operations for fear of a spill, the port of Vancouver closed with no way to transport goods, and over 12,000 people were displaced from their homes (Austen, 2021; Thompson, 2021).

## 2. Impacts

### 2.1 Loss of life

According to the BCCS, there were 619 heat-related deaths during the heatwave, of which 576 occurred during the hottest week (25 June – 1 July (BCCS, 2022)). Over 90 per cent of people who died were over 60, only around 7 per cent of people who died had access to air conditioning, and only 24 per cent of residences used a fan (BCCS, 2022). Approximately 30 per cent of decedents lived in communities that were socially or materially deprived, meaning living in neighbourhoods with relatively low socioeconomic status, without sufficient green surrounding areas or further from large bodies of water (Cecco, 2021; Henderson and others, 2021; Kulkarni, 2021; Silberner, 2021). Overall, British Columbia had 740 more deaths than expected for a typical summer (Bratu and others, 2022; Henderson and others, 2021). Importantly, this number is likely an underestimate as many deaths are difficult to attribute to heat, either because they go unreported or because the heat exacerbated an existing health issue listed as the primary cause of death (Frank, 2021).

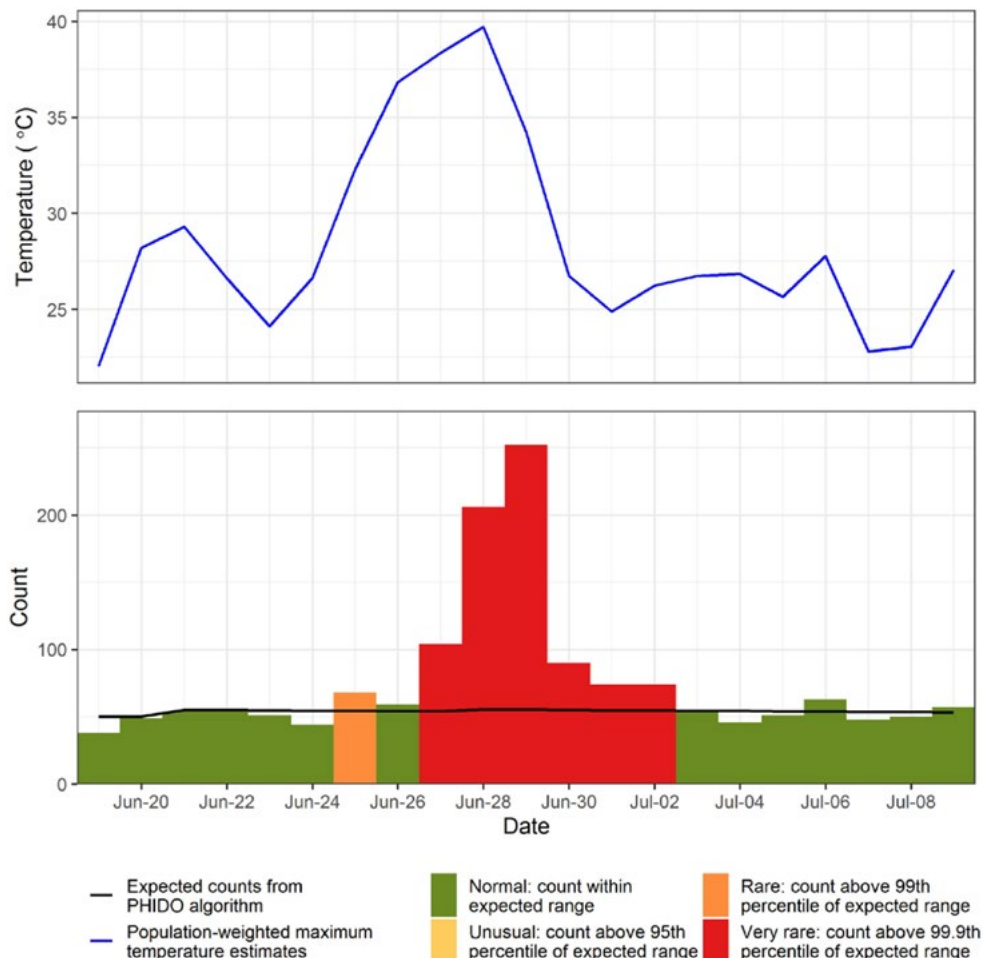


Figure 1: Analysis of community deaths (Henderson and others, 2022).

