Comments of the States of California, Illinois, Maryland, New Jersey, New Mexico, Oregon, Pennsylvania, Rhode Island, and Vermont; and the California Air Resources Board

to

EPA's Proposed Rule, Adopting Subpart Ba Requirements in Emission Guidelines for Municipal Solid Waste Landfills

Docket ID No. EPA-HQ-OAR-2018-0695; RIN 2060-AU09

Appendix A: Climate Change Impacts

Our States have already begun to experience adverse impacts from climate change. Based on the overwhelming scientific evidence, those harms are likely to increase in number and severity unless aggressive steps are taken to reduce emissions of carbon dioxide and other greenhouse gases. Summarized below are some of those most significant threats being faced by our States.

CALIFORNIA

Climate change's adverse effects have become impossible to ignore in California. The state weathered a historic five-year drought only to face successive record-setting fire seasons and a variety of other unprecedented phenomena that have harmed (and are likely to increasingly harm) the health and prosperity of Californians from all walks of life and all parts of the state, as described in more detail in a recent report of the California Air Resources Board.[1]

Drought conditions beginning in 2012 left reservoirs across the state at record low levels, often no more than a quarter of their capacity. The Sierra snowpack—critical to California's water supply, tourism industry, and hydroelectric power—was the smallest in at least 500 years.[2] The resulting cutbacks threatened the livelihoods of farmers and fishermen alike. In the Central Valley, the drought cost California agriculture about $2.7 billion and more than 20,000 jobs in 2015 alone.[3] In addition, the drought led to land subsidence, due to reduced precipitation and increased groundwater pumping, and the death of 129 million trees throughout the state.[4]

Even prior to the drought, the U.S. Forest Service had found that California was at risk of losing 12 percent—over 5.7 million acres—of the total area of forests and woodlands in the state due to insects and disease thriving in a hotter climate.[5] Several pine species are projected to lose around half of their basal area.[6] And a majority of the ponderosa pine in the foothills of the central and southern Sierra Nevada Mountains has already died, killed by the western pine beetle and other bark beetles.[7] The increasing threat from these insects is driven in large part by warmer summer temperatures attributable to climate change.[8] The very high levels of tree mortality led Governor Brown to issue an Emergency Proclamation on October 30, 2015, directing state

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[1] *See generally* California Air Resources Board, *California's 2017 Climate Change Scoping Plan Update: The Strategy for Achieving California's 2030 Greenhouse Gas Target*, (Nov. 2017), https://www.arb.ca.gov/cc/scopingplan/scoping_plan_2017.pdf.
[2] *See* NOAA, National Centers for Environmental Information: "Multi-Century Evaluation of Sierra Nevada Snowpack," https://www.ncdc.noaa.gov/news/multi-century-evaluation-sierra-nevada-snowpack.
[3] *California's 2017 Climate Change Scoping Plan Update*, *supra*, at 7.
[4] U.S Forest Service, *Record 129 Million Dead Trees in California* (2017), https://www.fs.usda.gov/Internet/FSE_DOCUMENTS/fseprd566303.pdf.
[5] *California's 2017 Climate Change Scoping Plan Update*, *supra*, at 7.
[6] *Id*.
[7] *Id*.
[8] Jeffry B. Mitton and Scott M. Ferrenberg, *Mountain Pine Beetle Develops an Unprecedented Summer Generation in Response to Climate Warming*, THE AMERICAN NATURALIST, Vol. 179, No. 5 (May 2012).

agencies to identify and take action to reduce wildfire risk through the removal and use of the dead trees.[9]

Notwithstanding the Governor's Proclamation, the hotter, drier weather and millions of dead trees have increasingly accelerated the damage from wildfires. The 2018 season—the worst on record—featured the Camp Fire, which devastated the town of Paradise, California, killing at last 85 people, destroying thousands of homes, forcing the entire regional community to evacuate, burning more than 150,000 acres,[10] and severely impacting air quality across northern California.[11] Prior to 2018, the worst year on record was 2017, and before that, 2015.[12] Climate change is expected to make longer and more severe wildfire seasons "the new normal" for California.[13] Besides the immediate threats they pose to life and property, wildfires significantly impair both air quality (via smoke and ash that can hospitalize residents) and water quality (via the erosion of hillsides stripped of their vegetation).

Off the coast, rising ocean temperatures and ocean acidification have spurred toxic algal blooms, resulting in high levels of the neurotoxin domoic acid.[14] This toxin has hit California's economically valuable Dungeness crab fishery particularly hard. From 2015 to 2017, domoic acid contamination forced California to close the fishery for parts of the season in order to protect consumers from serious health risks, with the 2015-16 season declared a federal disaster.[15] Other fisheries have suffered a similar fate. The Dungeness crab fishery is expected to decline significantly in the future as acidification increases.[16] In addition, high levels of domoic acid are poisoning marine mammals, and have been linked to reproductive failure (including high rates of miscarriage and premature birth) among California sea lions.[17]

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[9] "Proclamation of a State of Emergency," https://www.gov.ca.gov/wp-content/uploads/2017/09/10.30.15_Tree_Mortality_State_of_Emergency.pdf.

[10] See http://www.fire.ca.gov/current_incidents/incidentdetails/Index/2277.

[11] Julie Turkewitz and Matt Richtel, *Air Quality in California: Devastating Fires Lead to a New* Danger, NY TIMES (Nov. 16, 2018), https://www.nytimes.com/2018/11/16/us/air-quality-california.html

[12] Lauren Tierney, *The Grim Scope of 2017's California Wildfire Season Is Now Clear; The Danger's Not Over.*, WASH. POST (Jan. 4, 2018), https://www.washingtonpost.com/graphics/2017/national/california-wildfires-comparison/.

[13] California Department of Forestry and Fire Protection, *California's Forests and Rangelands: 2010 Assessment*, Ch. 3-7 (2010).

[14] S. Morgaine McKibben et al., *Climatic Regulation of the Neurotoxin Domoic Acid*, 114 PROCEEDINGS OF THE NATIONAL ACADEMY OF SCIENCES 2 (2007).

[15] See Tara Duggan, *Toxin again an issue as Dungeness crab season nears*, S.F. CHRONICLE (Oct. 30, 2017), https://www.sfchronicle.com/food/article/Dungeness-crab-season-could-be-delayed-again-by-12318483.php; Mary Callahan, *California's crab fleet awaits share of $200 million in disaster relief*, SANTA ROSA PRESS-DEMOCRAT (Feb. 15, 2018), http://www.pressdemocrat.com/news/7996795-181/californias-crab-fleet-awaits-share?sba=AAS.

[16] Marshall, K.N. et al.. *Risks of Ocean Acidification in the California Current Food Web and Fisheries: Ecosystem Model Projections*, 21 GLOB. CHANGE BIOL. 4 (2017).

[17] T. Goldstein et al., *The Role of Domoic Acid in Abortion and Premature Parturition of California Sea Lions (Zalophus californianus) on San Miguel Island, California*, JOURNAL OF WILDLIFE DISEASES. 45(1): 91-108 (2009).

California's many miles of coastline, particularly coastal bluffs, make it uniquely vulnerable to sea-level rise and more intense storms. Even if storms do not become more intense or frequent, sea-level rise itself will magnify the adverse impact of any storm surge and high waves on the California coast. Some observational studies report that the largest waves are already getting higher and winds are getting stronger.[18] California is likely to face greater than average sea-level rise, because of gravitational forces and the rotation of the Earth. Recent projections indicate that if no significant greenhouse gas mitigation efforts are taken, the San Francisco Bay Area may experience sea level rise between 1.6 to 3.4 feet, and in an extreme scenario involving the rapid loss of the Antarctic ice sheet, sea levels along California's coastline could rise up to 10 feet by 2100.[19]

In addition to damage to the physical environment, increased temperatures California will experience due to climate change will put the health of state residents at risk. Increased hospitalizations for multiple diseases, including cardiovascular disease, ischemic heart disease, ischemic stroke, respiratory disease, pneumonia, dehydration, heat stroke, diabetes, and acute renal failure are associated with increases in same-day temperature.[20] Such temperature increases have also been found to be associated with increased risk of preterm delivery[21] and stillbirths.[22] Recent California studies suggest increased mortality risk not only with extreme heat, but also with increasing ambient temperature.[23]

In 2018, the State of California produced two substantial reports on the impacts of climate change in California, which incorporate the latest scientific research on the impacts of climate change in California. The first report, published May 2018 titled "***Indicators of Climate Change in California***" examines thirty-six separate indicators and reflects the contributions of dozens of scientists from California's universities, and state agencies, as well as the U.S.

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[18] National Research Council of the National Academy of Sciences, *Sea-Level Rise for the Coasts of California, Oregon and Washington: Past, Present, and Future*. National Academies Press (2012).

[19] Griggs, G, Árvai, J, Cayan, D, DeConto, R, Fox, J, Fricker, HA, Kopp, RE, Tebaldi, C, Whiteman, EA (California Ocean Protection Council Science Advisory Team Working Group). *Rising Seas in California: An Update on Sea-Level Rise Science*. California Ocean Science Trust, April 2017.

[20] Green R, Basu R, Malig B, Broadwin R, Kim J and Ostro B (2010). *The Effect of Temperature on Hospital Admissions in Nine California Counties.* INTERNATIONAL JOURNAL OF PUBLIC HEALTH 55(2): 113-121. *See also* Basu R, Pearson D, Malig B, Broadwin R and Green S (2012). *The effect of elevated ambient temperature on emergency room visits in California.* EPIDEMIOLOGY 23(6):813-20; Sherbakov T, Malig B, Guirguis K, Gershunov A, Basu R. (2018) *Ambient temperature and added heat wave effects on hospitalizations in California from 1999 to 2009*. ENVIRON RES. 160:83-90.

[21] Basu R, Malig B and Ostro B (2010). *High ambient temperature and the risk of preterm delivery*. AM J EPIDEMIOLOGY 172(10): 1108-1117.

[22] Basu R, Sarovar V, Malig BJ (2018) *Association Between High Ambient Temperature and Risk of Stillbirth in California*. AM J EPIDEMIOL. 183(10):894-901.

[23] Basu R and Ostro BD (2008a). *A multicounty analysis identifying the populations vulnerable to mortality associated with high ambient temperature in California*. AM J EPIDEMIOL. 168(6): 632-637; Basu R, Feng W and Ostro B (2008b). *Characterizing temperature and mortality in nine California counties, 1999-2003*. EPIDEMIOLOGY 19(1): 138 -145; Basu R and Malig B (2011). *High ambient temperature and mortality in California: Exploring the roles of age, disease, and mortality displacement*. ENVIRONMENTAL RESEARCH 111(8): 1286-1292.

National Oceanic and Atmospheric Administration and the U.S. Department of Energy's Lawrence Berkeley National Laboratory.[24] A copy of the full "Indicators" report is included in the attachments to the States' comments.

The second report, published August 2018 titled "***California's Fourth Climate Assessment***" includes thirty-three papers from State-funded research, and eleven papers from externally funded researchers, as well as regional summaries and a statewide summary of climate vulnerabilities, and a key findings paper.[25] A copy of selected research papers and the regional and statewide summaries and key findings reports are included in the attachments to the States' comments.

