Excessive Heat Events (EHE)

Key Points

- Heat is an extremely deadly but hidden killer. In August 2003, excessive heat killed more than 15,000 people in France. In Cook County, Illinois in 1995, more than 700 deaths were attributed to heat. Because heat does no physical damage and deaths tend to occur in private dwellings, a heat disaster's extent is often not visible to the public.
- Since the mid-1970s, an average of three or four fatalities has occurred each summer in Seattle. During excessively warm summers, such as the summer of 1992, up to 50 to 60 deaths have occurred.
- The season, humidity, duration and availability of cooling systems all strongly influence the impact of Excessive Heat Events.
- Seattle's typical cool summers result in a population that is less acclimatized to extreme heat compared with that of many other cities in the United States. Health effects associated with heat begin in Seattle at lower temperatures than many other places; the relative temperature compared to seasonal normals is often more important than the actual temperature. Seattle is among the cities with the highest heat sensitivity in the country
- Many Seattle homes and businesses lack cooling systems, increasing our vulnerability.
- The most vulnerable people in heat events are the elderly, infants, the homeless, the poor and people who are socially isolated. As a community, Seattle presents a mixed picture in terms of vulnerable population. We have fewer elders and infants than many other cities, but many more single-person households.
- Heat cramps, heat exhaustion and heat stroke are examples of negative health effects associated with both average warmer summer temperatures and temperature extremes.
- In Seattle, most fatalities are indirectly caused by heat, e.g., heart attacks, strokes and respiratory illness.
- Climate research shows that extreme heat events have become more frequent and severe in the Pacific Northwest in recent decades, and climate models project that this trend will continue in the future.
- Heat can be costly. The costs of one extreme heat wave in California in 2006 were estimated at over $200 million.

Context

On July 29, 2009, the temperature reached 103˚at SeaTac airport, an all-time record. Two people in Western Washington died. The most brutal temperatures lasted three days. If the extreme weather had lasted a few days more, the number of fatalities would probably have climbed dramatically. Seattle has a famously mild climate that makes extreme heat even more dangerous when it occurs.

An EHE, or heat wave, is a weather pattern that is substantially hotter and/or more humid than average for a location at that time of year and can cause dehydration, heat cramps, heat exhaustion, heat stroke and even death.

Of all the natural hazards in the United States, heat is the number one, non-severe weather-related killer. In an average year, about 658 Americans succumb to the effects of summer heat[1]. During the summer of 2006, more than 150 people in the United States died as a direct result of heat. Heat waves in August 2003 that affected all of Western Europe resulted in more than 15,000 deaths in France alone. In July 1995, “excessive heat” conditions were blamed for more than 700 deaths in Cook County, Illinois. In July 1993, similar temperature extremes led to roughly 120 deaths in Philadelphia, Pennsylvania.

Human bodies dissipate heat by varying the rate and depth of blood circulation, by losing water through the skin and sweat glands and by panting when the body’s core is heated above 98.6 degrees Fahrenheit. The heart begins to pump more blood, blood vessels dilate to accommodate the increased flow and the bundles of tiny capillaries threading through the upper layers of skin are put into operation. The body’s blood is circulated closer to the skin’s surface and excess heat drains off into the cooler atmosphere. At the same time, water diffuses through the skin as perspiration. The skin handles about 90% of the body’s heat dissipating function.

Sweating, by itself, does nothing to cool the body unless the water is removed by evaporation. High relative humidity retards evaporation. The evaporation process itself works this way: the heat energy required to evaporate the sweat is extracted from the body, thereby cooling it. Under conditions above 90 degrees Fahrenheit and high relative humidity, the body is doing everything it can to maintain 98.6 degrees Fahrenheit inside. The heart is pumping a torrent of blood through dilated circulatory vessels; the sweat glands are pouring liquid, including essential dissolved chemicals like sodium and chloride, onto the surface of the skin.

Heat disorders generally have to do with a reduction or collapse of the body’s ability to shed heat by circulatory changes and sweating, or a chemical imbalance of salt caused by too much sweating. When heat gain exceeds the level the body can remove or when the body cannot compensate for fluids and salt lost through perspiration, the temperature of the body’s inner core begins to rise and heat-related illness may develop.