## 2.2 Health impacts

Heatwaves have multiple implications for public health as they are associated with sudden increases in mortality rates and exacerbate pre-morbidity conditions in cardiovascular diseases (Bratu and others, 2022). Thus, during the hottest days in British Columbia, for every death, about ten or more people suffered from a heat-related illness such as heatstroke, dehydration, exhaustion, fever, loss of consciousness, respiratory afflictions, and even life-altering injuries (LaFortune and others, 2021; Silberner, 2021). This was exacerbated by the ongoing COVID-19 pandemic, as many residents were uncomfortable going to cooling stations for fear of contracting the virus (LaFortune and others, 2021). Additionally, the intense solar radiation and trapped air mass due to the heat-dome effect led to increasing ozone concentrations at the ground level, deteriorating the air quality in the region because of its toxicity (Henderson and others, 2022).

Heatwaves are known to increase mental health problems, such as increased irritability, anxiety or symptoms of depression. The June 2021 heatwave increased anxiety, specifically climate anxiety, among the population of British Columbia (Bratu and others, 2022). Additionally, heat and relative humidity significantly correlate with suicide (Florido Ngu and others, 2021). Heat-related deaths were higher in populations with mental health conditions such as schizophrenia, because these conditions or their medications (such as antidepressants or antipsychotics) affect how bodies regulate temperature (American Psychiatric Association, 2021).



*People rest at the Oregon Convention Center cooling station in Oregon, Portland on June 28, 2021, as a heatwave moves over much of the United States. (Image credit: Kathryn Elssesser/AFP)*

## 2.3 Ecosystem damage and biodiversity loss

The extreme heat also had severe repercussions for marine life. Due to the duration of the extreme temperatures, the heatwave caused countless deaths of mussels, oysters, clams, shellfish, crabs and snails in the Salish Sea. It was estimated that about 1 billion small marine creatures died along more than 6,400 km of coastline (Migdal, 2021; Westfall and Coletta, 2021). The loss of many individuals, especially bivalve molluscs, may negatively impact the ecosystem due to their role in purifying water and their place in the food chain (Westfall and Coletta, 2021).

The scorching weather affected the balanced ecological conditions of freshwater ecosystems too. High temperatures and drought conditions reduced the water flow in rivers, while the heat increased the water temperature, leading to a decrease in dissolved oxygen levels (Alam, 2021). For instance, the flow of the Fraser River, the largest salmon river in British Columbia, was reduced by 27 per cent and between 1°C and 3°C warmer than the usual historic mean temperature, which affected the salmon's spawning and ultimately led to high fish mortality (Government of Canada, 2021; Rasmussen, 2021). Since salmon stay in water between 12°C and 18°C and can only stand the heat for a short period, the 24°C reached in the water during the hottest days in British Columbia was lethal for the species (Alam, 2021). Since salmon are a keystone species, their loss could trigger problems for the predators, such as bears and eagles, that depend on them for nutrients (Bugas, 2020). Additionally, there could be more social losses, as the salmon run generates significant revenues from tourism and is strongly tied to the cultural heritage and subsistence of many First Nations peoples (Reid, 2022).

Furthermore, the British Columbia heatwave was linked to severe wildfires. Among the more than 3,000 wildfires that occurred during the record-breaking heat, one spread over Sparks Lake (north-east of Vancouver), burning around 2,300 ha of forest (Isai and others, 2021). Though wildfires are a natural occurrence in the region, their increasing frequency and severity make response and resilience much more difficult.

