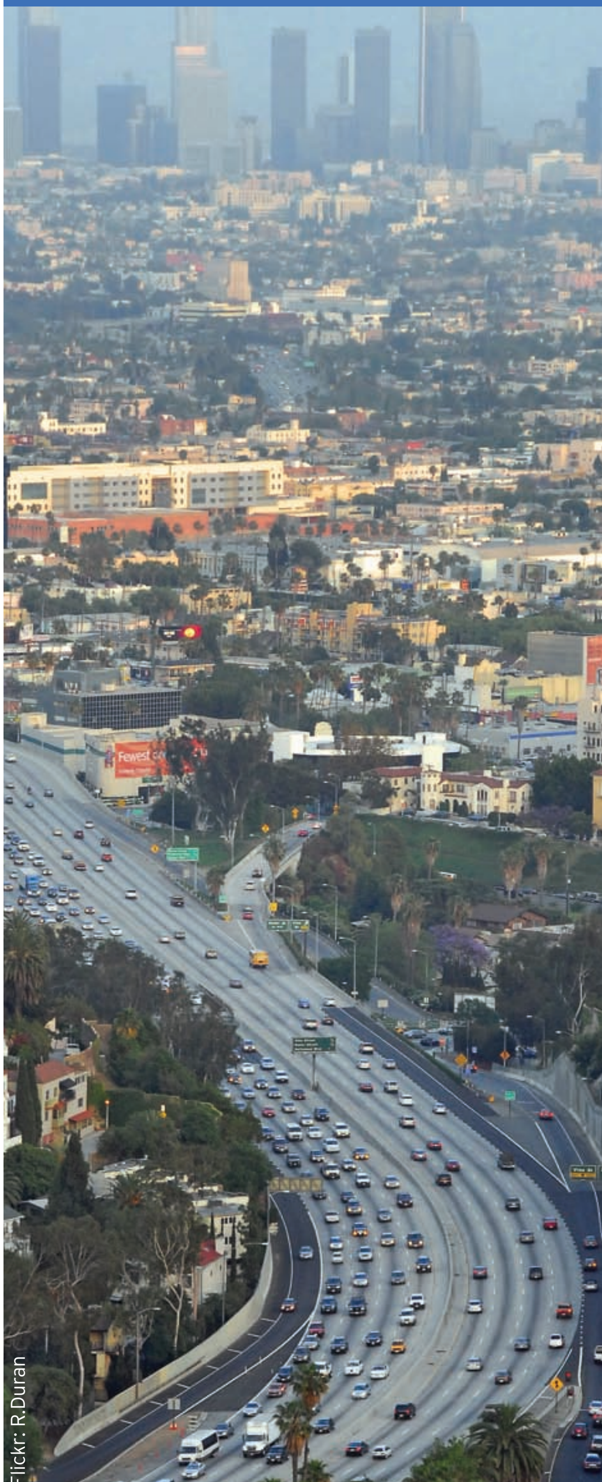
More Extreme Heat Waves: Global Warming's Wake Up Call

NATIONAL WILDLIFE FEDERATION 2009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Global warming will bring more extreme heat waves. As the United States warms another 4 to 11°F on average over the next century, we will have more extremely hot summer days. Every part of the country will be affected. Urban areas will feel the heat more acutely because asphalt, concrete, and other structures absorb and reradiate heat, causing temperature to be as much as 10°F higher than nearby rural areas.

Urban air pollution will be exacerbated by more extreme heat. Warm, sunny conditions accelerate the formation of ground-level ozone, a major component of smog. Even if air pollution is improved, as required by the Clean Air Act, global warming could mean an extra 10 parts per billion (ppb) of ozone during heat waves in the Midwest and Northeast, forcing some cities to take even more aggressive steps to meet the 75 ppb ozone standard.

Heat waves disproportionately impact the very old and very young, as well as people who are poor, have asthma or heart disease, or live in big cities. With often diminished health and a greater likelihood of living alone, the elderly are especially vulnerable. As the U.S. demographics shift toward an older and more urban population, efforts to protect these at-risk communities from extreme heat will become increasingly important.

Natural habitats and agriculture are also vulnerable to extreme heat. More extreme temperatures are already pushing wildlife and their habitats beyond their normal tolerance levels. Heat-related declines have been documented for wild salmon and trout, moose, and pika. Livestock and crops have lower productivity and increased mortality associated with heat stress and drought.

We can reduce the severity of heat waves and their impacts on vulnerable people. Curbing global warming pollution as much and as quickly as possible is an essential first step. Shifting to clean solar energy is an especially promising option because sunlight is plentiful during heat waves, when electricity demand for air conditioning peaks. At the same time, we must make our cities cooler and greener; for example, introducing more green space — parks, trees, and "green" roofs — can greatly reduce the urban heat island effect. Furthermore, cities must implement public health measures to reduce the impact of extreme heat that we can not avoid.