Key findings from those reports and other sources include the following:

Temperature Changes and Air Quality Impacts

> "Since 1895, annual average air temperatures have increased throughout the state, with temperatures rising at a faster rate beginning in the 1980s. The last four years were notably warm, with 2014 being the warmest on record, followed by 2015, 2017, and 2016. Temperatures at night have increased more than during the day: minimum temperatures (which generally occur at night) increased at a rate of 2.3 degrees Fahrenheit (°F) per century, compared to 1.3°F per century for maximum temperatures."[26]

> "Extremely hot days and nights — that is, when temperatures are at or above the highest 2 percent of maximum and minimum daily temperatures, respectively — have become more frequent since 1950. Both extreme heat days and nights have increased at a faster rate in the past 30 years. Heat waves, defined as five or more consecutive extreme heat days or nights, are also increasing, especially at night. Nighttime heat waves, which were infrequent until the mid-1970s, have increased markedly over the past 40 years."[27]

> In addition, rising temperatures "could lead to increases in ground-level ozone and reduce the effectiveness of emission reductions taken to achieve air quality standards…."[28]

> "A recent detailed analysis suggests that adoption of low-carbon energy in California to reduce GHG emissions 80 percent below 1990 levels would lead to a 55 percent

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[24] *See* Office of Environmental Health Hazard Assessment, California Environmental Protection Agency (2018). *Indicators of Climate Change in California*. Available at www.oehha.ca.gov/climate-change/document/indicators-climate-change-california (last visited October 24, 2018) (hereinafter "California Climate Indicators 2018").
[25] *See* California Natural Resources Agency, *California's Fourth Climate Change Assessment* (2018), *available at* www.ClimateAssessment.ca.gov (last visited October 24, 2018) (hereinafter "California 4th Assessment").
[26] California Climate Indicators 2018 at S-4.
[27] *Id.* at S-5.
[28] California's Fourth Climate Change Assessment, California's Changing Climate 2018: Statewide Summary Report at 40 (Aug. 2018), *available at* http://www.climateassessment.ca.gov/state/docs/20180827-StatewideSummary.pdf. (hereinafter "California Statewide Summary").

reduction in air pollution mortality rates relative to 2010 levels (Zapata et al., 2018). These public health improvements have a value of $11-20 billion/year in California (Zapata et al., 2018)."[29]

Human Health Impacts

Climate change poses direct and indirect risks to public health, as people will experience earlier death and worsening illnesses.

"Nineteen heat-related events occurred from 1999 to 2009 that had significant impacts on human health, resulting in about 11,000 excess hospitalizations. However, the National Weather Service issued Heat Advisories for only six of the events. Heat-Health Events (HHEs), which better predict risk to populations vulnerable to heat, will worsen drastically throughout the state: by midcentury, the Central Valley is projected to experience average Heat-Health Events that are two weeks longer, and HHEs could occur four to ten times more often in the Northern Sierra region."[30]

"The 2006 heat wave killed over 600 people, resulted in 16,000 emergency department visits, and led to nearly $5.4 billion in damages. The human cost of these events is already immense, but research suggests that mortality risk for those 65 or older could increase ten-fold by the 2090s because of climate change."[31]

Environmental Justice Impacts

"Multiple studies of vulnerability and climate impacts indicate that existing inequities can be exacerbated by climate change. For example, the consequences of climate-related water impacts are particularly acute for communities already dealing with a legacy of inequalities. A recent study on drought and equity in California found that low-income households, people of color, and communities already burdened with environmental pollution suffered the most severe impacts caused by water supply shortages and rising cost of water (Feinstein et al., 2017). In a report prepared as part of the Fourth Assessment, Ekstrom et al. (2018) found that while all water districts faced similar challenges during the drought, small water districts (defined as those serving less than 10,000 people or less than approximately 3,300 connections) were less likely to have the resources and capacity to overcome those challenges. These districts are most likely to serve small, rural communities in California. Furthermore, for marginalized populations in rural areas of the state, agricultural actions in response to the drought, including increases in groundwater pumping and crop choices, are increasing and reshaping their vulnerability to drought and water shortage (Greene, 2018).[32]

"Inequities not only exist in varying exposures to climate risk, but also in the availability and implementation of potential adaptation or resilience solutions. Recent research analyzed differences in tree canopy, an important tool for adapting to the effects of extreme heat, at the census block group scale in coastal Los Angeles and found

[29] *Id.* at 71.
[30] *Id.* at 10.
[31] *Id.*
[32] California Statewide Summary at 36-37.

disparities between canopy in high-income and low-income neighborhoods (Locke et al., 2017). This disparity can have implications for communities because of the benefits tree canopy provides in reducing the negative effects of extreme heat events. A study prepared for the Fourth Assessment provides one of the first estimates of these benefits in one location (Taha et al., 2018)."[33]

Tribal and Indigenous Communities Impacts

"Tribes and Indigenous communities in California face unique challenges under a changing climate. Tribes maintain cultural lifeways and rely on traditional resources (e.g., salmon fisheries) for both social and economic purposes. However, tribes are no longer mobile across the landscape. For many tribes in California, seasonal movement and camps were a part of living with the environment. Today these nomadic options are not available or are limited. This is the result of Euro-American and U.S. policy and actions and underpins several climate vulnerabilities. Tribes with reservations/Rancherias/allotments are vulnerable to climate change in a specific way: tribal lands are essentially locked into fixed geographic locations and land status. Only relatively few tribal members are still able to engage in their cultural traditions as livelihoods."[34]

Precipitation and Water Supply Impacts

"California has the highest variability of year-to-year precipitation in the contiguous United States."[35] By 2050, "the average water supply from snowpack is projected to decline by 2/3 from historical levels."[36]

"Statewide precipitation has become increasingly variable from year to year. In seven of the last ten years, statewide precipitation has been below the statewide average (22.9 inches). In fact, California's driest consecutive four-year period occurred from 2012 to 2015. In recent years, the fraction of precipitation that falls as rain (rather than snow) over the watersheds that provide most of California's water supply has been increasing — another indication of warming temperatures."[37]

"Spring snowpack, aggregated over the Sierra Nevada and other mountain catchments in central and northern California, declines substantially under modeled climate changes (Figure 6). The mean snow water equivalent (SWE) declines to less than two-thirds of its historical average by 2050, averaged over several model projections under both RCP 4.5 and 8.5 scenarios. By 2100, SWE declines to less than half the historical median under RCP 4.5, and less than one-third under RCP 8.5. Importantly, the decline in spring snowpack occurs even if the amount of precipitation remains relatively stable over the

[33] *Id.* at 37.
[34] *Id.* at 10.
[35] *Id.* at 24.
[36] California's Fourth Climate Change Assessment, California's Changing Climate 2018: A Summary of Key Findings from California's Fourth Climate Change Assessment 6 (Aug. 2018), *available at* http://www.climateassessment.ca.gov/state/docs/20180827-SummaryBrochure.pdf. (hereinafter "California Key Findings") at 5.
[37] California Climate Indicators at S-5.

central and northern California region; the snow loss is the result of a progressively warmer climate. Furthermore, while the models indicate that strong year-to-year variation will continue to occur, the likelihood of attaining spring snowpack that reaches or exceeds historical average is projected to diminish markedly (Pierce et al., 2018) (Figure 6)."[38]

Agriculture Impacts

"Agricultural production could face climate-related water shortages of up to 16% in certain regions. Regardless of whether California receives more or less annual precipitation in the future, the state will be dryer because hotter conditions will increase the loss of soil moisture."[39]

"Winter chill has been declining in certain areas of the Central Valley. This is the period of cold temperatures above freezing but below a threshold temperature needed by fruit and nut trees to become and remain dormant, bloom, and subsequently bear fruit. When tracked using "chill hours," a metric used since the 1940s, more than half the sites studied showed declining trends; with the more recently developed "chill portions" metric, fewer sites showed declines."[40]

"[I]t is evident from recent droughts that agricultural production will be challenged by water shortages, higher temperatures, changing atmospheric conditions, and conversion of agricultural land to developed uses (Medellín-Azuara et al., 2018; Wilson et al., 2017). Agriculture is the economic foundation for many of California's communities, particularly rural communities where other employment opportunities are limited. Roughly 6.7 percent of jobs statewide are generated by farms and farm processing, and in the Central Valley the figure is much higher (22 percent) (UC Agricultural Issues Center, 2012). This means that climate change impacts to agriculture, and even nuanced impacts such as shifting cropping patterns, may create hardships in the rural communities where agriculture is foundational. Different crops have different labor demands (Medellín-Azuara et al., 2016), and shifting crop patterns may result in changes in employment throughout the agricultural sector (Greene, 2018; Villarejo, 1996). A Fourth Assessment study found that in the 2012-2016 drought, to access higher market prices and compensate for the higher cost of water, many farms switched to higher value crops, for which cultivation and harvesting could be largely automated— leaving agricultural workers with employment shortages beyond the drought (Greene, 2018). A report by the University of California found that in 2016, the drought resulted in a $603 million loss to the economy and the loss of 4,700 jobs due to the impacts on agriculture (Medellín-Azuara et al., 2016)."[41]

Forest Impacts

A new paper published on October 18, 2018, estimates that "human-caused climate change caused over half of the documented increase in fuel aridity since the 1970s and

[38] California Statewide Summary at 27.
[39] *Id.*
[40] California Climate Indicators at S-5.
[41] California Statewide Summary at 59.

doubled the cumulative forest fire area since 1984," contributing an additional 4.2 million ha [hectares] of forest fire.[42] As the paper notes, "[i]ncreased forest fire activity across the western United States in recent decades has contributed to widespread forest mortality, carbon emissions, periods of degraded air quality and substantial fire suppression expenditures."[43]

"A changing climate combined with anthropogenic factors has already contributed to more frequent and severe forest wildfires in the western U.S. as a whole (Abatzoglou & Williams, 2016; Mann et al., 2016; Westerling, 2016)."[44]

"One Fourth Assessment model suggests large wildfires (greater than 25,000 acres) could become 50% more frequent by the end of century if emissions are not reduced. The model produces more years with extremely high areas burned, even compared to the historically destructive wildfires of 2017 and 2018."[45]

"By the end of the century, California could experience wildfires that burn up to a maximum of 178% more acres per year than current averages."[46] Increased wildfire smoke will also lead to more respiratory illness.[47]

In addition, the changes in climate make trees more vulnerable to pest infestations.