## 2.4 Livelihood loss

The hot spell also ruined yields and affected business. Between 15 and 20 per cent of lettuce crops were lost (Rasmussen, 2021), and up to 75 per cent of some fruits were severely damaged (Gomez, 2021). Mainly, the heatwave damaged raspberry crops (~75 per cent), cherry crops (50-70 per cent), and blueberry crops (10-30 per cent), as well as apples, apricots and other stone fruits to a lesser degree (Gomez, 2021). These losses significantly impacted many farmers' incomes and cash flow since they wait an entire year for this harvest (Rasmussen, 2021; Gomez, 2021). The financial impact of the heatwave in 2021 on farmers' livelihoods was more critical because, for the third consecutive year, crops were damaged by extreme weather events, starting with the torrential rain in 2019 and followed by a cold spell in 2020 (Gomez, 2021). Similarly, the heatwave was devastating for shellfish farmers. The hot temperatures killed 80 per cent of the oysters in the coastal farms, forcing many businesses to close as the production cycles are two or three years long (Westfall and Coletta, 2021).

## 2.5 Infrastructure damage

Among the most notorious infrastructure damage was the destruction of 90 per cent of the 250-person village of Lytton, which cost an estimated US\$150 million (Aon, 2021). The heatwave also set a peak electricity demand record at 8,500 MW from BC Hydro and may have been responsible for the outage of several transformers, which disrupted service to hundreds of customers (Herrera, 2021; Nesbit, 2021). The hot season in 2021 caused rapid and extensive snow melting in the region, followed by floods in several parts of British Columbia. These, combined with wildfire and the heatwave, affected critical infrastructures such as roads, railways, schools and power networks, as well as causing power outages (Philip and others, 2021).

### 3. Drivers

#### 3.1 Heat dome

A heat dome occurs when an area of high pressure traps hot air underneath it, increasing temperatures until it dissipates. Warmed by solar radiation, the air expands into the atmosphere as the area of high pressure pushes the warm air down. As the air is pushed down, it compresses and heats up, trapping even more heat underneath. Moreover, high-pressure domes keep clouds and wind at bay, increasing the heat even more (Culbertson, 2021).

This particular heat dome formed as the polar vortex split into two parts, with one of the centres extending from the Bering Sea southward along the west coast of North America (Overland, 2021). As cold air from the Arctic moved south, this pushed warm air from the tropics north, weakening the jet stream (Philip and others, 2021). This weakened jet stream, normally flowing parallel with the northern latitudes, became “wavy” and formed an atmospheric pressure ridge called an “omega block”, which blocked the flow of air from west to east and kept the area of high pressure trapped above the Pacific Northwest (Overland, 2021; Philip and others, 2021).