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PSR Physicians for Social Responsibility

CONFRONTING GLOBAL WARMING Report

Hot Days Ahead

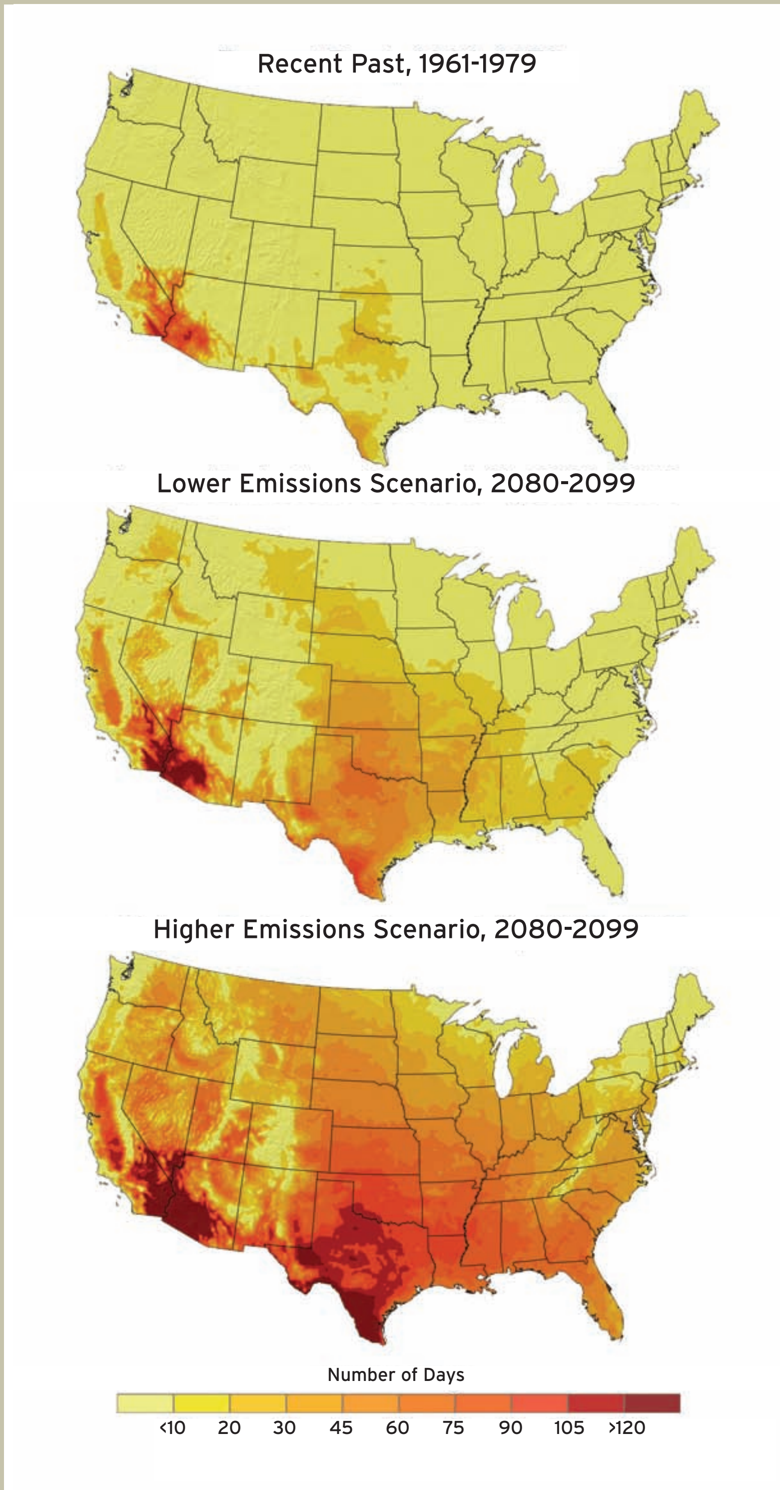

FIGURE 1:

The number of days in which the temperature exceeds 100°F for (top) the 1960s and 1970s, (middle) the 2080s and 2090s under a lower emissions scenario, and (bottom) the 2080s and 2090s under a higher emissions scenario.[12] If global warming emissions are not curbed, many parts of the country will have more than two months each year with 100-degree weather.