"Moisture stress in conifer forests enhances tree vulnerability to insect infestation, particularly by bark beetles (Anderegg et al., 2015; Bentz et al., 2010; Berryman, 1976; Gaylord et al., 2013; Hart et al., 2014; Kolb et al., 2016; Raffa et al., 2008). Between 2010 and 2017, an estimated 129 million trees have died (Young et al., 2017). Bark beetle outbreaks may be promoted by warming for multiple reasons (Bentz et al., 2010). Warming may promote successful beetle overwintering (Weed et al., 2015) and may also promote earlier timing of adult emergence and flight in spring/early summer, which may enable beetles to increase the frequency at which they can mate, lay eggs, and emerge as adults (Bentz et al., 2016)."[48]

Drought and Land Subsidence Impacts

"The recent 2012-2016 drought was exacerbated by unusual warmth (Williams, Seager, et al., 2015), and disproportionately low Sierra Nevada snowpack levels (Dettinger & Anderson, 2015). This drought has been described as a harbinger of projected dry spells in future decades, whose impacts will likely be worsened by increased heat (Mann & Gleick, 2015). A very wet winter in 2016-2017 followed this drought, a further indication

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[42] John T. Abatzoglou and A. Park Williams, Impact of Anthropogenic Climate Change on Wildfire Across the Western U.S. Forests, *Proceedings of the National Academy of Science*, vol. 113, no. 42 (Oct. 18, 2018), *available at* https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5081637/pdf/pnas.201607171.pdf.
[43] *Id.*
[44] California Statewide Summary at 28.
[45] California Key Findings at 6.
[46] *Id.*
[47] *Id.* at 8.
[48] California Statewide Summary at 64.

of potential continued climate volatility in the future (Berg & Hall, 2015; Polade, et al., 2017; Swain et al., 2018)."[49]

"Warming air temperatures throughout the 21st century will increase moisture loss from soils, which will lead to drier seasonal conditions even if precipitation increases (Thorne et al., 2015). Warming air temperatures also amplify dryness caused by decreases in precipitation (Ault et al., 2016; Cayan et al., 2010; Diffenbaugh et al., 2015). These changes affect both seasonal dryness and drought events. Climate projections from the previous and present generation of GCMs (e.g. Pierce et al., 2014; Swain et al., 2018) show that seasonal summer dryness in California may become prolonged due to earlier spring soil drying that lasts longer into the fall and winter rainy season. The extreme warmth during the drought years of 2014 and 2015 intensified some aspects of the 2012-2016 drought (Griffin & Anchukaitis, 2014; Mao et al., 2015; Stephenson et al., 2018; Williams, Seager, et al., 2015) and may be analogous for future drought events (Diffenbaugh et al., 2015; Mann & Gleick, 2015; Williams, Seager, et al., 2015)."[50]

In addition, a "secondary, but large, effect of droughts is the increased extraction of groundwater from aquifers in the Central Valley, primarily for agricultural uses. The pumping can lead to subsidence of ground levels, which around the San Joaquin-Sacramento Delta has been measured at over three-quarters of an inch per year."[51]

"This subsidence compounds the risk that sea-level rise and storms could cause overtopping or failure of the levees, exposing natural gas pipelines and other infrastructure to damage or structural failure. At this rate of subsidence, the levees may fail to meet the federal levee height standard (1.5 ft. freeboard above 100-year flood level) between 2050-2080, depending on the rate of sea-level rise."[52]

Sea-Level Rise, Coastal Erosion and Infrastructure Impacts

"Along the California coast, sea levels have generally risen. Since 1900, mean sea level has increased by about 180 millimeters (7 inches) at San Francisco and by about 150 millimeters (6 inches) since 1924 at La Jolla. In contrast, sea level at Crescent City has declined by about 70 millimeters (3 inches) since 1933 due to an uplift of the land surface from the movement of the Earth's plates. Sea level rise threatens existing or planned infrastructure, development, and ecosystems along California's coast."[53]

"If emissions continue at current rates, Fourth Assessment model results indicate that total sea-level rise by 2100 is expected to be 54 inches, almost twice the rise that would occur if greenhouse gas emissions are lowered to reduce risk."[54]

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[49] *Id.* at 13.
[50] *Id.* at 26.
[51] *Id.* at 14.
[52] California Statewide Summary at 12.
[53] California Climate Indicators at S-7.
[54] California Key Findings, at 6.

"31 to 67% of Southern California beaches may completely erode by 2100 without large-scale human interventions."[55]

"Flooding from sea-level rise and coastal wave events leads to bluff, cliff, and beach erosion, which could affect large geographic areas (hundreds of kilometers). In research conducted for the Fourth Assessment, Erikson et al. (2018) found that if a 100-year storm occurs under a future with 2m (6.6 feet) of SLR, resultant flooding in Southern California could affect 250,000 people and lead to damages of $50 billion worth of property and $39 billion worth of buildings."[56]

In addition, airports in major urban areas will be susceptible to major flooding from sea-level rise and storm surge by 2040-2080, and 370 miles of coastal highway will be susceptible to coastal flooding by 2100.[57]

Ocean Acidity and Health Impacts

"Increasing evidence shows that climate change is degrading California's coastal and marine environment. In recent years, several unusual events have occurred along the California coast and ocean, including a historic marine heat wave, record harmful algal bloom, fishery closures, and a significant loss of northern kelp forests."[58]

In addition:

"[o]cean acidification … is predicted to occur especially rapidly along the West Coast (e.g., Gruber et al., 2012). Ocean acidification presents a clear threat to coastal communities through its significant impacts on commercial fisheries and farmed shellfish (Ekstrom et al., 2015) as well as to ocean ecosystems on a broader scale. Ocean acidification affects many shell-forming species, including oysters, mussels, abalone, crabs, and the microscopic plankton that form the base of the oceanic food chain (Kroeker et al., 2013; Kroeker et al., 2010). Significant changes in behavior and physiology of fish and invertebrates due to rising CO2 and increased acidity have already been documented (e.g., Hamilton et al., 2017; Jellison et al., 2017; Kroeker et al., 2013; Munday et al., 2009). Species vulnerable to ocean acidification account for approximately half of total fisheries revenue on the West Coast (Marshall et al., 2017)."[59]

ILLINOIS

Climate change is affecting Illinois in a number of ways—both by fundamentally altering the state's environment in ways never seen before and by intensifying well-recognized weather hazards. The fundamental changes can be seen in Illinois' farming industry and in the state's greatest environmental asset, Lake Michigan.

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[55] *Id.* at 15.
[56] California Statewide Summary at 31.
[57] *Id.* at 54-55.
[58] *Id.* at 12.
[59] *Id.* at 66-67.

The farming sector is particularly vulnerable to extreme precipitation caused by climate change. 2012 was Illinois' third driest summer on record. The very next year, heavy rainfall caused flooding in parts of the state that, together with the wettest January-to-June period ever recorded in Illinois, forced farmers to delay planting and lose revenue.[60] Heat waves during the crop pollination season may reduce future yield: hotter weather and altered rain patterns could cause 15% loss in the next 5 to 25 years and up to a 73% average loss by the end of the next century.[61] Milder winters will lead to more weeds, insects, and diseases surviving throughout winter, also hurting yield and quality.[62]

Climate disruption also contributes to whipsawing water levels on Lake Michigan. In January 2013, the lake fell to an all-time low water level. In 2015, it climbed to its highest level since 1998, the second-largest recorded gain over a 24-month span.[63] Rapidly swinging water levels hurt the commercial shipping industry, recreational boaters, wildlife, and beach-goers. For example, for every inch the lake loses, a freighter must forgo 270 tons of cargo. High water erodes beaches and damages property.[64]

Climate change has already turned up the volume on well-recognized catastrophic extreme weather events, causing stronger storms, increased precipitation, and higher average temperatures. In recent years, the state has been struck by deadly tornadoes in November 2013 and the 2014 polar vortex.[65]

Illinois also suffers from frequent flooding, and climate change has and will cause the frequency and strength of these floods to increase. For instance, flooding caused by increased precipitation causes dramatic damage to the lives and property of Illinois residents; this toll will increase as climate change intensifies. For example, in 2009, a freight train carrying ethanol derailed in Cherry Valley, Illinois due to washout of train tracks following heavy rains.[66] Fourteen of the tanker cars carrying ethanol caught fire, killing a woman in her car waiting for

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[60] University of Illinois–Institute of Government & Public Affairs, *Preparing for Climate Change in Illinois: An Overview of Anticipated Impacts*, https://igpa.uillinois.edu/sites/igpa.uillinois.edu/files/reports/Preparing-for-Climate-Change-in-Illinois.pdf (last visited Oct. 11, 2018).
[61] *Id.*
[62] *Id.*
[63] Tony Briscoe, *Lake Michigan Water Levels Rising at Near Record Rate*, CHICAGO TRIBUNE (July 12, 2015), *available at* http://www.chicagotribune.com/news/local/breaking/ct-lake-michigan-water-levels-met-20150710-story.html.
[64] *Id.*
[65] National Weather Service, *Historic Tornado Outbreak of November 17, 2013*, https://www.weather.gov/ilx/17nov13 (last visited Oct. 11, 2018); National Weather Service, *The Bitterly Cold Air of January 27-28, 2014*, https://www.weather.gov/lot/2014jan28 (last visited Oct. 11, 2018).
[66] National Transportation Safety Board, *Derailment of CN Freight Train U70691-18 with Subsequent Hazardous Materials Release and Fire*, https://www.ntsb.gov/investigations/AccidentReports/Pages/RAR1201.aspx (last visited Oct. 11, 2018).

the train to pass. Seven other people were injured and about 600 nearby homes were evacuated.[67] A few days later, a 54-mile-long fish kill occurred on the Rock River when ethanol that was not consumed by the fire flowed downstream, killing over 70,000 fish.[68]

CHERRY VALLEY TRAIN DERAILMENT

Image from Rockford Register Star

In another instance, a major flood struck Jo Daviess County in northwestern Illinois in 2011 after 15 inches of rain fell during a 12-hour time period. The flood waters caused extensive damage to roads and train tracks and at least one fatality.[69] Illinois has also struggled with urban flooding caused by heavy rains falling on impervious surfaces.[70]

[67] CBC.ca, *CN Blamed for Fatal Train Derailment in Illinois*, https://www.cbc.ca/news/canada/cn-blamed-for-fatal-train-derailment-in-illinois-1.1139430 (last visited Oct. 12, 2018).
[68] Illinois Attorney General, *Attorney General Madigan Reaches Settlement to Recover Costs of Rockford Train Derailment, Ethanol Leak*, http://www.illinoisattorneygeneral.gov/pressroom/2015_03/20150305.html (last visited Oct. 12, 2018).
[69] *Crews Find Body of Woman Swept Away by Flood in Galena*, ROCKFORD REGISTER STAR (July 30, 2011), *available at* www.rrstar.com/x555032097/Crews-find-body-of-woman-swept-away-by-flood-in-Galena
[70] NOAA National Centers for Environmental Information, *State Climate Summaries: Illinois*, https://statesummaries.ncics.org/il (last visited Oct. 11, 2018).

2011 JO DAVIESS COUNTY FLOOD

Images from Rockford Register Star

Furthermore, rising average temperatures injures Illinois residents. Hotter weather will inevitably harm public health and lead to heat-related deaths. For instance, over 700 Illinois residents died due to the historically intense heat wave in July 1995.[71] Intensified drought conditions strengthen these impacts—the inverse of heavy precipitation.

Though catastrophes such as these have occurred from time to time throughout Illinois' history, climate change will cause them to happen more frequently and with more ferocity than ever before, at the cost of the lives and health of Illinois residents.

MARYLAND

With more than 3,000 miles of coastline, Maryland's coast is particularly vulnerable to rising sea levels and the more extreme weather events associated with climate change: shoreline erosion, coastal flooding, storm surges, inundation, and saltwater intrusion into groundwater supplies.