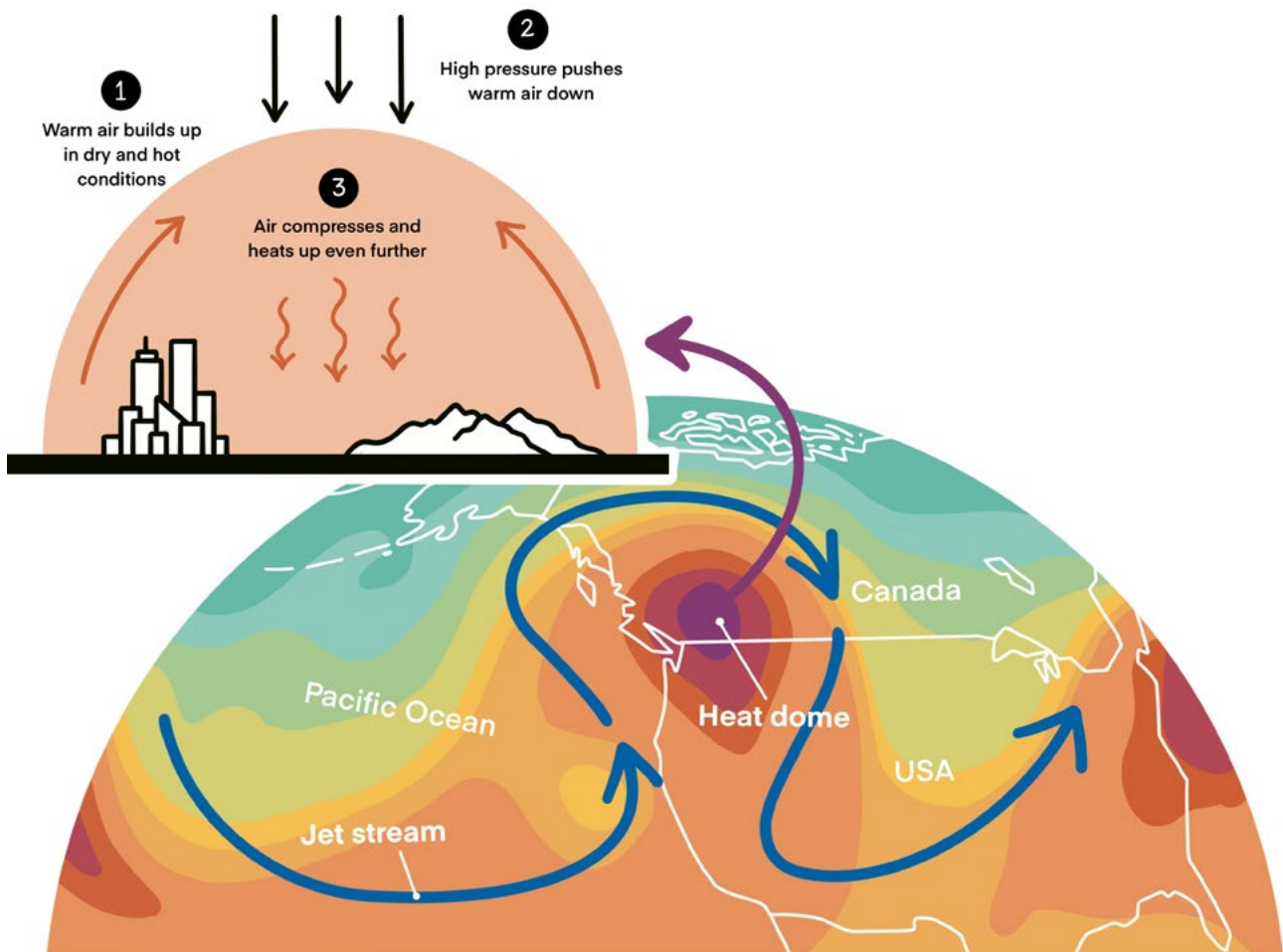


Figure 2: How a heat dome forms, adapted from AFP, 2021 and Hills and others, 2021

## Atmospheric river

The heat dome prevented the hot air from escaping and kept it circulating internally while the high atmospheric pressure compressed the air, thus heating it adiabatically and increasingly. Additionally, the heat dome prevented the formation of clouds and deflected them at its periphery. In this way, direct solar radiation intensifies the heat inside the dome and the average ground temperature. These combined effects increased the evaporation, contributing to the already humid air from the Pacific Ocean, forming an “atmospheric river.” As a result, the air had a high-water vapour content, which created a positive feedback loop that correlated with high temperatures on the hottest days (26-30 June) (Mo and others, 2022).

## Drought

Another element of this event was the drought conditions that preceded the hot days. According to the satellite soil moisture measurements of the European Space Agency provided by the Copernicus service, the soil moisture and precipitation in Western North America were below normal levels from April until June. Consequently, the regional evapotranspiration rate decreased, and its latent cooling led to a substantial temperature amplification during the heatwave (Philip and others, 2021). Drought conditions in British Columbia rank on a scale from 0 to 5, and over ten watersheds quickly reached drought levels 4 and 5 during the summer, meaning adverse socioeconomic and environmental impacts were certain (Schisler, 2021).



*A scorching heatwave in usually cool Canada is threatening to kill off one million tulips in Ottawa, Ontario only days after planting for the annual spring Canadian Tulip Festival on May 7, 2013. (Image credit: Michel Comte/AFP)*