SOURCE: U.S. Global Change Research Program

The United States has warmed more than 2°F over the last 50 years, even more than the warming averaged for the whole planet.[1] This warming has shifted the annual distribution of temperatures to warmer temperatures, thereby making record hot days more likely and extremely cold days less likely. Nighttime temperatures have increased somewhat more than peak daytime temperatures, an alarming trend because excess heat-related mortality has been linked to unusually warm nights.[2]

The Dust Bowl Era in the 1930s brought some of the most frequent and severe heat waves on record for the United States. These extremely high temperatures were associated with an intense multi-year drought pattern that affected the Great Plains, likely caused by natural oscillations in ocean surface temperatures.[3] In contrast, the recent increase in heat waves is associated with world-wide warming, attributed to human-caused emissions of greenhouse gases. Furthermore, the recent heat waves have often been accompanied by high humidity, which contributes to elevated nighttime temperatures as water vapor condenses and releases heat to the atmosphere.[4]

With another 4 to 11°F warming projected for the United States over the next century, heat waves will continue to get worse, especially if steps are not taken to reduce greenhouse gas emissions.[5] In fact, the magnitude of emissions will have a significant impact on the number of days over 100°F we will have each year, as shown in Figure 1. For example, heat wave days in Chicago could quadruple by the end of the century. The average number of deaths associated with extremely hot weather could increase by twice that, even after accounting for the likely acclimatization to warmer temperatures and efforts to put public health assistance programs in place.[6]

It is well known that cities feel the heat more acutely due to the urban heat island effect. Asphalt, concrete, and other structures absorb and reradiate heat in cities, increasing temperatures by as much as 10°F compared to nearby rural areas.[7] Urban parks, tree planting, and "green" roofs can reduce the urban heat island effect by providing shade and increasing the rate of daytime evaporation, which has a cooling effect.[8]

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BUT THIS SUMMER HAS BEEN SO COOL WHERE I LIVE...

With mostly pleasant temperatures across the Midwest and Northeast in summer 2009, it is easy to lose sight of the long-term warming trend. But, this is not the time to let down our guard. This temporary respite is due largely to natural climate oscillations working in our favor. We are nearing the end of a minimum in the 11-year solar cycle during which the Earth is receiving slightly less heat from the Sun. At the same time, the jet stream has taken an unusually southern track across the nation this summer, bringing more Arctic air and less tropical air to the Midwest and Northeast.

These sorts of natural variations will continue to take place as the climate warms.[9] When it comes to heat waves, we need to prepare for the years when the natural variations line up in the opposite way: a year with maximum solar heating, a northward shift in the jet stream, and global warming could add up to record hot weather.[10]

Furthermore, while it has been pleasantly cool in some parts of the country, the South and West have been sweltering. At the end of June 2009, numerous daily temperature records were equaled or broken in Texas, Louisiana, and Mississippi.[11] In late July the Pacific Northwest had an extreme heat wave as a high pressure weather system stalled overhead. While these specific events can not be blamed on global warming, it is likely that warming did make them worse than they might otherwise have been.

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CHICAGO HEAT WAVE OF JULY 1995

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Chicago experienced one of the most severe heat waves to strike the United States in recent memory. Temperatures peaked at 106°F on July 13, and high humidity and high nighttime temperatures exacerbated the impact. Over 5 days in July 1995, approximately 739 people died and 3,300 people visited the emergency room with heat-related ailments.[13] The high demand for electricity led to brownouts and blackouts, leaving people without air conditioning when they needed it most.

Many of the victims were elderly poor living in the heart of the city, who had no air conditioning or could not afford to turn it on. Other vulnerable groups included those already suffering from chronic illness,[14] confined to bed, unable to care for themselves, or isolated. Because people with pre-existing medical conditions are more vulnerable to heat, the number of deaths attributed to this episode is probably underestimated because the other illness would be recorded as the primary cause of death.[15] Mortality rates among black people were 50 percent higher than those for white people,[16] perhaps reflecting discrepancies in poverty and access to health care.

Following this devastating heat wave, the City of Chicago developed detailed response plans. When a similar heat wave occurred in 1999, strongly worded warnings were issued immediately, over 90 cooling centers were opened across the metropolitan area, and over 30,000 at-risk individuals were personally contacted. These efforts are credited with limiting the heat-related mortalities to 114 individuals.[17] In addition, the city embarked on a program to identify places in the city where heat tends to build up, figure out the reasons for these hot spots, and identify steps to address them, such as reflective or green roofing.[18]

Flickr: Center for Neighborhood Technology

U.S. Global Change Research Program

A green roof at Chicago's City Hall has been observed to be as much as 77°F cooler than nearby conventional roofs.[19] The infrared photograph on the right shows the temperature difference between the two types of roofs on a hot day.

Warming Degrades Urban Air Quality

In areas that already have problems with air pollution, global warming will make it even harder to reduce smog. Warmer temperatures accelerate the chemical reactions in the atmosphere that create unhealthy ground-level ozone, a major component of smog. At the same time, warmer conditions increase emissions of ozone precursors. For example, increased demand for air conditioning means more emissions from electricity generation, and wildfires are more common when the weather is hot and dry. Finally, heat waves are typically associated with stagnant air masses and strong inversions that trap and recirculate ozone pollution, rather than allowing it to disperse.[20]

Future ozone pollution levels will depend on the emissions pathways for both greenhouse gases and other ozone precursors. Figure 2 shows that average surface ozone could increase by 2 to 15 percent under a higher emissions scenario, or could decrease 4 to 12 percent under a lower emissions scenario.[21] A subsequent study quantified the climate penalty, even if ozone precursor emissions are decreased as required by the Clean Air Act. They found that global warming could increases the daily maximum 8-hour average concentration of ground-level ozone 3 to 5 parts per billion (ppb) by 2050 in the Midwest and Northeast. During heat waves, higher temperatures and increased stagnation could lead to increases exceeding 10 ppb.[22] This climate penalty will require some cities to take even more aggressive steps to meet the 75 ppb ozone standard.