Once the ambient temperature exceeds skin temperature, convective cooling from the skin is no longer possible and the effects of ventilation/wind reverse –adding heat to the body. This is a dangerous scenario that causes individuals sitting in hot rooms with fans on to accelerate deterioration under hot conditions. Some decedents in the Chicago heat wave were found in indoor spaces with the fan on and are believed to have died as a result of this mechanism.

History

Looking at Seattle area weather and mortality statistics back to the mid-1970s, an average of three or four fatalities have occurred each summer[2]. During excessively warm summers, such as the summer of 1992, up to 50 to 60 deaths have occurred. While good meteorological records exist for Seattle, heat waves are more complex that just high temperatures. Other factors like time of year, humidity, duration, extent of nighttime cooling and the availability of cooling systems all strongly influence the effect. Because of these factors and the recognition of heat as a source of disaster only recently, records are marginal.

Statistical analysis of King County mortality data by David Hondula found that adverse health effects for heat begin to rise at 25.9° C (78.6° F). This is several degrees lower that other cities in the United States. This research studies day to day baseline conditions and not extreme events. It suggests that mortality and morbidity can spike sharply in extreme heat events.[3]

The Washington Climate Change Impacts Assessment studied heat events from 1980 to 2006. It found that the Greater Seattle Area had an average of 1.7 heat events per year with an average duration of 2.2 days and a maximum of six days. It correlated the heat increases and found that "risk of death from non-traumatic and circulatory causes was significantly elevated for all ages on most days of heat events."

Some of the major heat events from this time period are:

1981. A heat wave lasted several days in the upper 90s.

1992. A record 15 heat warnings were issued by the National Weather Service for the Seattle area. An estimated 50 – 60 people died because of the heat[4].

1994. A city-wide heat extreme is set, recorded at 100 degrees.

2009. A new all-time record set, and two deaths in Western Washington are directly attributable to the heat.

Likelihood of Future Occurrences

The Washington Climate Change Impacts Assessment looked at the likelihood of future extreme heat events. It used three different scenarios of summer warming—low, moderate and high—and developed estimates for the number heat events. In every scenario, they predict a rise. In the worst case scenario, Seattle could have an average of ten heat events per year with a maximum duration of 57 days by 2085.

Table 1. Projected Heat Events

	1980 - 2006	2025	2045	2085
1980 - 2006				
Mean annual heat events	1.7			
Mean (max) event duration in days	2.2(6)			
Low				
Mean annual heat events		2.6	3.1	3.8
Mean (max) event duration in days		2.2(6)	2.3(7)	2.3(8)
Medium				
Mean annual heat events		3.6	4.7	7.2
Mean (max) event duration in days		2.3(7)	2.6(14)	2.9(18)
High				
Mean annual heat events		5.8	8.8	10.1
Mean (max) event duration in days		2.7(18)	3.2(18)	6.1(57)

Source: Washington State Climate Change Impact Assessment, 2009.