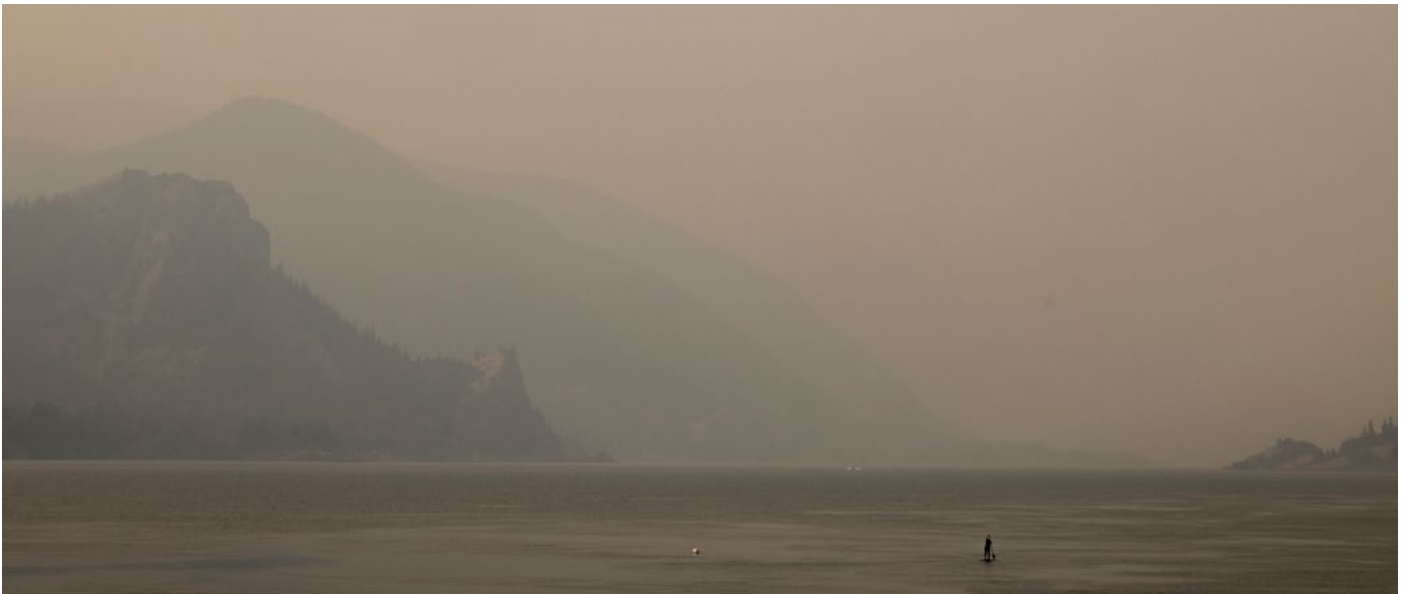
## 3.2 Unpreparedness

The silent, invisible, chronic and pervasive heat hazard surprised an unprepared provincial government of British Columbia, which was criticized for not providing an adequate warning. While the heat emergency was announced internally among every regional health authority, the public was not warned about the extreme heat emergency status (LaFortune and others, 2021). Additionally, the British Columbia Emergency Health Services activated their emergency facilities and protocols, such as increasing paramedic staff, only after the heat dome began to fade away (Daflos, 2021). This resulted in the ambulance services becoming completely overwhelmed, with many people waiting for medical assistance for hours and many dying in the process (Ghoussoub, 2021). In the absence of an effective and timely provincial alert of the heat emergency, many municipalities did not have sufficient cooling centres to cope with the record-breaking heat. For example, many cooling centres had limited hours, though nighttime temperatures were similarly high (LaFortune and others, 2021). Still others were afraid to go to a cooling centre for fear of contracting COVID-19, as many cooling centres stayed open despite exceeding COVID-19 capacity rules (Little, 2021). Though some cities, such as Vancouver, opened dedicated cooling centres and misting stations, added public water fountains and distributed bottled water, much of the guidance and response from the province was geared towards individual actions, with few options for the unhoused population or people with chronic illnesses or mobility issues that may have required extra assistance (Aslam, 2021; LaFortune and others, 2021).

## 3.3 Low heat risk perception

Unlike other parts of North America, British Columbia is not used to extreme heat events. Therefore, most of the province's population lacks air conditioning and other cooling measures that can dampen the high temperatures (Aslam, 2021). Community infrastructure and housing are not built to consider extreme heat conditions (Freedman, 2021). For example, only 39 per cent of households in Vancouver have air-conditioning systems (Philip and others, 2021), which led to record indoor temperatures of nearly 40°C in some houses (Henderson and others, 2021). Natural ventilation and insulation are similarly absent. A 2017 study found that many municipalities in British Columbia considered planning for extreme heat a low priority because the risk seemed low, because of fixed resources and competing priorities or because they didn't consider it their responsibility (BCCS, 2022).