Some emissions reductions offer a win-win in terms of both limiting global warming and improving air quality. Methane is both an ozone precursor and a potent greenhouse gas, which makes a strong case for reducing its emissions.[23] Curbing emissions of fine soot particles, which include black carbon that directly absorbs incoming solar heat, would have similar benefits. These particles can exert a strong local warming effect and have significant impacts on respiratory and cardiovascular health.[24]

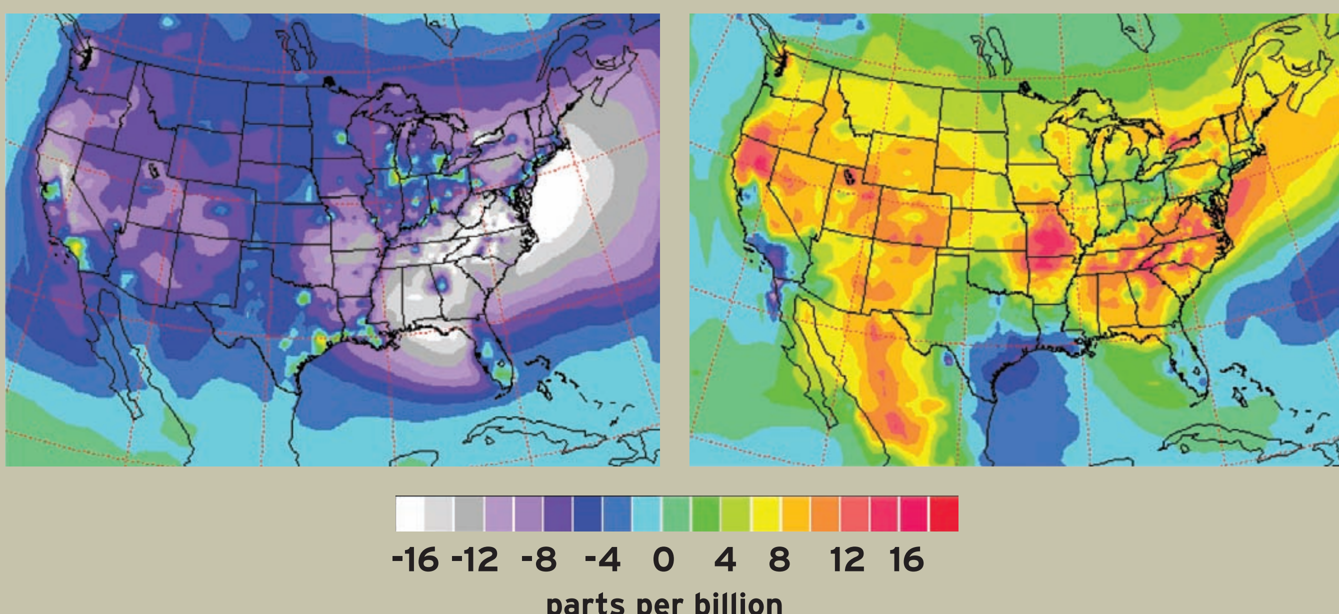

FIGURE 2:

Change in summertime ground-level ozone in the 2090s compared to the average for 1996-2000. The left panel shows decreasing ozone almost everywhere under a lower emissions scenario. The right panel shows widespread increases in ozone under a higher emissions scenario.[25]

SOURCE: U.S. Global Change Research Program

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Heat Waves and Health

Heat waves can be deadly, especially for the very old and the very young. Between 1999 and 2003, more than 3,400 people in the United States died from exposure to excessive heat.[26] Historically, about 20 to 28 percent of weather-related deaths have been due to heat, more than any other single weather-related cause in some analyses.[27]

Mortality can occur due to heat stroke or exacerbation of underlying health conditions, one reason that the elderly are more vulnerable.[28] For example, extreme heat increases the risk of heart attack, strokes, and asthma attacks. The increased air pollution that typically accompanies heat waves can especially harm children, who have a higher risk of developing asthma, have lungs that are still developing and growing, and have higher exposure because they breathe at a higher rate than adults and spend more time outdoors engaging in vigorous physical activity.[29]