Vulnerability

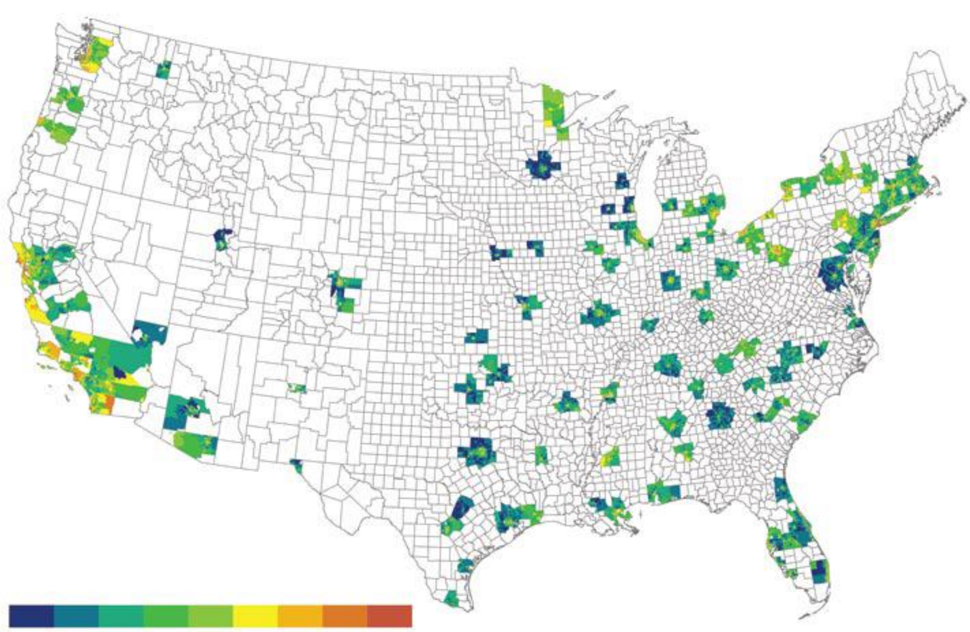
Demographic vulnerability to extreme heat events is similar to other hazards. Factors that increase vulnerability include: age (65+), ethnicity (especially Pacific Islander), lower levels of educational attainment, lower incomes and minority status.

Many residents lack efficient cooling systems in their homes or businesses and remain unaware how to protect themselves. The difference between the normal temperature and the current temperature dictates the real impact that heat has on the individual. Since we normally have fairly mild temperatures, our population can feel stressed at lower temperatures than many other places, especially if the rise happens suddenly.

Warmer average summer temperatures experienced in cities across the United States and elsewhere have led to premature death among certain populations, including those who are elderly, very young, poor, cognitively or physically impaired and already burdened with chronic disease, e.g., hypertension and diabetes. The most vulnerable people in Seattle tend to be the elderly.

A 2009 study of vulnerability on a national scale found that Seattle is on par with Chicago, site of a 1995 event that killed over 700 people. The study found that four factors drove heat vulnerability. These four are social isolation, lack of air conditioning, the proportion the population with chronic medical conditions and social vulnerability factors such as race, poverty, age and housing conditions. The authors suggested that local and regional factors also play a role and suggested research of these as a next step in defining local hazard exposure.[5]