## 4. Root causes



*A lone standup paddleboarder heads west on the Columbia River near Troutdale, Oregon on August 13, 2021 during an abnormal heat wave in the Pacific Northwest. (Image credit: Michael Hanson/AFP)*

### 4.1 Human-induced greenhouse gas emissions

This heatwave was made 2°C warmer and around 150 times more likely due to human-induced climate change. Although the heatwave in British Columbia was a one-in-a-thousand-year event, similar heatwaves would likely occur every 5 to 10 years under the current trend in greenhouse gas emissions (Philip and others, 2021).

### 4.2 Insufficient risk governance

Given the historical lack of experience with extreme heat, heat risks are underestimated in many municipalities in British Columbia and the Pacific Northwest. Unlike other hazards, no single organization or department coordinates preparation or response to extreme heat events in British Columbia (Keith and others, 2021). For example, while extreme heat events involve Weather Canada, which monitors temperature and trigger warnings, Environment Canada, which issues heat warnings, and Emergency Health Services, which receives the affected population, no office within the provincial or municipal governments leads preparation and responses locally. Very few municipalities had heat response and adaptation plans in the region (Lubik and others, 2017). Therefore, many of the responses to the heatwave were reactive rather than proactive and were thus insufficient, contributing to the unnecessary suffering of the people.



*Woman fanning herself with the restaurant menu to refresh and protect from the heatwave in Vancouver on June 27, 2021. (Image credit: Kris Durlen / Shutterstock)*

## 5. Big picture

Heatwaves are one of the deadliest hazards in the world and are the leading cause of weather-related deaths in Canada (Philip and others, 2021; BCCS, 2022). They are considered an invisible threat or a silent killer since attributing deaths to heat is much more complicated than to a flood or an earthquake. The combination of land and ocean-surface temperatures made July 2021 the hottest month recorded in 142 years, at 0.93°C above the global average of 15.8°C, most prominently in the northern hemisphere, where the heat exceeded the average land surface temperature by 1.54°C (National Oceanic and Atmospheric Administration (NOAA), 2021). Still, it was a warning that we must improve detection and emergency systems, as well as developing better prevention and response plans for extreme heat events (Henderson and others, 2021).

Climate models suggest more intense, frequent, extensive and long-lasting hot spells as the climate changes (Henderson and others, 2021; Keith and others, 2021). The global average cumulative heat during heatwaves is increasing, with trends ranging from ~1 to 4.5 °C per decade, depending on the region (Perkins-Kirkpatrick and Lewis, 2020). Based on the current trend, by 2030, extreme heatwaves will triple in number compared to 2001, with about 30 heat peaks expected (United Nations Office for Disaster Risk Reduction, 2022). In a 1.5°C to 2°C warmer future, the population exposed to severe heatwaves every five years will be three times greater, reaching 37 per cent of global inhabitants (Keith and others, 2021).

Global average temperatures have risen 1.1°C since 1880, and 9 of the last 10 years have been the warmest on record (NASA Earth Observatory, 2021). This changing climate creates new hazards in places that are unprepared and unaware of the heat for which governments, companies, organizations and citizens must start preparing to prevent future disasters.

## 6. Solutions

Heat-related impacts can be sufficiently avoided by having well-prepared local governments, investing in appropriate public infrastructure, fostering mutual caring among the inhabitants and enhancing early-warning systems (Ban and others, 2019). Some potential solutions to better manage heat risk are explained below.