In 2007, the Maryland Commission on Climate Change (MCCC) was established by Executive Order 01.01.2007.07 and was charged with evaluating and recommending state goals to reduce Maryland's greenhouse gas emissions to 1990 levels by 2020 and to reduce those emissions to 80 percent of their 2006 levels by 2050. The MCCC was also tasked with developing a plan of action that addressed the causes and impacts of climate change and included firm benchmarks and timetables for policy implementation. As a result of the work of more than 100 stakeholders and subject matter experts, the MCCC produced a climate action plan. That

[71] Jan C. Semenza, *et al*., *Heat Related Deaths During the 1995 Heat Wave in Chicago*, THE NEW ENGLAND JOURNAL OF MEDICINE (July 11, 1996), *available at* https://www.nejm.org/doi/full/10.1056/NEJM199607113350203.

plan was the impetus for Maryland's Greenhouse Gas Emissions Reduction Act of 2009, an enhanced version of which became law in 2016.[72]

As emphasized by the MCCC's Science and Technical Working Group, estimates show that "Maryland is projected to experience between 2.1 and 5.7 feet of sea level rise over the next century. In fact, sea level could be as much as 2.1 feet higher in 2050 along Maryland's shorelines than it was in 2000."[73]

Sea level rise could inundate some facilities of the Port of Baltimore, placing one of the most important ports along the East Coast at risk. In 2016, for instance, the Port generated nearly $3 billion in wages and salaries, supported over 13,000 direct jobs, and moved 31.8 million tons of international cargo.[74]

The state's tourism sector is also likely to feel the impact of climate change.[75] In 2015, for instance, tourism resulted in $2.3 billion in tax revenue, which directly supported more than 140,000 jobs with a payroll of $5.7 billion.[76] Rising sea levels, flooding, and heightened storm surges will place further strain on Maryland's low-lying urban and coastal lands, making tourism less feasible and increasing the costs of maintaining bridges, roads, boardwalks, and other tourism infrastructure.[77] Beaches, moreover, "will move inland at a rate 50 to 100 times faster than the rate of sea level elevation" and "the cost of replenishing the coastline after a 20-inch rise in sea level would be between $35 million and $200 million."[78]

Further, skiing and other snow sports "are at obvious risk from rising temperatures, with lower-elevation resorts facing progressively less reliable snowfalls and shorter seasons."[79] Wisp Mountain Park, for example, is a popular skiing destination in Western Maryland, and the only ski resort in the State. Even in late December of 2015, only one of the resort's 35 trails was open because of the difficulty keeping snow on the ground in above-freezing temperatures.[80]

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[72] Maryland Commission on Climate Change, 2016 Annual Report 7, http://mde.maryland.gov/programs/Air/ClimateChange/MCCC/Documents/MCCC_2016_final.pdf ("MCCC 2016 Annual Report").
[73] Maryland Commission on Climate Change, 2015 Annual Report 13, http://mde.maryland.gov/programs/Air/ClimateChange/MCCC/Publications/MCCC2015Report.pdf ("MCCC 2015 Annual Report").
[74] Maryland Commission on Climate Change, 2017 Annual Report 12, http://www.mde.state.md.us/programs/Air/ClimateChange/MCCC/Documents/MCCC_2017_final.pdf ("MCCC 2017 Annual Report").
[75] Center for Climate and Energy Solutions, Cost of Inaction Supplement, September 2015, https://www.c2es.org/document/climate-change-the-cost-of-inaction-for-marylands-economy/.
[76] Maryland Office of Tourism Development, Fiscal Year 2016 Tourism Development Annual Report, 2016, available at: http://industry.visitmaryland.org/research/annual-reports/annual-reports-archive/.
[77] MCCC 2015 Annual Report 14, *supra*.
[78] MCCC 2017 Annual Report 16, *supra*.
[79] MCCC 2016 Annual Report 18-19, *supra*.
[80] MCCC 2017 Annual Report 15, *supra*.

Climate change may also adversely impact Maryland's agricultural industry, which employs some 350,000 people.[81] In 2015, the market value of agricultural products produced in Maryland was $2.2 billion, with net farm income exceeding $500 million.[82] By 2050, absent additional action, rising summer temperatures could result in nearly $150 million in median annual losses for corn, soy, and wheat.[83] Increased flooding could adversely affect the stability, salinity, drainage, and nutrient balance of soil in low-lying areas, causing declines in crop production and making farming less viable. Rising seas could lead salt water to flow into aquifers used for irrigation. Livestock could suffer from higher temperatures, too, and would need more access to cooler areas. By causing soil erosion and nutrient runoff, moreover, increased rainfall could adversely affect water quality, including in the Chesapeake Bay.[84]

Climate change will have significant effects on forests, which contribute some $2.2 billion to the Maryland economy, as well as $24 billion in ecological services.[85] Climate change will exacerbate species' existing stressors and alter their distribution, with some species likely to leave or decline and others likely to arrive or increase. Further, the services that forests provide—such as temperature regulation and water filtration—may be affected by climate change.[86]

Climate change also threatens the Chesapeake Bay, the largest estuary in the United States. Development and pollution have made the Bay and its ecosystems more vulnerable to stressors, including those resulting from climate change. Already, the Bay has warmed by three degrees Fahrenheit. Further temperature increases could change the composition of commercial fisheries and deprive aquatic life of the oxygen needed to survive. Some species are likely to move north towards cooler waters and more suitable habitats. Other forms of aquatic life, including invasive pests and diseases, are likely to arrive or proliferate in the Bay's newly-warmed waters.[87]

In terms of health impacts, Maryland is likely to experience increasing numbers of 90-degree days, markedly exacerbating heat-related illnesses and mortality, particularly among the elderly.[88] A two-week heat wave in 2012, for instance, led to 12 deaths in Maryland.[89] By mid-century, rising temperatures could cause 27 additional deaths each summer in Baltimore alone.[90]

NEW JERSEY

New Jersey's coastal geomorphology – its sandy beaches, flat coastal plain with a gradually sloping shoreline, low-lying barrier islands, and gradual subsidence – makes the risks of sea level rise from global warming particularly severe in the state. New Jersey's nearly 1,800

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[81] *Id.* at 13.
[82] *Id.* at 14.
[83] MCCC 2015 Annual Report 15, *supra.*
[84] *Id.*
[85] *Id.*
[86] *Id.* at 15-16.
[87] *Id.* at 16.
[88] MCCC 2017 Annual Report 9, 17, *supra*.
[89] MCCC 2016 Annual Report 18-19, *supra*.
[90] *Id.*

miles of tidally-flowed shoreline, its 239 coastal communities, and its 2 million coastal county residents, are especially vulnerable to flooding, inundation, and erosion from sea level rise and the effects of stronger, fiercer storms.[91] New Jersey has been ranked as one of the most threatened states in terms of the value of coastal real estate at risk from sea level rise and chronic flooding in the coming decades.[92] Rising sea levels also endanger water supplies as saltwater intrusion of New Jersey's coastal and lower Delaware River aquifers increases water salinity above drinking standards.[93]

Sea levels in New Jersey are already rising by an average of 1.6 inches per decade, almost double the global rate.[94] USEPA has projected that the global warming will cause sea levels to rise an additional 18 inches to 4 feet in New Jersey by 2100.[95] Further sea level rise of even 12 inches could cause shorelines to recede by as much as 120 feet.[96] Barrier islands on the state's Atlantic Coast from Bay Head to Cape May could be broken up by new inlets or lost to erosion if sea level rises three feet by 2100.[97] And up to 3 percent of New Jersey's land area could be inundated by four-foot sea level rise,[98] which would affect countless homes, businesses, hospitals, schools, and critical infrastructure.

These effects of sea level rise are magnified during storm events, which increase the severity of coastal flooding and erosion. For example, in 2012, Superstorm Sandy wreaked havoc in the state when a storm surge reached 9-10 feet above normal in some coastal areas. The extensive damage the State experienced from severe winds and coastal flooding reached an estimated $29.4 billion in repair, response and restoration costs.[99] Sandy also cost the state an estimated $11.7 billion in lost gross domestic product, including $950 million in tourism losses.[100] Sandy

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[91] Small-Lorenz, S., Shadel, B. and Glick, P., *Building Ecological Solutions to Coastal Community Hazards: A Guide for New Jersey Coastal Communities* (2017), at 10, available at https://www.nj.gov/dep/oclup/docs/bescch-final.pdf (last accessed October 17, 2018); Union of Concerned Scientists (UCS), *New Jersey: Confronting Climate Change in the U.S. Northeast* (2007), at 2, available at https://www.state.nj.us/dep/cleanair/hearings/pdf/09_confronting.pdf (last accessed October 21, 2018).
[92] Union of Concerned Scientists, *Underwater: Rising Seas, Chronic Floods, and the Implications for US Coastal Real Estate* (June 2018), at 5-7, 10-11, available at https://www.ucsusa.org/sites/default/files/attach/2018/06/underwater-analysis-full-report.pdf (last accessed October 23, 2018).
[93] NJ Climate Adaptation Alliance, *A Summary of Climate Change Impacts and Preparedness Opportunities for the Water Resources Sector in New Jersey* (March 2014), at 5, available at https://njadapt.rutgers.edu/docman-lister/resource-pdfs/98-njcaa-water/file (last accessed October 21, 2018).
[94] NOAA National Centers for Environmental Information, *State Climate Summaries: New Jersey*, available at https://statesummaries.ncics.org/nj (last accessed October 15, 2018).
[95] USEPA, *What Climate Change Means for New Jersey*, EPA 430-F-16-032 (August 2016), available at https://www.epa.gov/sites/production/files/2016-09/documents/climate-change-nj.pdf (last accessed October 17, 2018).
[96] Small-Lorenz et al., *Building Ecological Solutions*, supra, n.1, at 16.
[97] USEPA, *What Climate Change Means for New Jersey*, supra, n.5, at 1.
[98] Small-Lorenz et al., *Building Ecological Solutions*, supra, n.1, at 12.
[99] NOAA, *New Jersey Climate Summary*, supra, n.4.
[100] NJ Climate Adaptation Alliance, *Summary of Climate Change Impacts and Preparedness Opportunities for the Coastal Communities* (April 2014), at 5, available at https://njadapt.rutgers.edu/docman-lister/working-briefs/108-njcaa-coastal-communities/file (last accessed October 21, 2018).

had a catastrophic effect on regional electric and wastewater infrastructure: 73% of the state's electric customers experienced outages[101] and the state's largest treatment plant was inundated and dumped 240 million gallons of sewage into the Newark Bay.[102]

Sea level rise and coastal flooding also threaten to obliterate New Jersey's extensive coastal wetlands. Its tidal marshes are one of the state's defining features, valuable as a buffer for back-bay communities against erosion and tidal flooding, and as wildlife habitat. The state's coastal wetlands are an important stopover point for about 1.5 million migratory birds, including rare and endangered species like the red knot, and the Delaware Bay's tidal shores are the breeding grounds for the world's largest population of horseshoe crabs.[103]

With more frequent and intense storms and accelerated sea level rise, tidal flats and marshes could become open water, jeopardizing species that entirely depend on this ecosystem to feed and nest. In Barnegat Bay and Little Egg Harbor, the rising sea is already eroding and submerging small marsh islands, which are important nesting areas for many seabirds. USEPA found that the salt marshes all along the Atlantic Coast between Cape May and the Meadowlands could be entirely displaced by sea level rise of three feet. Coastal wetlands along Delaware Bay in Cumberland County are more vulnerable still and could be lost if the sea rises by only two feet.[104]