Figure 1. Heat Vulnerability



Source: Reid et al, 2009

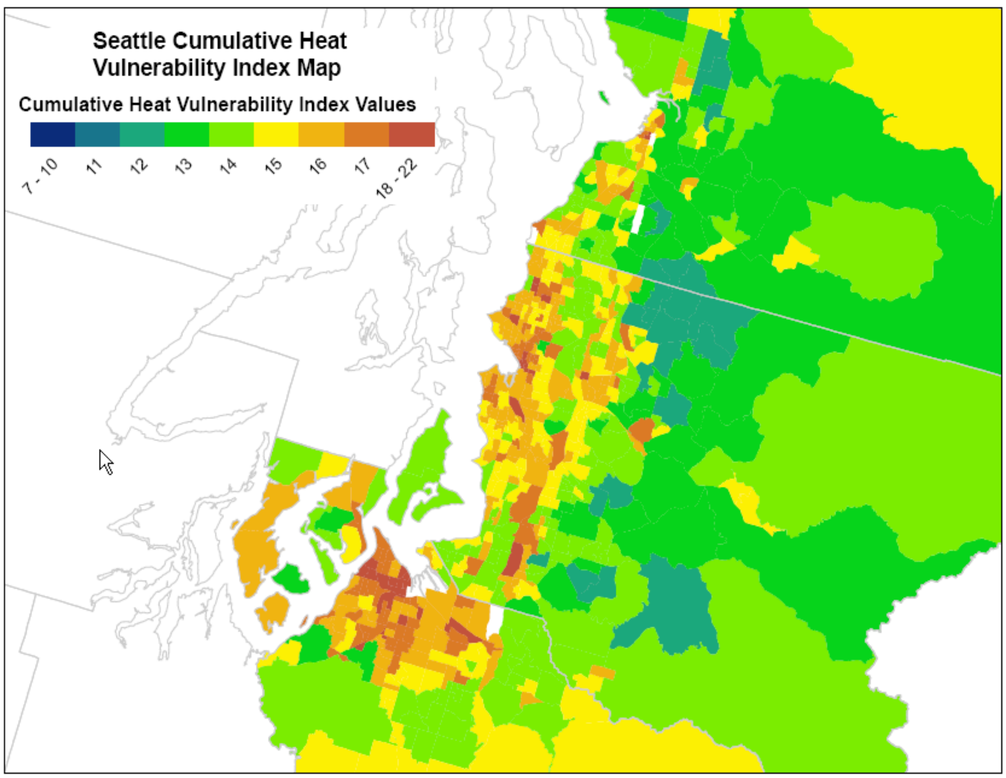
Consequences

Two studies based on Seattle's 1990 population found that the city had widely varying averages of five and 96 estimated heat-attributable deaths and a heat-attributable mortality rate of 0.17 and 3.27 deaths per 100,000 people, respectively[6]. In Seattle, most fatalities are indirectly caused by heat, e.g., heart attacks, strokes and respiratory illness.

Hotter temperatures may also make people with certain heath conditions such as diabetes and obesity less likely to pursue physical activity critical to management and improvement of their health conditions.

Warmer temperatures are typically associated with precursors of air pollutants that are in turn linked to respiratory disease and reduced lung function. In addition to causing climate change, high carbon dioxide concentrations in the atmosphere are associated with production of allergens such as ragweed pollen that can, in turn, contribute to asthma cases by combining with fossil fuel pollutants, especially diesel exhaust.

Figure 2. Seattle Heat Vulnerability Index



Source: Colleen Reid, personal communication. 2009.

Urban areas can also have reduced air flow because of tall buildings and increased amounts of waste heat generated from vehicles, factories and air conditioners. When vegetation in urban areas is replaced with buildings, especially those with dark roofs, and dark paving materials, the heat absorbed during the day increases and cooling from shade and evaporation of water from soil and leaves is lost. These factors can contribute to the development of an urban heat island with higher daytime maximum temperatures and less nighttime cooling than surrounding rural areas.

Climate research suggests an increase in EHE frequency and severity, discussed further in the chapter on climate change.

Most Likely Scenario

Seattle experiences an event slightly more extreme than the previous milestone, the 2009 heat wave. Temperatures are over 90° for seven straight days with two over 100°. Lows are over 70°. The heat has built slowly making it easier for people to adjust. A major festival is happening at Seattle Center and a road race is scheduled. One nursing home loses its air conditioning system.

Category	Impacts 1 = low 5 = high	Narrative
Frequency	5	Seattle is experiencing more extreme heat events recently. It seems likely that the previous record of 103° will be broken in the near future. This scenario captures an event that is more severe than the 2009 extreme heat event. Because a breaking of the current record is viewed as likely in the next 10 to 50 years this event is given the highest frequency rating.
Geographic Scope	5	The whole region is affected during extreme heat events. Seattle has more paved area than any other city in the region and suffered from an 'urban heat island' effect.
Duration	3	The apex of this event is two days of triple digit temperatures and five more in the 90s. The consequences of heat events rise with duration, especially if temperatures do not drop significantly at night.
Health Effects, Deaths and Injuries	2	2 people are killed by heat stroke and 103 need medical attention. One nursing home does not have adequate cooling for residents.
Displaced Households and Suffering	2	89 people seek overnight shelter in air conditioned facilities. Thousands of people seek shelter in air conditioned spaces (malls, libraries and community centers) during the day.
Economy	2	Significant but hidden costs resulting from excess medical attention (hospitalizations, ER visits, ambulance callouts and premature deaths). The heat prompts a run on fans and air conditioners. Two major events are cancelled and energy use spikes.
Environment	1	The heat stresses plants but does not damage whole areas or ecosystems.
Structures	1	The heat event does not destroy any buildings.
Transportation	2	The Seattle Department of Transportation must cool the older drawbridges over the Ship Canal or risk having them become stuck and unable to open. The Ballard Bridge's leaves expand to the point they are touching. The bridge can't be opened safely. Maritime traffic is impacted. Streets and sidewalks begin to crack in the heat. None of these cracks imped traffic, but they are a cost to local government.
Critical Services and Utilities	1	Critical services and utilities are able to be maintained, but the City must increase staffing and seek volunteers to help at daytime cooling centers.
Confidence in Government	1	The public views the government's response to the heat as adequate.