### 6.1 Innovate

Urban planners and designers can harness the power of nature to cool and refresh cities (Keith and others, 2021). Given the cooling effect of evapotranspiration, green urban areas can act as urban heat sinks, preventing and controlling extreme temperatures – given that sufficient water is available to maintain these spaces (Viguié and others, 2020). For example, a model of urban greening in Phoenix, United States, would cool the city by 8°C (Keith and others, 2021). Besides that, greening cities also support biodiversity and contribute to mitigating climate change as plants can absorb and store carbon dioxide (Hintz and others, 2018). The creation of parks, green rooftops, home gardens, urban forests and other green spaces can be complemented with blue infrastructure (e.g. fountains, wetlands, ponds), reflective surfaces (e.g. painting facades white), improved natural ventilation and building insulation to prevent more severe urban heatwaves and ensure the well-being of city residents (Lowe and others, 2011; Keith and others, 2021; Viguié and others, 2020; Hintz and others, 2018).

Air conditioning remains one of the best ways to cool down during high temperatures and humidity. However, increasing air-conditioning usage can contribute to greenhouse gas emissions and strain the power grid during peak demand times (Lowe and others, 2011). Innovations in using and distributing alternative, renewable energy sources, such as solar electric technology, or proper installation and timing of air-conditioner use can mitigate some of these trade-offs (Ban and others, 2019).



*View of sign Extreme Heat Cooling Centre at the entrance of Denman Community Centre in Vancouver, Canada - July 29, 2021 (Image credit: Margarita Young / iStock)*

## 6.2 Strengthen governance

Heat should be taken seriously as a natural hazard and integrated into existing governance structures as such. Creating an entity responsible for heat governance would allow coordinating activities among the various actors and sectors of the territory (e.g. housing, health, finance, insurance, urban planning, energy and social services) while consistently managing heat mitigation measures (Keith and others, 2021). The city of Phoenix recently adopted an Office of Heat Response and Mitigation to “establish a strategic action plan to address the growing hazard of urban heat” (City of Phoenix, 2021). Additionally, municipalities and the provincial government should work to establish heat alert and response systems (HARS) that alert the public of heat risk through a method of organized communication to help people prepare and protect themselves, as shown in Figure 3 (Deegan and others, 2022).