Air conditioning and other responses can mitigate some of the risk associated with extreme heat.[30] Air conditioning use has expanded significantly in the United States. Fifty-six percent of households had air conditioning in 1978 compared to 84 percent in 2005, including 97 percent of households in the South.[31] Expanded use of air conditioning along with heat warning and watch systems and other public health interventions helped reduce mortality from heat waves from the 1970s through the 1990s. Since then, however, mortality has stayed about the same, suggesting that the combination of an aging population and more oppressively hot days may be offsetting the benefits of more widespread access to air conditioning.[32]

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Residents of cities are at elevated risk due to the urban heat island effect. Northern city residents have less access to air conditioning on average and are often not as well acclimated to extremely hot temperatures, especially early in summer.[33] That ozone pollution and high temperatures affect mortality synergistically further increases the risk in cities where air quality is typically poorer.[34]

HEAT WAVES AND THE ELDERLY

The elderly are especially vulnerable to extreme heat because their bodies are less able to effectively regulate temperatures.[35] Their risk is further heightened because the elderly often have diminished health and are more likely to live alone.[36] The severe European heat wave in 2003 is a stark example of this risk: more than 30,000 people, mostly elderly, perished due to heat that summer.

At the same time that extreme heat waves are becoming more likely, the U.S. population is aging. More than one fifth of U.S. citizens are expected to be over 65 years of age by 2050 and 5 percent will be over 85 years.[37] By 2030, Florida, California, and Texas are projected to add the greatest number of elderly people, and the largest number of elderly poor, as shown in Figure 3.[38] These elderly poor can have the added risk of being unable to afford health care or air conditioning. Thus, efforts to protect the elderly from extreme heat will become increasingly imperative in the coming decades.

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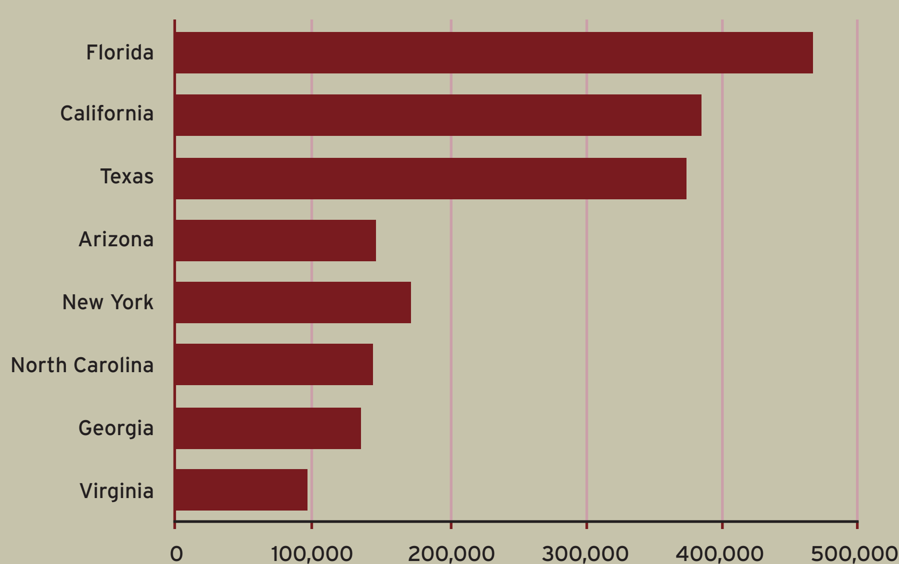

FIGURE 3:

Projected increase in number of elderly poor from 2000 to 2030.

SOURCE: U.S. Census Bureau

HEAT WAVES AND ENVIRONMENTAL JUSTICE

People living in cities and those with low income are more vulnerable to extreme heat waves. Over 43 percent of black people in the United States live in urban areas, compared to 20 percent of white people. And, blacks are twice as likely as other Americans to live in poverty. Thus, they are both more likely to live in the places where heat waves are most severe and less likely to be able to afford air conditioning, insulation, and other home improvements that reduce exposure to extreme heat.[39]

The prevalence of asthma is about 28 percent higher for black people in the United States than for white people, making them more vulnerable to the elevated air pollution associated with heat waves. Even more troubling is that the asthma mortality rate for blacks is nearly triple the rate for whites.[40] This startling discrepancy is largely attributed to socioeconomic differences, including indoor and outdoor air quality, smoke exposure, and access to healthcare.[41]

