Chapter 7: Human Health

Summary
Climate change threatens the health of Oregonians. More frequent heat waves are expected to increase heat-related illness and death. More frequent wildfires and poor air quality are expected to increase respiratory illnesses. Warmer temperatures and extreme precipitation are expected to increase the risk of exposure to some vector- and water-borne diseases. Access to sufficient, safe, and nutritious food may be jeopardized by climate change. Extreme climate or weather events, or even the threat of one, can lead to adverse, and sometimes lasting, mental health outcomes. Certain populations, including the elderly, the young, pregnant women, the poor, persons with chronic medical conditions, persons with disabilities, outdoor workers, immigrants and limited English proficiency groups, and Indigenous peoples will be disproportionately affected by such climate-related health impacts. However, adaptation strategies may reduce the projected adverse health outcomes.

Introduction
Climate change threatens the health of people in the United States and around the world (Crimmins et al., 2016; IPCC, 2014). The previous Oregon Climate Assessment found that the potential health impact of climate change is lower for the Pacific Northwest than for other areas in the United States; however, extreme heat events, wildfires, changes in infectious disease dynamics, and flooding are key climate-related hazards facing people of the Pacific Northwest (Dalton et al., 2013). Many potential health impacts from climate change can be avoided by preparedness actions (Crimmins et al., 2016). With funding from the Centers for Disease Control and Prevention, Oregon has become a leader in assessing and planning for the health impacts of climate change (Haggerty, 2015; Haggerty et al., 2014). Oregon has evaluated climate change vulnerabilities and recently released a statewide climate and health resilience plan (Haggerty et al., 2014). This chapter describes updated information on the climate-related health impacts that are relevant to Oregon, and largely follows the findings of a recent synthesis of human health impacts of climate change in the United States (Crimmins et al., 2016).

Temperature-Related Death & Illness
Increases both in average and extreme temperatures are expected to increase the number of heat-related deaths and to decrease the number of cold-related deaths (Sarofim et al., 2016). Even small increases in the average summer temperature can result in increased heat-related deaths (Sarofim et al., 2016). In some areas across the globe, this trend is already apparent (IPCC, 2014). Mid-century climate in Portland, Oregon, under a medium emissions pathway (RCP 6.0) is projected to result in 81–118 more heat-related premature deaths than the present-day baseline, although this figure does not account for future population growth or possible adaptations (Schwartz et al., 2015). The number of cold-related premature deaths is projected to decrease but by a smaller margin than heat-related premature deaths would increase (Schwartz et al., 2015). Projections for changes in the number of heat-related premature deaths are listed in Table 7.1 for Portland, Eugene, Medford, and Klamath Falls.
Table 7.1 Projected increase in heat-attributable premature deaths for four cities in Oregon for 2030, 2050, and 2100 relative to the 1990 baseline for each model. The range is based on climate projections from two global climate models forced with a medium emissions pathway (RCP 6.0). Numbers are rounded to the nearest integer. (Schwartz et al., 2015)

<table>
<thead>
<tr>
<th>City</th>
<th>2030</th>
<th>2050</th>
<th>2100</th>
</tr>
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<tbody>
<tr>
<td>Portland</td>
<td>59–78</td>
<td>81–118</td>
<td>153–234</td>
</tr>
<tr>
<td>Eugene</td>
<td>8–13</td>
<td>12–22</td>
<td>27–49</td>
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<tr>
<td>Klamath Falls</td>
<td>1–2</td>
<td>2–2</td>
<td>3–6</td>
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<td>Medford</td>
<td>6–8</td>
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Adaptation, such as increased use of air conditioning, improved social and behavioral responses, and physiological acclimatization, may reduce the projected increase in heat-related illnesses and deaths (Sarofim et al., 2016). The relative risk of heat mortality in the United States decreased during 1985–2006 and this trend likely reflects the increasing penetration of air conditioning and public health interventions, despite an aging population (Gasparrini et al., 2015). About half of Oregonian households have air conditioning, with greater penetration in southwest Oregon (NEEA, 2014). Future population growth, broad shifts in population distribution (Jones et al., 2015) and adaptation measures (Petkova et al., 2016) are significant components that should be included in projections of future extreme heat risk and mortality.