Cascading Effects	1	The heat event does not cause significant secondary incidents.

Maximum Credible Scenario

Seattle experiences an unprecedented heat event. Temperatures are over 90° for 14 consecutive days with three over 100°. Temperatures do not sink below 75° overnight. The heat has built quickly making it harder for people to cope. A major festival is happening at Seattle Center and a road race is scheduled. Despite cooling efforts, one bascule bridge is stuck open. Crime is a worry for older residents who won't open their windows.

Category	Impacts 1 = low 5 = high	Narrative
Frequency	3	Seattle has never come close to experiencing a heat event this extreme. Because Seattle has broken the 100° mark this scenario is not viewed as unrealistic. It is viewed as having a 1 in 100 chance of occurring per year.
Geographic Scope	5	The whole region is affected during extreme heat events. Seattle has more paved area than any other city in the region and suffers from an urban heat island effect.
Duration	4	The most severe part of the heat wave lasts for fourteen days. The longer a heat wave lasts the more its consequences grow. The night time temperatures do not dip below 75° which makes the event more dangerous.
Health Effects, Deaths and Injuries	3	42 deaths are attributed to the heat, especially among residents in poorer areas of the city who keep their doors and windows locked and lack air conditioning. Over 1000 people seek medical attention.
Displaced Households and Suffering	4	854 people seek overnight shelter in spaces with air conditioning systems. Most of the general population is extremely uncomfortable.
Economy	3	The heat event costs $50 million in excess medical expenses, premature deaths, increased energy costs and cancelled events.
Environment	2	Air quality significantly decreases in the hot stagnant air. Many plants are stressed and some die.
Structures	1	The heat does not destroy buildings.
Transportation	3	The University and Ballard Bridges are opened to avoid having them expand and damage themselves. This causes disruption to emergency services and the general public. Streets and sidewalks crack. Aircraft coming into Sea-Tac have weight restrictions imposed. Train rails kink and impede freight and passenger traffic.
Critical Services and Utilities	3	Heat out of the area causes high demand on the power generation and transmission system. High heat causes power lines to sag causing shorts and outages. Water consumption spikes prompting worries about a water shortage. Fire and police are unable to use the University and Ballard Bridges. The heat does not cause the loss of any responders.

Confidence in Government	3	As the event continues, the public clamors for more assistance with cooling.
Cascading Effects	2	The heat causes power outages and is raising concerns about a water shortage.

Conclusions

Meteorologists can accurately forecast EHE development and the severity of the associated conditions with several days of lead time. The National Weather Service (NWS) has developed a Heat Health Watch/Warning System that tailors excessive heat guidance to specific regions in the country. The Seattle area implemented this new system in 2005, becoming the 15th urban region of at least 500,000 in population to do so. Excessive heat events may be on the rise. This may help acclimate people to relatively hotter conditions but may also increase the exposure of vulnerable populations.

[1] Center for Disease Control and Prevention (CDC) website. (http://www.cdc.gov/mmwr/preview/mmwrhtml/mm6222a1.htm). Accessed 2/24/2014.

[2] National Oceanic and Atmospheric Administration, 2005.

[3] Hondula, 2014. Personal Communication.

[4] National Oceanic and Atmospheric Administration, 2005.

[5] Reid, 2009.

[6] Kalkstein and Greene, 1997. and Davis et al., 2003a. Although differences in the time series, definitions of urban populations, and other analytical methods prevent an exact comparison of results from Kalkstein and Greene *(1997)* and Davis et al. *(2003a)*, their other findings correspond closely.