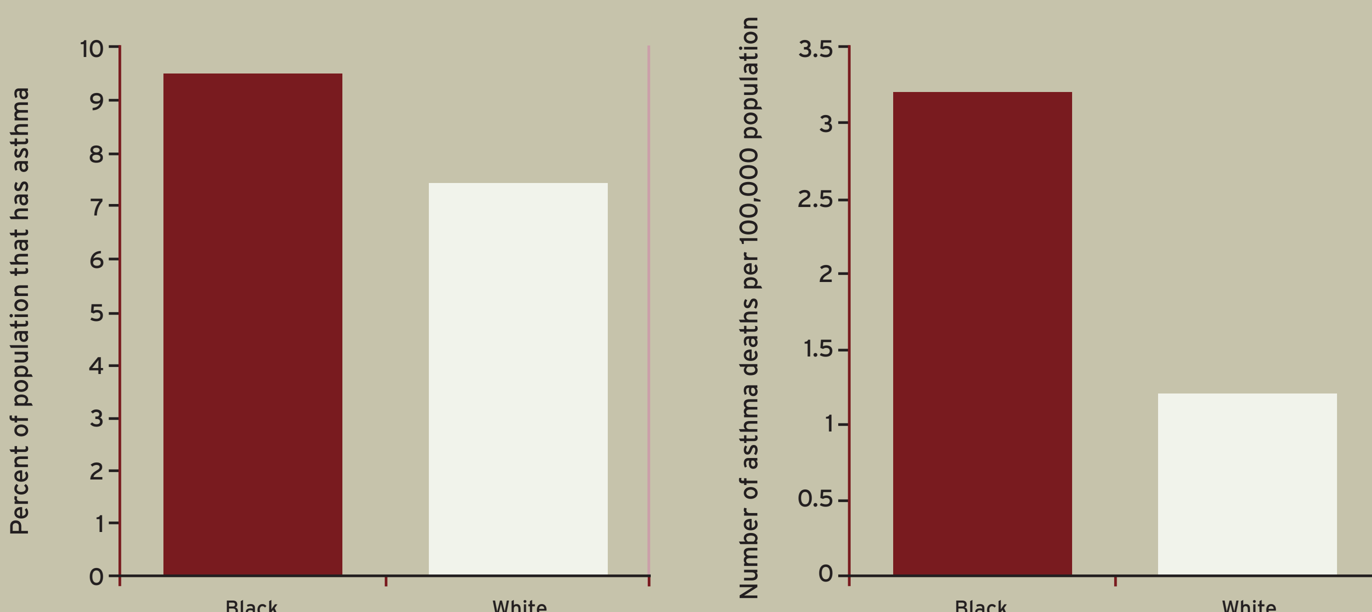

FIGURE 4:

Asthma prevalence and mortality rate for black and white Americans in 2005.

SOURCE: Center for Disease Control

Cities on the Frontlines

Cities are especially vulnerable to heat waves. Global warming will mean that nearly every city in the United States will be affected by more extreme heat. Yet, differing climatic, demographic, and socioeconomic conditions will mean that some locations at more risk than others.

We examined four major risk factors associated with heat-related mortality to identify 30 large cities in the United States that are especially vulnerable to heat waves based on current conditions (see Table 1).[42] Factors considered include:

- **Number of oppressively hot days each year.** We used the Spatial Synoptic Classification system developed by Scott Sheridan at Kent State University to calculate the 1979 to 2008 average of daily dry tropical and moist tropical air masses during the summer months of June, July, and August. A subset of extremely hot tropical days is used for areas where hot weather is common.[43]

- **Fraction of homes without central air conditioning.** We used the *American Housing Survey* conducted by the U.S. Census Bureau.[44] The Metropolitan-level surveys are conducted in different years for selected locations. Possible trends in air conditioning use could modify results slightly.


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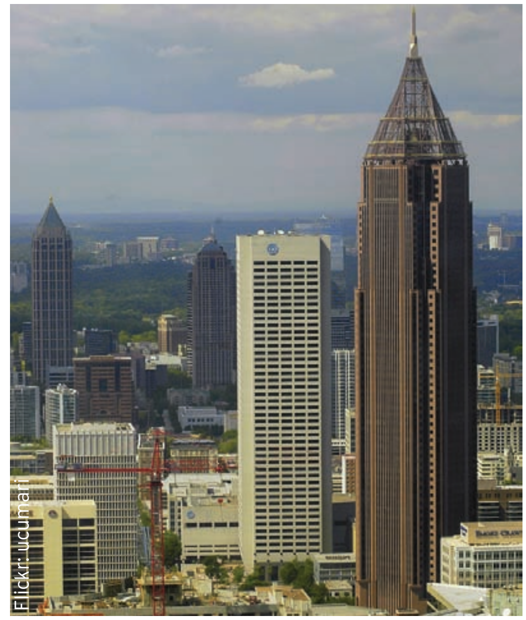
- **Ground-level ozone pollution.** For the most populous county in each metropolitan region, we used the quantity designated by the U.S. Environmental Protection Agency (EPA) for compliance with air quality standards: the 4th highest 8-hour ozone concentration. The 2006-2008 average of this value was considered in this analysis. Metropolitan areas must keep this quantity below 75 ppb to meet the current standard.[45]

- **City population living in poverty.** We used the 2007 U.S. Census Bureau estimates for population and poverty rates, where the poverty level is defined as annual income of less than $16,530 for a family of three.[46]

These four factors were given equal weight and summed to identify the 30 cities in Table 1 that have elevated risk. The cities are grouped into three tiers, with Tier 1 having the most vulnerability. More than 10 percent of the U.S. population resides in these cities, and many more live in the broader metropolitan areas they anchor.