More frequent heat waves are expected to increase the burden of heat-related illnesses including heat rash and heat stroke in addition to exacerbating chronic conditions such as cardiovascular and kidney disease (Bethel et al., 2013). Frequent heat exposure during physical exertion without drinking enough water can lead to a form of kidney disease distinct from other causes; it is suggested that heat-stress kidney disease may be one of the first climate change epidemics (Glaser et al., 2016). Recent studies in King County, Washington, found that the risk of heat-related hospital admissions and deaths were 2% and 10% higher, respectively, during extreme heat events of the last few decades (Isaksen et al., 2015, 2016). Extreme heat events increased the relative risk of hospitalizations due to kidney disease, kidney failure, and natural heat exposure (e.g., heat stroke) for all ages.

The elderly (85+) are particularly vulnerable to heat (Sarofim et al., 2016), but age groups 45+ also experienced significant increased risk of hospitalization due to heat in King County (Isaksen et al., 2015). Children are also at higher risk of heat-related illness as they are less able to regulate their internal temperature (Sarofim et al., 2016). New evidence from New York City suggests that extreme heat experienced during pregnancy could modestly reduce birth weight (Ngo and Horton, 2016). Other groups especially vulnerable to extreme heat include outdoor workers, the socially isolated and economically disadvantaged, and those with chronic illnesses (Sarofim et al., 2016). Urban dwellers may be more exposed to heat waves when they occur due to the urban heat island effect which raises the temperature even more in certain areas within the built environment (Stanforth and Johnson, 2016) shows the City of Portland’s heat islands, or areas that experience higher temperatures during heat waves.
Air Quality Impacts

Climate change is expected to worsen outdoor air quality. Warmer temperatures may increase ground level ozone pollution, more wildfires may increase smoke and particulate matter, and longer, more potent pollen seasons may increase aeroallergens (Fann et al., 2016). Such poor air quality is expected to exacerbate allergy and asthma conditions and increase respiratory and cardiovascular illnesses and death (Fann et al., 2016).

Climate warming is expected to increase the formation of ground level ozone pollution thereby increasing the risk of ozone-related respiratory illness and death, though the impact in the Pacific Northwest would be small compared to other regions of the United States (Fann et al., 2016).

Fine particulate matter (PM$_{2.5}$) concentrations from climate, emissions, and land use changes are generally projected to decrease in the western United States by mid-century under both low (RCP 4.5) and high (RCP 8.5) emissions pathways, largely owing to declining emissions of air pollutants and more stringent air quality standards over time embedded in the RCPs (Val Martin et al., 2015). However, wildfire-specific PM$_{2.5}$ is
Projected to increase over the western United States, resulting in overall greater concentrations in the future (Val Martin et al., 2015; Yue et al., 2013). Climate change is expected to result in a longer wildfire season with more frequent wildfires and greater area burned (Sheehan et al., 2015). Wildfires are primarily responsible for days when air quality standards for PM$_{2.5}$ are exceeded in western Oregon and parts of eastern Oregon (Liu et al., 2016), although woodstove smoke and diesel emissions are also main contributors (Oregon DEQ, 2016). Across the western United States, PM$_{2.5}$ levels from wildfires are projected to increase 160% by mid-century under a medium emissions pathway (SRES A1B) (Liu et al., 2016). This translates to a greater risk of wildfire smoke exposure through increasing frequency, length, and intensity of “smoke waves”—that is, two or more consecutive days with high levels of PM$_{2.5}$ from wildfires (Liu et al., 2016) (fig. 7.2). Such smoke waves during 2004–2009 were associated with a 7.2% increase in respiratory hospital admissions among adults aged 65 and older in the western United States (Liu et al., 2017). Similarly, correlations were found between wildfire-specific PM$_{2.5}$ and emergency department visits for asthma and chronic obstructive pulmonary disease during the 2012 wildfire season in Colorado (Alman et al., 2016) and the 2008 season in northern California (Reid et al., 2016).