NEW MEXICO

The Southwest and New Mexico are experiencing the effects of climate change at a rate much faster than the majority of U.S. states. Warming trends in the southwestern U.S. have exceeded global averages by nearly 50 percent since the 1970s, and average temperatures in New Mexico have been increasing 50 percent faster than the global average over the past century.[105] Temperatures in the Upper Rio Grande River basin are increasing at a rate of roughly 0.7° F per decade, contributing to an average warming of 2.7° F since 1970.[106] Mountains have shown a higher rate of temperature rise when compared to lower elevations.[107] Both minimum and

[101] NJ Climate Adaptation Alliance, *Summary of Climate Change Impacts and Preparedness Opportunities for Telecommunications and Energy Utilities* (March 2014), at 5-6, available at https://njadapt.rutgers.edu/docman-lister/resource-pdfs/97-njcaa-utilities/file (last accessed October 21, 2018).
[102] NJ Climate Adaptation Alliance, *Summary of Climate Change Impacts and Preparedness Opportunities for the Water Resources Sector* (March 2014), at 5, available at https://njadapt.rutgers.edu/docman-lister/resource-pdfs/98-njcaa-water/file (last accessed October 21, 2018).
[103] NJ Climate Adaptation Alliance, *Summary of Climate Change Impacts and Preparedness Opportunities Affecting Natural Resources* (March 2014), at 1, available at https://njadapt.rutgers.edu/docman-lister/working-briefs/106-njcaa-natural-resources/filehttps://njadapt.rutgers.edu/docman-lister/resource-pdfs/97-njcaa-utilities/file (last accessed October 21, 2018).
[104] USEPA, *What Climate Change Means for New Jersey*, supra, n.5, at 2.
[105] Nature Conservancy, *Implications of Recent Climate Change*, at iii; Robert Repetto, *New Mexico's Rising Economic Risks from Climate Change*, DĒMOS, at 1 (2012).
[106] Jason Funk et al., *Confronting Climate Change in New Mexico* at 6-7, 9 (Union of Concerned Scientists, April 2016); www.ucsusa.org/NewMexicoClimateChange (last visited Oct. 18, 2018).
[107] Dagmar Llewellyn & Seshu Vaddey, *West-Wide Climate Risk Assessment: Upper Rio Grande Impact Assessment*, at 1, 37-38, 117 (U.S. Department of Interior, Bureau of Reclamation, Dec.

maximum monthly temperatures also show rising trends. The number of very hot days and nights -- defined as temperatures above the warmest 10 percent of days on record -- has increased since 1950. Heat waves lasting longer than four days have also significantly increased since 1960.[108] These occurrences do not only affect a specific part of the state; over 95 percent of New Mexico has experienced mean temperature increases.[109]

Key findings from the Third U.S. National Climate Assessment (Assessment) for the Southwest include:

- Snowpack and streamflow amounts are projected to decline in parts of the Southwest, decreasing surface water supply reliability for cities, agriculture, and ecosystems.[110] (This is a critical issue for New Mexico because the state's social, economic and environmental systems are already water-scarce and thus vulnerable to the supply disruptions which are likely to accompany future climate changes.[111]).

- Increased warming, drought, and insect outbreaks caused by or linked to climate change have increased the frequency of catastrophic wildfires impacting people and ecosystems in the Southwest. Fire models project more wildfire and increased risks to communities across extensive areas.[112]

- The Southwest's 182 federally recognized tribes and communities share particularly high vulnerabilities to climate changes such as high temperatures, drought, forest fires, and severe storms. Tribes may face loss of traditional foods, medicines, and water supplies due to declining snowpack, increasing temperatures, increasing drought, forest fires, and subsequent flooding. Historic land settlements and high rates of poverty – more than double that of the general United States population – constrain tribes' abilities to respond effectively to climate challenges.[113]

2013); https://www.usbr.gov/watersmart/baseline/docs/urgia/URGIAMainReport.pdf (last visited Oct. 19, 2018).

[108] Repetto, Robert, *New Mexico's Rising Economic Risks from Climate Change*, at 1, *available at* https://www.demos.org/sites/default/files/publications/UpdatedNMFullReport.pdf (last visited Oct. 24, 2018); *see also* Nature Conservancy, *Implications of Recent Climate Change*, *supra*, at 4.

[109] Nature Conservancy, *Implications of Recent Climate Change*, *supra*, at iii.

[110] U.S. Global Change Research Program, *2014 National Climate Assessment*, at 463 (2014), *available at* https://nca2014.globalchange.gov/report/regions/southwest%0D (last visited Jan. 8, 2018).

[111] Brian H. Hurd & Julie Coonrod, *Climate Change and Its Implications for New Mexico's Water Resources and Economic Opportunities*, NM State University, Technical Report 45, at 1, 24 (2008); https://aces.nmsu.edu/pubs/research/economics/TR45.pdf (last visited Oct. 18, 2018).

[112] *Id.*

[113] The White House, Office of the Press Secretary, *FACT SHEET: What Climate Change Means for New Mexico and the Southwest*, at 3 (2014), *available at* https://obamawhitehouse.archives.gov/sites/default/files/docs/state-reports/NEWMEXICO_NCA_2014.pdf (last visited Oct. 18, 2018); *see also Confronting Climate Change in New Mexico, supra*, at 6-7, 9.

- The Southwest produces more than half of the nation's high-value specialty crops, which are irrigation-dependent and particularly vulnerable to extremes of moisture, cold, and heat. Reduced yields from increasing temperatures and increasing competition for scarce water supplies will displace jobs in some rural communities.[114]

- Increased frost-free season length, especially in already hot and moisture-stressed regions like the Southwest, is projected to lead to further heat stress on plants and increased water demands for crops. Higher temperatures and more frost-free days during winter can lead to early bud burst or bloom of some perennial plants, resulting in frost damage when cold conditions occur in late spring; in addition, with higher winter temperatures, some agricultural pests can persist year-round, and new pests and diseases may become established.[115]

Key findings from the Assessment for New Mexico include:

- Streamflow totals in the Rio Grande and other rivers in the Southwest were 5 percent to 37 percent lower between 2001 and 2010 than average flows during the 20th century. Projections of further reduction of late-winter and spring snowpack and subsequent reductions in runoff and soil moisture pose increased risks to water supplies needed to maintain cities, agriculture, and ecosystems.[116]

- Drought and increased temperatures due to climate change have caused extensive tree death across the Southwest. Winter warming due to climate change has exacerbated bark beetle outbreaks by allowing more beetles, which normally die in cold weather, to survive and reproduce.[117] Wildfire and bark beetles killed trees across one fifth of New Mexico and Arizona forests from 1984 to 2008.[118] Climate changes caused extensive piñon pine mortality in New Mexico between 1989 and 2003.[119]

- Exposure to excessive heat can aggravate existing human health conditions, such as respiratory and heart disease. Increased temperatures can reduce air quality because atmospheric chemical reactions proceed faster in warmer conditions. As a result, heat waves are often accompanied by increased ground level ozone, which can cause respiratory distress. Increased temperatures and longer warm seasons will lead to shifts in the distribution of disease-transmitting mosquitoes.[120]

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114 U.S. Global Change Research Program, *2014 National Climate Assessment*, *supra*, at 463.
115 *Id.*
116 *Id.*
117 *Id.*
118 *Id.* at 468.
119 *Id.* at 484.
120 *What Climate Change Means for New Mexico and the Southwest*, *supra*, at 2-3.

Additionally, a recent study led by Los Alamos National Laboratories found that greenhouse gas-driven warming may lead to the death of 72 percent of the Southwest's evergreen forests by 2050, and nearly 100 percent mortality of these forests by 2100.[121]

If action is not taken to reduce greenhouse gas emissions, climate models project substantial changes in New Mexico's climate over the next 50 to 100 years. Barring reduction efforts, projected climate changes by mid- to late 21st century include: air temperatures warming by 6-12 degrees Fahrenheit on average, but more so in winter, at night, and at high elevations; more episodes of extreme heat, fewer episodes of extreme cold; more intense storm events and flash floods; and winter precipitation falling more often as rain and less often as snow.[122] Severe and sustained drought will stress water sources, already over-utilized in many areas, forcing increasing water-allocation competition among farmers, energy producers, urban dwellers, and ecosystems.[123]

OREGON

Oregon is already experiencing adverse impacts of climate change and these impacts are expected to become more pronounced in the future, significantly affecting Oregon's economy and environment:

Loss of Snowpack and Drought

The seasonal flow cycles of rivers and streams are changing due to warmer winters and decreased mountain snowpack accumulation, as more precipitation falls as rain, not snow.[124] The Third Oregon Climate Assessment Report[125] explained that events in 2015 demonstrated the kind of impacts this has already had, and will have in the future:

> In 2015, Oregon was the warmest it has ever been since record keeping began in 1895 (NOAA, 2017). Precipitation during the winter of that year was near normal, but winter temperatures that were 5–6°F above average caused the precipitation that did fall to fall as rain instead of snow, reducing mountain snowpack accumulation (Mote et al., 2016). This resulted in record low snowpack across the state, earning official drought declarations for 25 of Oregon's 36 counties. Drought impacts across Oregon were widespread and diverse:

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[121] Chris Mooney, *Scientists say climate change could cause a 'massive' tree die-off in the U.S. Southwest*, WASH. POST, Dec. 21, 2015, *available at* https://www.washingtonpost.com/news/energy-environment/wp/2015/12/21/scientists-say-climate-change-could-cause-a-massive-tree-die-off-in-the-southwest/ (last visited Oct. 18, 2018).
[122] *Confronting Climate Change in New Mexico, supra*, at 3.
[123] *What Climate Change Means for New Mexico and the Southwest*, *supra*, at 1-2.
[124] P. Zion Klos et al., *Extent of the Rain-Snow Transition Zone in the Western U.S. Under Historic and Projected Climate*, 41 Geophysical Res. Letters 4560, 4560–68 (2014).
[125] *The Third Oregon Climate Assessment Report*, Oregon Climate Change Research Institute, January 2017.