Some cities make the list because they have a high number of extremely hot days each year, for example, cities in Texas and Oklahoma. Because hot weather is common in these places, central air conditioning is installed in most homes, and the remaining homes typically have one or more room air conditioning units. The widespread use of air conditioning reduces the vulnerability to some extent.

Another group of cities make the list because of the low availability of air conditioning. For example, only 24 percent of homes in Buffalo, New York have central air. If the number of extremely hot days there quadruples, as could be the case under a higher emissions scenario, then significant investments and planning will be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required to help residents cope with extreme heat. This effort will have to contend with high poverty levels in many of these cities. The eight cities on the list with low availability of central air in the Northeast and Midwest have an average poverty rate of 23 percent, about double the national average.

Philadelphia, Pennsylvania stands out as a city with high levels of all the risk factors considered. This is no doubt a reason that the city has been especially proactive in developing a system to reduce the risk of heat-related mortality. The program combines heat alerts, personalized outreach to elderly residents, a voluntary program by which electric utilities refrain from shutting off services, public cooling places with extended hours, and home improvement assistance for low-income residents. Over its first three years, the program is estimated to have saved 117 lives.[47]

Other factors could be considered in such an analysis, for example, the percentage of city residents who are elderly, live alone, and other demographic variables; health indicators such as prevalence of asthma, cardiovascular disease, or diabetes; the amount of green space in the city; and climate projections for future heat waves. Analyses that have considered these other factors have identified a similar distribution of cities at risk.[48]

TABLE 1: EXTREME HEAT RISK FACTORS FOR 30 U.S. CITIES

	City	Average number of days per summer with oppressive heat	Percent of households without central air conditioning	Ground-level ozone in parts per billion relevant to EPA standard	Percent of households below poverty line
TIER 1	Boston, MA	12	73	79	20
	Charlotte, NC	15	16	94	12
	Dallas, TX	20	8	82	21
	Houston, TX	18	11	93	21
	Los Angeles, CA	9	61	110	19
	New York, NY	11	84	78	19
	Philadelphia, PA	16	52	89	24
	Phoenix, AZ	20	8	82	18
	Sacramento, CA	19	20	103	14
	San Diego, CA	10	65	93	12
TIER2	Austin, TX	21	8	78	18
	Baltimore, MD	12	25	87	20
	Buffalo, NY	5	76	82	28
	Chicago, IL	11	40	78	21
	Detroit, MI	10	39	82	34
	Memphis, TN	15	19	83	26
	Oklahoma City, OK	18	16	80	16
	Saint Louis, MO	19	14	82	22
	Tulsa, OK	21	16	79	19
	Washington, DC	15	12	88	16
TIER 3	Atlanta, GA	10	9	93	23
	Cincinnati, OH	5	36	85	24
	Cleveland, OH	8	49	82	30
	Las Vegas, NV	15	8	83	12
	Louisville, KY	15	17	79	17
	New Orleans, LA	10	25	79	32
	Pittsburgh, PA	6	48	86	21
	Raleigh, NC	16	16	80	12
	San Antonio, TX	12	22	80	18
	Toledo, OH	11	49	76	23

Heat Waves Could Cause Waves of Extinction

Wildlife and their habitats have natural mechanisms to help them endure normal summertime heat waves. However, the more extreme temperatures brought on by global warming are pushing wildlife and their habitats beyond their normal tolerance levels.[49]

Fish that prefer cold water are already being impacted by more intense heat waves. The summer of 2007 brought the largest known fish kill in the 135-year history of Yellowstone National Park as trout succumbed to high water temperatures. Park rangers had little choice but to implement unprecedented fishing closures on some 232 miles of rivers throughout the Park to reduce stress on the fish.[50] Warmer water could also shrink available habitat for Coho salmon by 23 to 41 percent by 2100 if greenhouse gas emissions are not reduced.[51]

Terrestrial species are also vulnerable to heat waves. Minnesota's northwestern population of moose has plummeted from over 4,000 to fewer than 200 animals in the last two decades. Scientists believe that warmer summers stressed the moose, which then ate less and became more vulnerable to parasites and diseases as their body condition declined.[52] The pika, a small mammal related to the rabbit, has also been disappearing from the lowest portions of its western high mountain habitat. Pikas are well adapted to the cold, but stop foraging for grasses and herbs when summer midday heat becomes too warm. Currently, the U.S. Fish and Wildlife Service is considering whether the pika should be listed under the Endangered Species Act because global warming is rapidly eliminating viable habitat.[53]