**Vector-Borne Diseases**

Climate change is expected to result in increased incidence of vector-borne diseases by altering geographic and seasonal distribution of vectors (e.g., mosquitoes, ticks) and the diseases they carry. However, adaptive capacity measures such as controlling vectors and protecting oneself can limit disease incidence (Beard et al., 2016).

Since appearing in Oregon in 2004, 168 human cases of West Nile virus (WNV) have been reported through 2015 (fig. 7.3). Warmer than average temperatures were associated with the emergence of WNV in the western United States in the early 2000s, and prior drought may have factored into the initial outbreak (Bethel et al., 2013). Warming temperatures, changes in precipitation, and more extreme weather may affect the number and location of WNV-carrying mosquitoes by altering their habitat and their rate of reproduction, thereby altering the disease risk for people (Beard et al., 2016). One
study projected WNV incidence under a medium emissions pathway (SRES A1B) to increase in northern US states, including Oregon, by at least 10% by mid-21st century due to increasing temperature (Harrigan et al., 2014).

Lyme disease incidence may also increase with climate change. Between 2002 and 2014, 163 cases of Lyme disease were reported in Oregon (fig. 7.3). In response to warming temperatures associated with climate change, ticks capable of transmitting Lyme disease will emerge earlier in the season and their range will expand northward (Beard et al., 2016). However, climate change’s effect on Lyme disease incidence remains uncertain (Beard et al., 2016).


**Water-Related Illness**

The risk of exposure to waterborne pathogens and algal toxins is expected to increase under climate change (Trtanj et al., 2016). Warming waters are expected to alter the seasonal windows of growth and the geographic range of suitable habitat for freshwater and marine toxin-producing harmful algae and certain naturally occurring *Vibrio* bacteria (Trtanj et al., 2016). In the Puget Sound, under a medium emissions pathway (SRES A1B), local atmospheric heating of surface waters is projected to result in thirty more days a year that are favorable to algal blooms and an increased rate of bloom growth (Moore et al., 2015). Toxins from such harmful algal blooms accumulate in filter-feeding shellfish, leading to illnesses for those who eat them (Bethel et al., 2013). In 2015, during the largest harmful algal bloom ever observed off the West Coast from California to Alaska, high levels of domoic acid led to the closure of shellfish harvesting from the Columbia River to Tillamook Head, and high levels of paralytic shellfish toxins led to the closure of mussel harvesting along the Oregon coast north of Gold Beach (Milstein, 2015).

*Vibrio parahaemolyticus* is a common culprit behind seafood-associated gastroenteritis worldwide, and some of the most virulent strains are found in coastal waters of the Pacific Northwest (Martinez-Urtaza et al., 2013). *Vibrio* concentrations
increase seasonally as waters warm in spring and summer and higher ocean, and estuarine temperatures associated with climate change could increase the risk of infection from eating compromised shellfish (Bethel et al., 2013). From 1999 to 2014, nearly 200 cases of *Vibrio* infection have been reported in Oregon (fig. 7.3).

More frequent and intense extreme precipitation events projected under climate change could increase the risk of exposure to water-related illnesses as the runoff introduces pathogens, such as *Cryptosporidium*, into recreational and drinking water (Trtanj et al., 2016). Extreme precipitation events may also lead to more combined sewer overflows, thereby compromising the sources of drinking water and increasing the risk of gastrointestinal illness (Jagai et al., 2015). Approximately 23% of Oregon’s population relies on private wells for drinking water and may be at risk of water contamination (Haggerty et al. 2014). Extreme precipitation runoff can also influence the prevalence of toxic algal blooms and human exposure to compromised harvested shellfish (Trtanj et al., 2016).

The projected increase in flooding related to extreme precipitation, and combined with sea level rise on the coast, may also threaten to disrupt the infrastructure that is essential to safeguarding physical safety and human health. For example, infrastructure that becomes compromised by mold and mildew can lead to respiratory illnesses (Haggerty et al. 2014). Flooding may disproportionally affect some populations including people with disabilities, older adults, pregnant women and children, low-income populations, and some occupational groups (Bell et al., 2016).