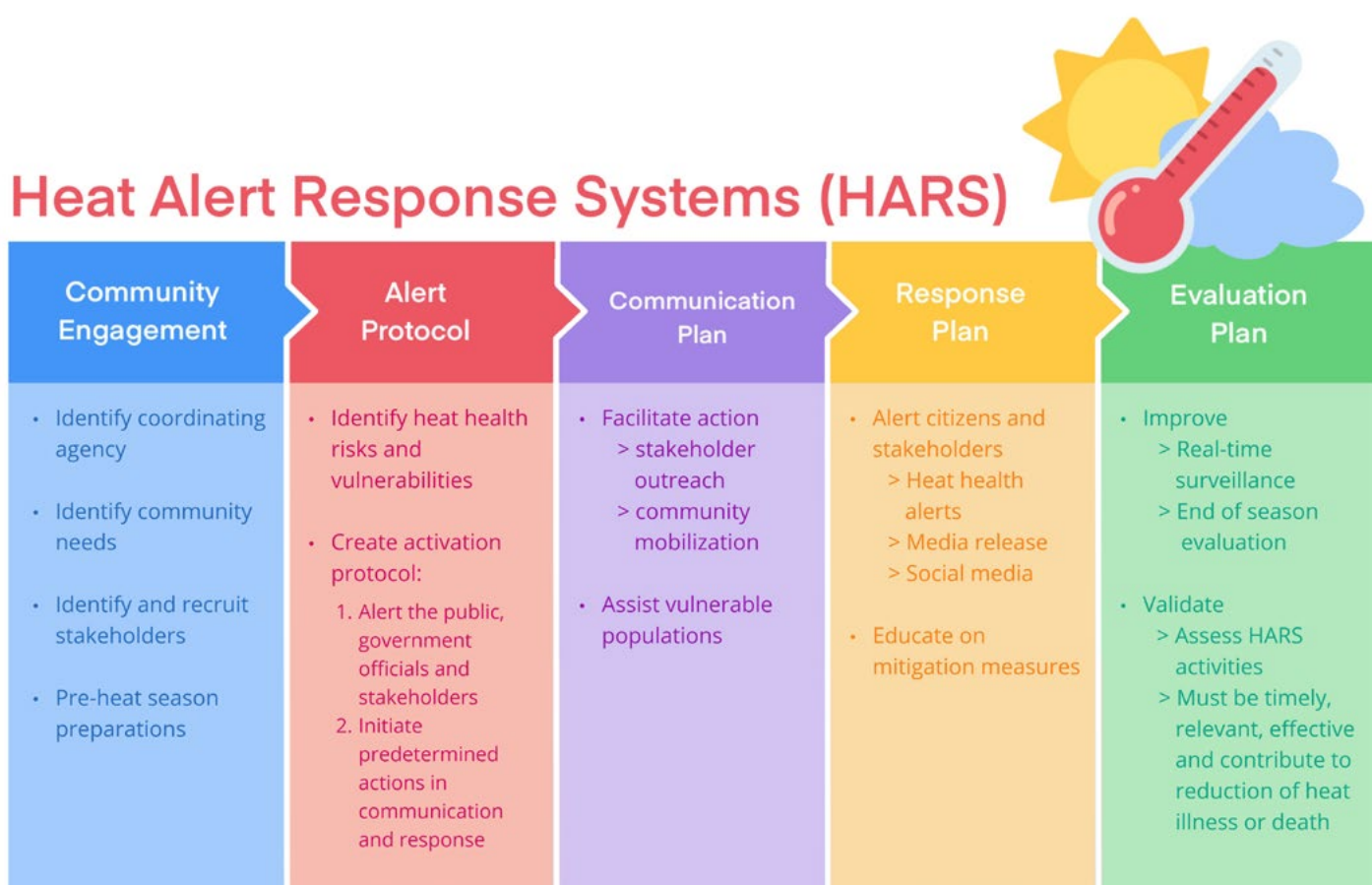


Figure 3: Five core elements of HARS, adapted from Deegan and others, 2022

## 6.3 Boost early warning

Investing in different forms of early warning is one way to significantly reduce the impacts of extreme temperatures (Lowe and others, 2011; Keith and others, 2021). Some strategies to improve early-warning systems include heatwave forecasting models, zoning and behavioural mapping of heat events, predicting heat-related public health outcomes, triggering timely notifications, and effectively communicating prevention responses through social media, push messages on phones, public notice boards, newspapers and postal services (Lowe and others, 2011; C40 Cities Climate Leadership Group and C40 Knowledge Hub, 2021). These systems should be integrated as part of the HARS, as shown in Figure 4. Recently, the British Columbia provincial government expanded the national alert system (Alert Ready) to include warnings on wildfires, floods and extreme heat events (BCCS, 2022). Increasing public awareness through educational campaigns of the dangers of extreme heat is equally as important as the public's perception of threat was one of the main drivers of risk of this heatwave.

## 6.4 Work together

Increasing social capital by enhancing support networks can significantly reduce the health impacts of many disasters, including heatwaves (Wolf and others, 2010). For example, New York's Be A Buddy program encourages mutual care among citizens by training local volunteers to check on heat-vulnerable neighbours (C40 Cities Climate Leadership Group and C40 Knowledge Hub, 2021). Another example is an initiative in Paris, France, called Chalex, which consists of a self-registration system in which people vulnerable to high temperatures sign up to receive check-up calls, cooling advice and, if necessary, medical services sent to their homes (O'Sullivan, 2019).

## 6.5 Conclusion

The solutions outlined above are only a selection of possible solutions for heatwaves in British Columbia. Many other solutions may be necessary for different contexts, such as educational outreach, electricity demand reduction or enhancing public water supply. The solutions outlined above give a brief snapshot of those that could address the root causes, reduce the impact and increase resilience to a heatwave in a similar context. Additionally, these solutions are intended to work together as a package to take advantage of the different co-benefits and synergies of the collected solutions to address multiple challenges while minimizing trade-offs. This approach signifies that none of these solutions alone is sufficient; only a combination of various solutions targeting the multifaceted nature of the problem can truly address it.

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Cover Image Credit: Don MacKinnon / AFP

The city of Vancouver, British Columbia, is seen through a haze on a scorching hot day, June 29, 2021.

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