> Farmers in eastern Oregon's Treasure Valley received a third of their normal irrigation water because the Owyhee reservoir received inadequate supply for the third year in a row (Stevenson, 2016) …
>
> People near the Upper Klamath Lake were warned not to touch the water as algal blooms that thrived in the low flows and warm waters produced extremely high toxin levels (Marris, 2015) …
>
> More than half of the spring spawning salmon in the Columbia River perished, likely due to a disease that thrived in the unusually warm waters (Fears, 2015) …
>
> The West Coast–wide drought developed alongside a naturally-driven large, persistent high-pressure ridge (Wise, 2016). However, anthropogenic warming exacerbated the drought, particularly in Oregon and Washington (Mote et al., 2016; Williams et al., 2015) …
>
> Oregon's temperatures, precipitation, and snowpack in 2015 are illustrative of conditions that, according to climate model projections, may be considered "normal" by mid-century.[126]

And there has been more bad news since 2015. In 2018, researcher John Abatzoglou reported that:

> Drought impacts are being felt most notably in Oregon, which endured a period of substandard snowpack followed by unusually dry and warm conditions since May. The impacts cover the gamut from fire to farms to fish …
>
> Fishing restrictions have been enacted in the Umpqua River in western Oregon due to critically warm stream temperatures for steelhead and salmon. The combination of very low flows—including recent daily record low flows—due to subpar precipitation and warm temperatures have allowed water temperatures to warm faster than usual.[127]

Sea Level Rise

Ocean sea levels will rise between four inches and four-and-a-half feet on the Oregon coast by the year 2100, and coastal residents, cities and towns along Oregon's 300 miles of coastline and 1400 miles of tidal shoreline will be threatened by increased flooding

[126] *Id.* at 12-13, citing: P. W. Mote et al.,. *Perspectives on the causes of exceptionally low 2015 snowpack in the western United States.(*2016).; D. Fears, *As salmon vanish in the dry Pacific Northwest, so does Native heritage*, Washington Post (2015); J. Stevenson, *Documenting the Drought*, The Climate CIRCulator (2016); E..Marris, *In the Dry West, Waiting for Congress,* The Klamath Tribes Tribal News and Events (2015); A.P. Williams et al., *Contribution of anthropogenic warming to California drought during 2012-14,* Geophysical Research Letter, 2015.

[127] Abatzoglou, "Drought Returns to the Pacific Northwest," OCCRI Climate Circulator (August 2018).

and erosion as a result. Residential development, state highways, and municipal infrastructure are all at risk to such threats.[128]

Ocean Acidification and Hypoxia

As a result of climate change, ocean waters are now more acidified, hypoxic (low oxygen), and warmer, and such impacts are projected to increase, with a particular detrimental impact on some marine organisms like oysters and other shellfish, which will threaten marine ecosystems, fisheries and seafood businesses that play a vital role in Oregon's economy and culture.[129] As the Third Oregon Climate Assessment Report observed, "[T]he West Coast has already reached a threshold and negative impacts are already evident, such as dissolved shells in pteropod populations … and impaired oyster hatchery operations …"[130]

The Oregon Coordinating Council on Ocean Acidification and Hypoxia recently reported that "[n]ew research points to an ever-growing list of marine organisms that are now known to be vulnerable to the threats of ocean acidification and hypoxia (OAH). The list includes species such as Dungeness crabs, rockfishes and salmon that underpin livelihoods and connections to the sea for many Oregonians."[131]

In March of 2017, KVAL TV in Eugene, Oregon chronicled the experience of the Whiskey Creek Hatchery off Netarts Bay in Tillamook, Oregon. Manager Alan Barton said that "[w]e probably produce about a third of all oyster larvae on the West Coast." But in 2007 and 2008, hatchery output collapsed by 75%. Working with scientists from Oregon State University, Whiskey Creek identified ocean acidification as the problem. They developed a way to treat the water at the hatchery, which has been successful. But Barton does not believe that treatment is a long-term solution:

> "The short term prospects are pretty good. But within the next couple of decades we're going to cross a line I don't think we're going to be able to come back from," he says. "A lot of people have the luxury of being skeptics about climate change and ocean acidification. But we don't have that choice. If we don't change the chemistry of the water going into our tanks, we'll be out of business. It's that simple for us."[132]

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[128] *See* W. Spencer Reeder et al., *Coasts: Complex Changes Affecting the Northwest's Diverse Shorelines*, *in Climate Change in the Northwest: Implications for Our Landscapes, Waters, and Communities* 67–109 (Meghan M. Dalton et al. eds., 2013); Ben Strauss et al., Climate Cent., *California, Oregon, Washington and the Surging Sea: A Vulnerability Assessment with Projections for Sea Level Rise and Coastal Flood Risk* 29 (2014).
[129] *See* Francis Chan et al., Cal. Ocean Sci. Tr., *The West Coast Ocean Acidification and Hypoxia Science Panel: Major Findings, Recommendations, and Actions* (2015); Julia A. Ekstrom et al., *Vulnerability and Adaptation of U.S. Shellfisheries to Ocean Acidification*, 5 Nature Climate Change 207, 207–14 (2015).
[130] *Third Oregon Climate Assessment Report*, *supra*, at 36.
[131] Oregon Coordinating Council on Ocean Acidication and Hypoxia, 1st Biennial Report, at 8, September 15, 2018.
[132] KVAl-TV, '*One morning we came in and everything was dead*': *Climate Change and Oregon oysters*, March 1, 2017.

Forests, Pests and Fires

Oregon is largely defined by its iconic forests, which climate change threatens in myriad ways, as the Third Oregon Climate Assessment Report detailed:

> Future warming and changes in precipitation may considerably alter the spatial distribution of suitable climate for many important tree species and vegetation types in Oregon by the end of the 21st century. Changing climatic suitability and forest disturbances from wildfires, insects, diseases, and drought will drive changes to the forest landscape in the future. Conifer forests west of the Cascade Range may shift to mixed forests and subalpine forests would likely contract. Human-caused increases in greenhouse gases are partially responsible for recent increases in wildfire activity. Mountain pine beetle, western spruce budworm, and Swiss needle cast remain major disturbance agents in Oregon's forests and are expected to expand under climate change. More frequent drought conditions projected for the future will likely increase forest susceptibility to other disturbance agents such as wildfires and insect outbreaks.
>
> Future warming and changes in precipitation may considerably alter the spatial distribution of suitable climate for many important tree species and vegetation types in Oregon by the end of the 21st century (Littell et al., 2013). Furthermore, the cumulative effects of changes due to wildfire, insect infestation, tree diseases, and the interactions between them, will likely dominate changes in forest landscapes over the coming decades (Littell et al., 2013). ..
>
> Over the last several decades, warmer and drier conditions during the summer months have contributed to an increase in fuel aridity and enabled more frequent large fires, an increase in the total area burned, and a longer fire season across the western United States, particularly in forested ecosystems (Dennison et al., 2014; Jolly et al., 2015; Westerling, 2016; Williams and Abatzoglou, 2016). The lengthening of the fire season is largely due to declining mountain snowpack and earlier spring snowmelt (Westerling, 2016). In the Pacific Northwest, the fire season length increased over each of the last four decades, from 23 days in the 1970s, to 43 days in the 1980s, 84 days in the 1990s, and 116 days in the 2000s (Westerling, 2016). Recent wildfire activity in forested ecosystems is partially attributed to human-caused climate change: during the period 1984–2015, about half of the observed increase in fuel aridity and 4.2 million hectares (or more than 16,000 square miles) of burned area in the western United States were due to human-caused climate change (Abatzoglou and Williams, 2016).[133]

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[133] *The Third Oregon Climate Assessment Report* , citing J.T. Abatzoglou and A.P. Williams, *Impact of anthropogenic climate change on wildfire across western US forests.*, Proceedings of the National Academy of Sciences 113 (2016); P.E. Dennison et al, *Large wildfire trends in the western United States, 1984–2011,* Geophysical Research Letters 41 (2014); J.SD. Littell et al., *Forest ecosystems: Vegetation, disturbance, and economics*, Chapter 5. In: Dalton, Mot, and Snover(eds) *Climate Change in the Northwest: Implications for Our Landscapes, Waters, and Communities*, Island Press, Washington, DC (2013); A. L. Westerling , *Increasing western US forest wildfire activity: sensitivity to changes in the timing of spring*. Phil. Trans. R. Soc. B 371 (2016).

Health Effects

An increase in forest fire activity is one of the various ways in which climate change threatens human health. As the Third Oregon Climate Assessment noted, "Climate change threatens the health of Oregonians. More frequent heat waves are expected to increase heat-related illnesses and death. More frequent wildfires and poor air quality are expected to increase respiratory illnesses."[134] For example:

> 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).[135]

Oregon has already experienced a dramatic increase in "unhealthy air days" due to forest fires. The Medford metro region experienced 20 air quality alert days due to fire from 1985 through 2001, 19 of those in one year. From 2002 through 2012, Medford had 22 such days. But since 2013, Medford has had 74 such days, including 20 in 2017 and 35 in 2018.[136] Portland, meanwhile, had a total of two such days from 1985 through 2014 – but 13 such days from 2015 through 2018.[137]

During the 2017 Eagle Creek fire, the Oregon Health Authority (OHA) reported a 29% increase in emergency room visits for respiratory symptoms in the Portland metro region.[138]

In its 2014 Oregon Climate and Health Profile Report, OHA elaborated on the health effects of wildfire smoke:

> Particulate matter (PM) in smoke from wildfires is associated with cancer, cardiopulmonary disease and respiratory illness … As a result of projected increases in wildfire, Spracklen et al. (2009) anticipate an increase in aerosol organic carbon of up to 40% and an increase in elemental carbon in the western U.S. of up to 20% in 2046–2055 compared to 1996–2005 … PM associated with wildfires in California has been shown to

[134] *Third Oregon Climate Assessment Report, supra,* at 74.
[135] *Id.*, citing N. Fann et al.,Ch. 3: *Air Quality Impacts. The Impacts of Climate Change on Human Health in the United States: A Scientific Assessment. US Global Change Research Program*, Washington, DC (2016).
[136] In addition to the impact on human health, fires in the Medford area have punished a beloved Oregon institution, the Oregon Shakespeare Festival in Ashland. In 2018 alone, the Festival had to cancel – or move indoors, to smaller venues – 20 performances, costing the Festival money and ruining many theater-goers' plans. *Wildfire Smoke Disrupts Oregon Shakespeare Festival*, New York Times, August 24, 2018.
[137] Oregon DEQ, *Forest Fire Smoke Impact on Air Quality Health Trends in Bend, Klamath Falls, Medford, and Portland (1985 to 2018)*, DEQ18-NWR-0066-TR (October 2018). It is worth noting that although air quality alerts are often limited to especially vulnerable populations – "unhealthy for sensitive groups" – Medford in 2017-18 has experienced 38 days in which the air was unhealthy for all populations, including five "very unhealthy" days and one "hazardous" day.
[138] Statewide Fire Activation Surveillance Report (090517-090617), Oregon Health Authority.

be more toxic to the lungs than normal ambient PM … PM exposure from wildfire smoke is a risk beyond the immediate area of the fire, since high winds can carry the PM long distances … Increases in smoke are associated with hospital admissions for respiratory complaints, and long-term exposure worsens existing cardiopulmonary disease … bronchitis and pneumonia.[139]

Impact on American Indian Tribes

As the Legislative Summary of the Third Oregon Climate Assessment Report observed:

> Changes in terrestrial and aquatic ecosystems will affect resources and habitats that are important for the sovereignty, culture, economy, and community health of many American Indian tribes. Tribes that depend upon these ecosystems, both on and off reservation, are among the first to experience the impacts of climate change. Of particular concern are changes in the availability and timing of traditional foods such as salmon, shellfish, and berries, and other plant and animal species important to tribes' traditional way of life.[140]

The threat that climate change poses to salmon populations is a particular source of concern for the tribes:

> A 2015 study of Columbia River Basin tribes, including the Confederated Tribes of Warm Springs (CTWS) and the Confederated Tribes of the Umatilla Indian Reservation (CTUIR), found that the primary concerns regarding climate change impacts included the quantity and quality of water resources, snowpack, water temperatures for spawning conditions, and fishing rights (Sampson, 2015). Pacific salmon have great cultural, subsistence, and commercial value to tribes in the Pacific Northwest, and are central to tribal cultural identity, longhouse religious services, sense of place, livelihood, and the transfer of traditional values to the next generation (Dittmer, 2013). During the last 150 years, culturally important salmon populations have declined (Dittmer, 2013). Continuation of past trends of earlier spring peak, more extreme high flows and more frequent low flows in the low elevation basins of northeast Oregon, home to the CTWS

[139] Oregon Climate and Health Profile Report at 39 (Oregon Health Authority, Public Health Division, 2014), citing C.A. Pope et al,. *Cardiovascular mortality and long-term exposure to particulate air pollution: Epidemiological evidence of general pathophysiological pathways of disease,* Circulation. 2004;109:71–7.; C.A. Pope and D.Q. Dockery, Dockery, *Health effects of fine particulate air pollution: lines that connect*., Journal of the Air & Waste Management Association (1995). 2006;56:709–42; World Health Organization. *Review of Evidence on Health Aspects of Air Pollution–REVIHAAP Projec*t (2013.) J.L, Mauderly and J.C. Chow , *Health effects of organic aerosols. Inhalation toxicology*. 2008;20:257–88; T.C.Wegesser and K.E. Pinkerton KE, J.A. Last, *California wildfires of 2008: coarse and fine particulate matter toxicity,* Environmental Health Perspectives. 2009;117:893–7.; M. Ginsberg et al. *Monitoring Health Effects of Wildfires Using the BioSense System--San Diego County, California,* October 2007. Morbidity and Mortality Weekly Report. 2008;57(27):741–4; R.J. Delfino et al., *The relationship of respiratory and cardiovascular hospital admissions to the southern California wildfires of 2003,* Occupational and Environmental Medicine. 2009;66:189–97.

[140] *The Third Oregon Climate Assessment Report, supra,* (Legislative Summary).

> and CTUIR, may force earlier migration of juvenile salmon, challenge returning adults in low flow conditions, and increase scour risk for emerging young salmon (Dittmer, 2013).[141]
> Page 58:

The threat that climate change poses to forests is likewise a major concern for tribes:

> Changes in forest ecosystems and disturbances will affect resources and habitats that are important for the cultural, medicinal, economic, and community health of tribes (Lynn et al., 2013). In Oregon, 62% of tribal reservation land is forested, and the US government has a trust responsibility toward such forests (Indian Forest Management Assessment Team, 2013). American Indian and Alaska Native tribes that depend on forest ecosystems, whether on or off reservations, are among the first to experience the impacts that climate change is having on forests, such as the expansion of invasive species, insects, diseases, and wildfires (Norton-Smith et al., 2016). Invasive species that displace native species can negatively affect tribal subsistence and ceremonial practices, although there is little knowledge about on how climate change will interact with invasive species (Norton-Smith et al., 2016). Increasing wildfire, insects, and diseases have jeopardized the economic and ecological sustainability of tribally managed forests and important tribal resources (Indian Forest Management Assessment Team, 2013; Norton-Smith et al., 2016). Collaborative adaptive forest management that integrates tribal traditional ecological knowledge can support socio-ecological resilience to climate change (Armatas et al., 2016).[142]

PENNSYLVANIA

The Commonwealth of Pennsylvania faces two fundamental threats related to climate: (1) sea level rise and its impact on communities and cities in the Delaware River Basin, including the city of Philadelphia; and (2) more frequent extreme weather events, including large storms, periods of drought, heat waves, heavier snowfalls, and an increase in overall precipitation variability. Based on studies commissioned by the Pennsylvania Department of Environmental Protection, as part of its mandate under the Pennsylvania Climate Change Act, 71 P.S. §§ 1361.1 – 1361.8, Pennsylvania has undergone a long-term warming of more than 1°C over the past 110 years.[143] The models used in the 2015 Climate Impacts Assessment Update

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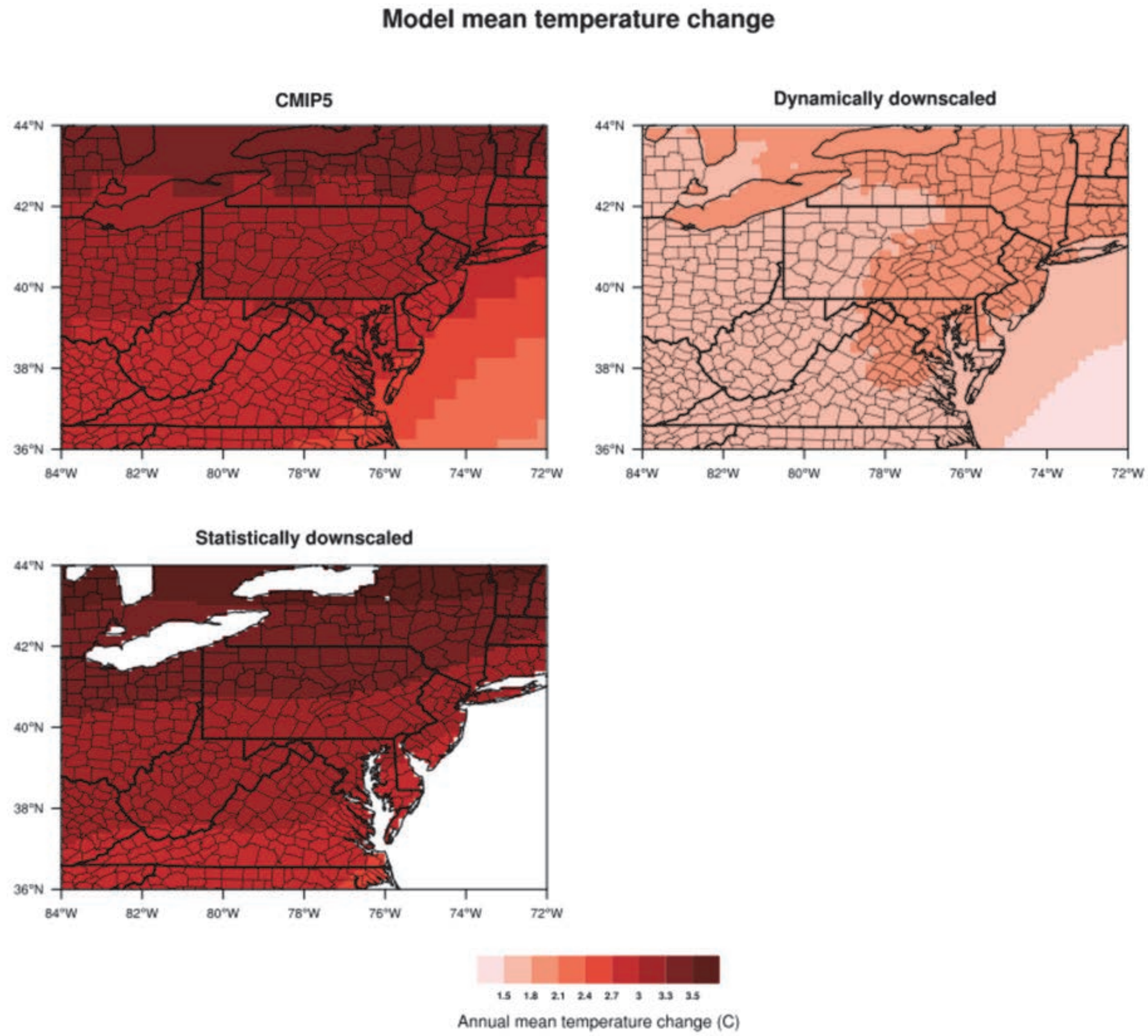
[141] K. Dittmer, *Changing streamflow on Columbia basin tribal lands—climate change and salmon*, Climatic Change 120(3) (2013); D. Sampson, *Columbia River Basin Tribes Climate Change Capacity Assessment*, Institute for Tribal Government, Hatfield School of Government, Portland State University: Portland, OR (2015)

[142] Citing C. Armatas et al., *Opportunities to utilize traditional phenological knowledge to support adaptive management of social-ecological systems vulnerable to changes in climate and fire regimes*, Ecology and Society 21 (2016); *Assessment of Indian Forests and Forest Management in the United States*, Indian Forest Management Assessment Team (2013) ; K. Lynn et al., *Northwest Tribes: Cultural Impacts and Adaptation Resources*: Chapter 8. In: M. M. Dalton et al., *Climate Change in the Northwest: Implications for Our Landscapes, Waters, and Communities*, Island Press: Washington, DC (2013); K. Norton-Smith et al., *Climate change and indigenous peoples: a synthesis of current impacts and experiences* (2016).

[143] *See* "Pennsylvania Climate Impacts Assessment Update," May 2015, available at http://www.elibrary.dep.state.pa.us/dsweb/Get/Document-108470/2700-BK-DEP4494.pdf. *See*

suggest this warming is a result of anthropogenic influence, and that this trend is accelerating. Projections in the 2015 Update show that by the middle of the 21st century, Pennsylvania will be about 3°C warmer than it was at the end of the 20th century.



Modeling charts from the 2015 Update show that in both the CMIP5 and statistically downscaled CMIP5 datasets, mid-century temperatures in the Philadelphia region are projected to be similar to historical temperatures in the Richmond, VA area. Similarly, Pittsburgh's temperatures are projected to resemble the historically observed temperatures in the Baltimore-

also "Pennsylvania Climate Impacts Assessment Update," October 2013, available at http://www.elibrary.dep.state.pa.us/dsweb/Get/Document-97037/PA%20DEP%20Climate%20Impact%20Assessment%20Update.pdf; "Pennsylvania Climate Assessment," June 2009, available at http://www.elibrary.dep.state.pa.us/dsweb/Get/Document-75375/7000-BK-DEP4252.pdf.

Washington area. The mean warming across the state simulated by these models is generally 3.0-3.5 °C (5.4-6.3°F). The CMIP5 model mean change is 3.0-3.3 °C (5.4-6.0 °F) across nearly the entire state. The statistically downscaled CMIP5 model mean change is 3.3-3.5 °C (5.9-6.3°F) in the northern half of the state and 3.0-3.3 °C (5.4-6.0°F) in the southern half. Finally, the dynamically downscaled dataset model mean change is only 1.5-1.8 °C (2.7-3.2°F) across the western half of the state and 1.8-2.1 °C (3.2-3.8 °F) across the eastern half. The reduced warming is likely at least partially because these models rely on a different emissions scenario, in which the buildup of greenhouse gases in the atmosphere occurs at a slower rate than in the than in the scenarios that the CMIP5 models use.

The 2015 Climate Impacts Assessment Update also finds that this warming trend will threaten Pennsylvania in other ways:

- Pennsylvania agriculture will have to adapt to by greater extremes in temperature and precipitation.[144] Pennsylvania dairy production is likely to be negatively affected by climate change due to losses in milk yields caused by heat stress, additional energy and capital expenditures to mitigate heat stress, and lower levels of forage quality.

- Pennsylvania's forests will be subject to multiple stressors.[145] The warming climate will cause tree species inhabiting decreasingly suitable habitat to become stressed. Mortality rates are likely to increase and regeneration success is expected to decline for these tree species, resulting in declining importance of those species in the state.