**Food Security**

Climate change may jeopardize food security—“permanent access to a sufficient, safe, and nutritious food supply needed to maintain an active and healthy lifestyle” (Brown et al., 2015; Ziska et al., 2016). Warmer temperatures and changes in extreme events could increase food’s exposure to pathogens and toxins, increasing risk of foodborne illness. However, this risk may be reduced by food safeguarding practices (Ziska et al., 2016). A heightened risk of salmonella infection was associated with extreme temperature and precipitation events in Maryland, with coastal communities disproportionately affected (Jiang et al., 2015). Climate change may also require more pesticide and drug use in food in response to greater pressure from agricultural pests and diseases, thereby increasing human exposure to chemical contaminants (Ziska et al., 2016). More frequent flooding may increase the risk of introducing contaminants into the food chain (Ziska et al., 2016). Warming oceans may result in higher mercury concentrations in seafood and more frequent high toxin levels in shellfish that are affected by harmful algal blooms (Trtanj et al., 2016; Ziska et al., 2016). The nutritional value of wheat, rice, and other crops may be reduced by higher atmospheric carbon dioxide concentrations (Ziska et al., 2016). Finally, more extreme weather events could disrupt food distribution, potentially limiting access to safe and affordable food (Ziska et al., 2016). Low-income people, children, and Indigenous populations are more vulnerable to climate impacts on food safety, nutrition, distribution and access (Ziska et al., 2016).

**Mental Health & Well-Being**

Extreme weather events can affect mental health, with impacts ranging from general anxiety disorder to post-traumatic stress disorder (Bethel et al., 2013; Dodgen et al., 2016). Most people recover from mental illness after a weather-related disaster, but trauma can have long-term effects, and some people develop chronic psychological...
dysfunction (Dodgen et al., 2016). The elderly, pregnant and post-partum women, children, those with pre-existing mental illness, the economically disadvantaged, the homeless, and first responders are at higher risk of experiencing adverse mental health outcomes from climate or weather-related events (Dodgen et al., 2016). In addition, people living in areas with greater exposure to climate change events and long-term climate disruptions, and people whose livelihood and sustenance depends upon the natural environment, are at higher risk (Dodgen et al., 2016). Even the threat of climate change can increase stress and adversely affect mental health outcomes (Bethel et al., 2013; Dodgen et al., 2016).

**Populations of Concern**

Previous Oregon climate assessments noted that certain groups, such as the elderly, young children, pregnant women, low-income individuals, persons with chronic medical conditions, and outdoor workers are particularly vulnerable to extreme heat events (Bethel et al., 2013). In addition, other groups are of particular concern, including immigrants, people with limited English proficiency, Indigenous peoples, and persons with disabilities. As is described in a chapter focused on populations of concern (Gamble et al., 2016), different degrees of vulnerability result from variations in levels of exposure to climate change, in inherent sensitivities, and in the ability to respond to climate-related health threats of people across locations, communities, and individuals throughout the lifespan.

Low-income groups, people with limited English proficiency, and undocumented immigrants are particularly vulnerable due to high exposure and low adaptive capacity (Gamble et al., 2016). In Oregon, 12% of the population is Hispanic or Latino, 15.5% is below the poverty level, 6% report speaking English less than very well, and 10% was born abroad (Haggerty et al., 2014). These people are more likely to live in areas that are prone to experience climate events. Their ability to deal with climate-related health risks is limited by income, education, and transportation, as well as limited access to and use of health and social services due to language barriers or citizenship status. In addition, chronic medical conditions are more common in these groups (Gamble et al., 2016).