Plants are also vulnerable to heat stress.[54] Although increases in carbon dioxide can enhance plant growth, normal metabolic processes such as photosynthesis become disrupted and plant growth slows when temperatures exceed certain tolerance levels. An even greater concern, however, is the reduced soil moisture that accompanies heat waves, which can stress and even kill otherwise healthy plants. The combined moisture and heat stress makes trees and other plants more susceptible to disease, insect infestation, and wildfire.[55]

Heat Waves and Agriculture

The nation's three most important commercial livestock species – cows, pigs, and poultry – are all sensitive to extreme heat.[56] Recent studies indicate that the negative effects of hotter summers will outweigh the positive effects of warmer winters. For example, the optimal temperature range for milk production is 31 to 79°F, with higher temperatures causing cows to decrease their food intake, which reduces milk production.[57] One study found that dairy operations in the Southeast, Appalachia, and the southern Plains could see a 10 percent decline in annual yield if global warming pollution continues unabated.[58]

Even relatively brief spikes in temperature can be deadly for livestock, especially if they come early in the summer, before animals have had a chance to acclimate to warmer conditions. In June 2009, nearly 4000 cattle died in Nebraska when temperatures jumped to the 90s after a long, cool spring. Elevated humidity kept the heat index high overnight, further stressing the animals.[59]

High temperatures at critical development stages can also significantly reduce yields of wheat, rice, maize, potato, and soybean crops.[60] Exposure to high temperatures during pollination can be especially detrimental. The most costly heat-related crop losses typically occur when extreme temperatures are paired with drought conditions. The August 2007 drought and heat wave that affected the Southern United States is a prime example. By late in the month, the corn crops in Alabama and Tennessee were devastated.[61]

Keeping Our Cool: Recommendations for a Warming World

We need to take these trends toward more extreme heat waves into account when designing urban areas and public health programs. We can no longer plan based on the climate we used to have. Fortunately, there are several common-sense strategies for addressing extreme heat waves, some of which also provide other benefits such as energy cost savings, air pollution reductions, and improved urban landscapes. In particular, we must:

Reduce global warming pollution to minimize future extreme heat waves. To limit the magnitude of changes to the climate and the impacts on communities and wildlife, we must curb global warming pollution as much and as quickly as possible. It is important that policy makers, industry, and individuals work together to reduce global warming pollution from today's levels by at least 80 percent by 2050. This target is achievable with technologies either available or under development, but we must take aggressive action now to avoid the worst impacts. Shifting from reliance on burning fossil fuels to solar energy sources has the combined benefits of greatly reduced air pollution and plentiful energy when electricity demand for air conditioning peaks during extreme heat waves. Furthermore, emissions of methane and black carbon should be reduced to address both global warming and air pollution.

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Environmental Protection Agency

Make cities cooler and greener. Well-designed urban areas can contribute significantly to reducing the potential health impacts of extreme heat waves. More reflective or lighter colored roof coatings and other building materials absorb less heat and can reduce some of the urban heat island effect. Similarly, introducing more green space — parks, trees, and "green" roofs — can greatly reduce the urban heat build-up. Vegetation absorbs less incoming sunlight than pavement, concrete, and other building materials, and also provides some cooling through evapotranspiration. Greener cities can have the added benefits of providing local sources of fresh produce from community gardens and creating educational and community-building opportunities.

Implement public health measures that reduce the impact of extreme heat waves. Planning for extreme heat waves has been shown to significantly reduce health impacts on urban residents. Cities vulnerable to extreme heat should develop heat watch and warning systems. Such programs can identify dangerous conditions and alert residents through public service announcements, hotlines, and personalized outreach to at-risk citizens, especially the elderly, homeless, and poor. Cities also can establish public cooling places and encourage electric companies to refrain from shutting off services for non-payment. In addition, cities and charitable organizations can provide assistance to low-income residents for light-colored roof coatings, improved insulation, and to lessen cooling costs (similar to programs that provide winter heating assistance). Stakeholders from vulnerable communities should be included in decision-making processes to ensure that policies and programs address their needs and concerns.

Safeguard wildlife, fish, and habitats from extreme heat. Targeted habitat restoration and wildlife management approaches can reduce the impact of extreme heat on key species. For example, cold water fish can be assisted by restoring stream-shading vegetation, maintaining sufficient in-stream flows to keep water cooler, and restricting catch and release fishing when summertime stream temperatures reach stressful levels. Congress should include dedicated funding to take these and other steps for safeguarding natural resources in comprehensive climate change legislation.


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Special thanks to: Rachel Harris from the Women's Environment and Development Organization, Jason Parson from Parson and Associates LLC, Tremaine Phillips from the Michigan Environment Council, and Michael Murray, Felice Stadler, Bruce Stein, Timothy Warman, and Aileo Weinmann from National Wildlife Federation for providing helpful review comments. Barbara Raab Sgouros skillfully handled the design and layout of the report.

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