- Suitable habitat for plant and wildlife species is expected to shift to higher latitudes and elevations.[146] This will reduce the amount of suitable habitat in Pennsylvania for species that are at the southern extent of their range in Pennsylvania or that are found primarily at high latitudes; the amount of habitat in the state that is suitable for species that are at the northern extent of their range in Pennsylvania will increase. The Canada lynx, which is already rare in Pennsylvania, will likely be extirpated from the state.

- The public health of Pennsylvanians is threatened because climate change will worsen air quality relative to what it would otherwise be, causing increased respiratory and cardiac illness.[147] The linkage between climate change and air quality is most strongly established for ground-level ozone creation during summer, but there is some evidence that higher temperatures and higher precipitation will result in increased allergen (pollen and mold) levels as well.

- West Nile disease is endemic in Pennsylvania.[148] It is currently most prevalent in Southeastern and Central parts of the state, and less prevalent in the Laurel Highlands and the Allegheny Plateau. However, climate change is expected to increase the prevalence of West Nile disease in the higher-elevation areas, due to higher temperatures. In addition

[144] 2015 Climate Impacts Assessment Update, *supra*, at 63.
[145] *Id*. at 114.
[146] *Id*.
[147] *Id*. at 321.
[148] *Id*. at 135.

to its range, the duration of the transmission season for West Nile disease is sensitive to climate. Warmer temperatures result in a longer transmission season, and therefore greater infection risk.

- Climate change will have a severe, negative impact on winter recreation in Pennsylvania.[149] Downhill ski and snowboard resorts are not expected to remain economically viable past mid-century. Snow cover to support cross country skiing and snowmobiling has been declining in Pennsylvania, and is expected to further decline by 20-60%, with greater percentage decreases in southeastern Pennsylvania, and smaller decreases in northern Pennsylvania.

- Climate change poses a threat to the fauna of the tidal freshwater portion of the Delaware estuary in Pennsylvania.[150] One reason is that increased water temperatures with climate change decrease the solubility of oxygen in water and will increase respiration rates, both of which will result in declines in dissolved oxygen concentration. Thus, climate change will worsen the currently substandard water quality in the tidal freshwater region of the Delaware Estuary.

- The freshwater tidal wetlands along Pennsylvania's southeastern coast are a rare, diverse, and ecologically important resource.[151] Climate change poses a threat to these wetlands because of salinity intrusion and sea-level rise. Sea-level rise, however, has the potential to drown wetlands if their accretion rates are less than rates of sea-level rise.

<u>RHODE ISLAND</u>

Climate change is adversely impacting Rhode Island in many diverse ways, including warming air temperatures, warming ocean temperatures, rising sea level, increased acidity of ocean waters, increased rainfall amounts, and increased intensity of rainfall events.

Rhode Island has experienced a significant trend over the past 80 years toward a warmer and wetter climate. Trends are evident in annual temperatures, annual precipitation, and the frequency of intense rainfall events. Temperatures have been steadily climbing in the Ocean State since the early 1930s. The average annual temperature for the state is currently increasing at a rate of 1 degree Fahrenheit every 33 years. The frequency of days with high temperatures at or above 90 degrees has increased while the frequency of days with minimum temperatures at or below freezing has decreased.[152]

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[149] *Id*. at 141.
[150] *Id*. at 152.
[151] *Id*.
[152] *Overview of a Changing Climate in Rhode Island*, David Vallee (Hydrologist-in-Charge, National Weather Service Northeast River Forecast Center, NOAA) and Lenny Giuliano (Air Quality Specialist, Rhode Island Department of Environmental Management, State Climatologist, State of Rhode Island), August 2014 at 2-3, available at http://research3.fit.edu/sealevelriselibrary/documents/doc_mgr/444/Valee%20&%20Giuliano.%202014.%20CC%20in%20Rhode%20Island%20Overview.pdf.

There has also been a pronounced increase in precipitation from 1930 to 2013. Increased precipitation has occurred as a result of large, slow moving storm systems, multiple events in the span of a few weeks (such as the 2010 spring floods), as well as an increase in the frequency of intense rain events. The average annual precipitation for Rhode Island is increasing at a rate of more than 1 inch every 10 years. The frequency of days having one inch of rainfall has nearly doubled. Intense rainfall events (heaviest 1 percent of all daily events from 1901 to 2012 in New England) have increased 71 percent since 1958. The increased amounts of precipitation since 1970 has resulted in a much wetter state in terms of soil moisture and the ground's ability to absorb rainfall.[153]

In addition, the water in Narragansett Bay is getting warmer. Over the past 50 years, the surface temperature of the Bay has increased 1.4° to 1.6° C (2.5° to 2.9° F). Winter water temperatures in the Bay have increased even more, from 1.6° to 2.0° C (2.9° to 3.6° F). Ocean temperatures are increasing world-wide, but temperature increases in the northwestern Atlantic Ocean are expected to be 2-3 times larger than the global average.[154] Warmer water temperatures in Narragansett Bay are causing many changes in ecosystem dynamics, fish, invertebrates, and plankton. Cold-water iconic fishery species (cod, winter flounder, hake, lobster) are moving north out of RI waters and warm-water southern species are becoming more prevalent (scup, butterfish, squid). Rhode Island's marine waters are also becoming more acidic due to increasing CO_2. This may cause severe impacts to shellfish, especially in their larval life stages.[155]

Sea levels have risen over 9 inches in Rhode Island since 1930 as measured at the Newport tide gauge. The historic rate of sea level rise at the Newport tide gauge from 1930 to 2015 is presently 2.72 mm/year, or more than an inch per decade.[156] At present rates, sea levels will likely increase 1 inch between every 5 or 6 years in Rhode Island. NOAA is projecting as much as 6.6 feet of sea level rise by the end of this century in Rhode Island. In the shorter-term, NOAA predicts upwards of 1 foot by 2035 and 1.9 feet by 2050. [157] This has critical implications for Rhode Island, as thousands of acres of Rhode Island's coast will be affected.

Climate change is also altering the ecology and distribution of plants and animals in Rhode Island. In southern New England, spring is arriving sooner and plants are flowering earlier (one week earlier now when compared to the 1850s). For every degree of temperature rise in the spring and winter, plants flower 3.3 days earlier. For woody plants, leaf-out is occurring 18 days earlier now than in the 1850s. Changes in the timing of leaf-out, flowering, and fruiting in plants can be very disruptive to plant pollinators and seed dispersers.[158]

Changes in the timing of annual cycles has been observed in Rhode Island birds. Based on a 45-year near-continuous record of monitoring fall migration times for passerine birds in

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[153] *Id*. at 4.
[154] Rhode Island Executive Climate Change Coordinating Council (EC4) Science and Technical Advisory Board (STAB) Annual Report to the Full Council of the EC4 (May 2016), appendix to Rhode Island Executive Climate Change Coordinating Council Annual Report, June 2016, at 33-35, available at http://climatechange.ri.gov/documents/ar0616.pdf.
[155] *Id*.
[156] *Id*. at 28-30.
[157] *Id*.
[158] *Id*. at 38-40

Kingston, RI, Smith and Paton (2011) found a 3.0 days/decade delay in the departure time of 14 species of migratory birds.[159]

VERMONT

Climate change is causing an increase in temperatures and precipitation in Vermont. Average annual temperature has increased by 1.3º F since 1960, and is projected to rise by an additional 2-3.6 º F by 2050.[160] Since 1960, average annual precipitation has increased by 5.9 inches.[161]

Heavy rainfall events are becoming more common.[162] Increasingly frequent heavy rains threaten to flood communities located in Vermont's many narrow river valleys. In 2011 Tropical Storm Irene dumped up to 11 inches of rain on Vermont, impacting 225 municipalities and causing $733 million in damage.[163] More than 1,500 residences sustained significant damage, temporarily or permanently displacing more than 1400 households.[164] More than 500 miles of state highway, 2000 municipal road segments, and 480 bridges were damaged.[165] Farms, water supply and wastewater treatment facilities were also damaged, and the channels of many streams were enlarged and/or relocated.[166]

In addition to threatening human lives and property, increasingly frequent heavy rains present challenges for state and local land use planning. Further, storm water runoff carries pollutants to the state's streams and lakes, and hinders the state's efforts to address phosphorous pollution and resulting algal blooms in Lake Champlain.

Climate change also threatens Vermont's environment and economy by affecting activities dependent on seasonal climate patterns, such as maple sugaring and winter sports.[167] Vermont is the nation's leading maple-syrup producing state[168]. Warmer temperatures are likely

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[159] *Id.*
[160] *Vermont Climate Change Assessment*, http://vtclimate.org/vts-changing-climate/ (last visited Oct. 24, 2018).
[161] *Id.*
[162] *Id.*
[163] Pierre-Louis, Kendra, *Five Years After Hurricane Irene, Vermont Still Striving for Resilience,* Inside Climate News (Sept. 1, 2016), *available at* https://insideclimatenews.org/news/31082016/five-years-after-hurricane-irene-2011-effects-flooding-vermont-damage-resilience-climate-change.
[164] *Tropical Storm Irene by the Numbers* (Aug. 28, 2013), http://www.vermontbiz.com/news/august/tropical-storm-irene-numbers (last visited Oct. 24, 2018).
[165] *Id.*
[166] *Id.*
[167] U.S. EPA, *What Climate Change Means for Vermont* (August 2006), *available at* https://19january2017snapshot.epa.gov/sites/production/files/2016-09/documents/climate-change-vt.pdf.
[168] Vermont Agency of Agriculture Food & Markets, *Vermont Leads Nation in 2018 Maple Season Production* (June 13, 2018), http://agriculture.vermont.gov/Vermont%20Leads%20Nation%20in%202018%20Maple%20Season%20Production (last visited Oct. 24, 2018).

to shift the suitable habitat for sugar maples farther north into Canada.[169] Warmer winters may bring more rain and less snow to Vermont, harming the skiing, snowboarding, and snowmobiling industries and local economies that depend on them. *Id.* During the winter of 2016-17, Vermont recorded more than 3.9 million skier visits, second only to Colorado among the states.[170]

Climate change is also contributing to increased distribution and abundance of ticks and increased tickborne diseases, including Lyme disease and Anaplasmosis, in Vermont.[171] Vermont has the nation's highest per-capita incidence of Lyme Disease.[172]

[169] U.S. EPA, *What Climate Change Means for Vermont, supra.*
[170] *Vermont ski industry rebounds to nearly 4 million visits,* Vermontbiz (June 15, 2017), https://vermontbiz.com/news/june/vermont-ski-industry-rebounds-nearly-4-million-visits (last vistited Oct. 24, 2018).
[171] Vermont Department of Health, *Climate Change and Tickborne Diseases*, http://www.healthvermont.gov/health-environment/climate-health/tickborne-diseases (last visited Oct. 24, 2018).
[172] DeSmet, Nicole, *Tick-borne diseases: Getting worse, CDC study finds*, Burlington Free Press (May 9, 2018), *available at* https://www.burlingtonfreepress.com/story/news/local/vermont/2018/05/09/tick-spreading-lyme-diseases-getting-worse-cdc-study-finds/589714002/.