Indigenous populations, especially those whose sustenance depends on the environment or those who live in isolated or impoverished communities, face greater exposure and lower resilience to health effects of climate change (Gamble et al., 2016). In Oregon, American Indians comprise 1.8% of the population (Haggerty et al., 2014). Some may lack adequate systems for safe water supply. Climate impacts on traditional foods, such as salmon, shellfish, and berries, which are integral to Indigenous culture and subsistence, may lead to poorer nutrition and higher prevalence of obesity and diabetes (Donatuto et al., 2014; Gamble et al., 2016). Indigenous communities are also at risk of losing part of their cultural identity through climate-related changes in the availability and timing of culturally relevant plant and animal species (Chisholm Hatfield and Mote, 2015; Donatuto et al., 2014). Health indicators specific to Indigenous peoples are important for assessing climate change sensitivity and creating adaptation plans for Indigenous communities, but key community health concerns are often omitted from local, regional and national climate assessments (Donatuto et al., 2014).

Children—from within their mother’s womb through their teenage years—are particularly vulnerable (Gamble et al., 2016). Children under the age of 18 comprise 23% of Oregon’s population, and 6% of Oregon’s population is younger than five-years-old (Haggerty et al., 2014). Some incidences of low birth weight and preterm birth are
associated with mothers being affected by extreme heat events, airborne particulate matter, and floods. Infants’ and toddlers’ developing bodies and immune systems, and their propensity to play on the ground and stick fingers in their mouths, increases their risk to a multitude of exposures that could result in negative health outcomes such as asthma, diarrhea, and heat-related illness. Older children’s behaviors and activities risk higher exposure to heat-related illness, vector-borne and waterborne disease, and respiratory effects from air pollution and allergens (Gamble et al., 2016).

Older adults—those age 65 years and older—will occupy a growing percentage of the population over the next several decades and are particularly vulnerable to heat waves, floods, droughts, wildfires, poor air quality, and exposure to infectious disease (Gamble et al., 2016). About 14% of Oregonians are age 65 and older; in rural areas, older adults comprise a greater percentage of the population (Haggerty et al., 2014). Older adults are already among those most affected by heat waves and they are at higher risk of becoming sick from contaminated waters. Vulnerability among older adults depends not only upon physiological factors, but also upon mobility and cognitive impairments: nearly half of older adults have some form of disability (Gamble et al., 2016).

Outdoors workers are especially exposed to extreme heat events and are at higher risk of heat-related illness; indoor workers that lack an air-conditioned environment are also at risk. Emergency responders, including firefighters, are at increased risk due to their occupational direct exposure to floods and wildfires. As wildfires increase in frequency and extent across the western United States due to climate change, more firefighters will be exposed to dangerous job conditions (Gamble et al., 2016). In Oregon, 3.4% of the workforce is employed in outdoor industries (Haggerty et al., 2014).

People with disabilities often also experience lower income and education levels leading to poorer health outcomes during extreme events or climate-related emergencies. Disabilities include limitations to hearing, speech, vision, cognition, and mobility (Gamble et al., 2016). In Oregon, 27% of adults and 37% of 8th and 11th graders report having a disability (Haggerty et al., 2014). People with disabilities are often “invisible” to decision-makers and planners who may overlook the need to make emergency response plans that specifically address the functional needs of disabled people (Gamble et al., 2016).

People with chronic medical conditions, such as cardiovascular and respiratory diseases, diabetes, asthma, obesity, and mental health challenges face higher risk of complications from heat waves (Gamble et al., 2016). For example, 11% of adults and 8% of children in Oregon have asthma (Haggerty et al., 2014). Certain medications may inhibit a person’s ability to regulate body temperature during a heat wave. Extreme climate-related events may interrupt ongoing medical treatment (Gamble et al., 2016).

The Oregon Health Authority assessed social vulnerability (Haggerty, 2015) by combining several indicators based on demographics, socioeconomic status, and health to understand Oregonians’ vulnerability to climate impacts across the state (fig. 7.4). High social vulnerability tracts “are distributed in many parts of the state, and largely overlap with broad indicators of socioeconomic status such as educational attainment” (Haggerty, 2015).
Figure 7.4 Oregon's social vulnerability composite index by census tract. This index is a combination of eleven indicators of social vulnerability including measures of demographics, socioeconomic status, and health. (Haggerty, 2015)
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