October 2007

Sneezing and Wheezing

How Global Warming Could Increase Ragweed Allergies, Air Pollution, and Asthma

Authors

Kim Knowlton, Dr.P.H.

Miriam Rotkin-Ellman, M.P.H.

Gina Solomon, M.D., M.P.H.

Natural Resources Defense Council

NRDC

The Earth's Best Defense

About NRDC

The Natural Resources Defense Council is an international nonprofit environmental organization with more than 1.2 million members and online activists. Since 1970, our lawyers, scientists, and other environmental specialists have worked to protect the world's natural resources, public health, and the environment. NRDC has offices in NewYork City, Washington, D.C., Los Angeles, Chicago, San Francisco, and Beijing. Visit us at www.nrdc.org.

Acknowledgments

The authors would like to thank Zev Ross and Rosanne Hoyem of ZevRoss Spatial Analysis, Ithaca, New York, for conducting the mapping of ragweed and ozone data. We would also like to thank Cindy and Alan Horn for their support of NRDC's Global Warming and Health Project.

We are grateful to the following peer reviewers who provided invaluable comments on this report: Lewis H. Ziska, USDA Agricultural Research Service; Paul R. Epstein, Center for Health and the Global Environment, Harvard Medical School; David J. Shulan, Certified Allergy and Asthma Consultants, Albany, New York; Patrick L. Kinney, Mailman School of Public Health, Columbia University; and Ivan J. Ramirez, Department of Geography, Michigan State University.

NRDC Director of Communications: Phil Gutis
NRDC Marketing and Operations Director: Alexandra Kennaugh
NRDC Publications Manager: Lisa Goffredi
NRDC Publications Editor: Anthony Clark

For additional copies of this report, send $5.00 plus $3.95 shipping and handling to NRDC Publications Department, 40 West 20th Street, New York, NY 10011. California residents must add 7.5% sales tax. Please make checks payable to NRDC in U.S. dollars. The report is also available online at www.nrdc.org/policy

This report is printed on paper that is 100 percent post-consumer recycled fiber, processed chlorine free.

Executive Summary

We already know that global warming is making the planet hotter. Scientific studies have also shown that our changing climate could favor the formation of more ozone pollution in some areas and also intensify the health problems stemming from allergenic pollen such as ragweed. This is bad news for allergy sufferers and asthmatics because both ragweed and ozone have been linked to respiratory problems such as asthma and to allergic symptoms in adults and children. Moreover, studies show that people exposed to both ragweed and ozone can become sicker than people exposed to just one of these pollutants.[1] These negative health effects will only get worse if carbon dioxide (CO_2) concentrations keep rising and global warming continues unchecked.

In order to better understand the scope of this problem and who will be most affected by it, NRDC conducted new research, mapping for the first time areas within the United States where ragweed and unhealthy ozone pollution overlap. The findings show that 110 million Americans live in areas with both ragweed and ozone problems. Among the most vulnerable regions are the Los Angeles basin, the southern Mississippi River valley, the Great Lakes area, the Mid-Atlantic states, the New York area, and New England. Our analysis found that people in 308 counties in the United States live in places with the double threat of ragweed and high ozone levels. In fact, 13 of the top 15 "Asthma Capitals 2007" identified by the Asthma and Allergy Foundation of America are in counties where both problems occur.

Allergies and Asthma: Serious Health Threats on the Rise

An estimated 36 million Americans have some type of seasonal allergy, and 20 to 30 percent of the population at some time suffers from seasonal *allergic rhinitis* (or "hay fever"), whose symptoms include inflammation and irritation of the nose, sinuses, throat, eyes, and ears; sneezing; runny nose; and itchy eyes.[2] Allergies can seriously affect health and

productivity: Eighty percent of seasonal allergy sufferers experience sleep problems, fatigue, or loss of concentration. It is estimated that more than 3.8 million days per year are missed at schools and businesses due to seasonal ragweed pollen allergies.[3] In many industrialized countries like the United States, there is evidence that respiratory allergic diseases are increasing in prevalence and severity,[4] at least one researcher suggests that people in cities are more likely to experience allergy symptoms than those living in rural areas, a concern that warrants further research.[5]

An estimated 17 million children and adults in the United States have asthma, a chronic lung disease in which air passages become inflamed and constricted, making breathing difficult. While asthma symptoms can be controlled, the disease cannot be cured. Allergies are among the factors that can trigger an asthma attack, and 80 percent of children and 50 percent of adults with asthma also have some type of allergy.[6] Between 60 and 78 percent of people with asthma also have coexisting allergic rhinitis.[7]

There has been a worldwide increase in the prevalence and severity of asthma in recent decades. In the United States, self-reported cases went up 75 percent from 1980 to 1994.[8] (After 1994, the methods for tracking asthma changed, so it is difficult to say whether the trend has continued.) An even greater increase—160 percent—was found among preschool-age children.[9] Some researchers have voiced concerns about children's health being threatened by global warming,[10] and have proposed that the observed rise in asthma cases could be an early impact of climate change.[11]

Global Warming Worsens Respiratory Health

The severity of both allergies and asthma is closely linked to environmental conditions, particularly air quality. Global warming and rising CO_2 levels are projected to worsen air quality and could threaten human health in many areas due to increased levels of allergenic pollen and ground-level ozone. Scientific studies have found that allergenic pollen production increases as carbon dioxide concentrations and temperatures climb. For example, ragweed plants have been shown to grow bigger and produce more pollen when the levels of greenhouse gases (specifically carbon dioxide) increase. Other important allergenic plants have not been as extensively studied in the United States. Ragweed plants have also shown increased tolerance to high ozone levels.[12] Warmer temperatures can enhance the reactions that form ground-level ozone smog in the air we breathe.

Government Agencies Must Protect Communities From the Health Effects of Global Warming

Many of the sources of ozone-producing chemicals are the same as those of global warming pollution—industrial facilities, electric utilities, and motor vehicle exhaust. Therefore, minimizing emissions from these sources can help reduce both ozone air pollution and global warming, helping to create better air quality conditions today and a cooler, healthier environment in the future. To achieve this goal, governments must act quickly to institute comprehensive controls on sources of air pollution and global warming pollution.

Picture this: Twenty years in the future, the "dog days" of August and September bring still, cloudless days that increase peak ozone concentrations. At the same time, years of heightened CO_2 emissions and blazing temperatures have created the perfect conditions for ragweed pollen production. Particularly in and around cities, where the urban heat island effect boosts temperatures and ragweed thrives in the disturbed soils of vacant lots and building sites, people who suffer from allergies and asthma will get sick with a host of debilitating symptoms. Thanks to the potential for weeds, grasses, and trees to increase their pollen production; worsening air quality on hot days; increased asthma attacks from smog in the air; and a prolonged allergy season, our health will likely suffer in a warming world.

Protecting Your Family From Pollen and Ozone

Follow these tips to avoid overexposure to ragweed pollen and ozone during the summer and fall, especially if you or family members have allergies or asthma:[13]

- Listen to the radio, watch TV, or visit online news outlets for daily pollen reports and air quality conditions (check EPA's www.airnow.gov website and the National Allergy Bureau's site at http://www.aaaai.org/nab). This is especially important on sunny days with little or no wind, when ozone concentrations can be particularly high.
- On days when pollen counts or ozone levels are high, minimize outdoor activities and keep windows closed when possible.
- Bathe or shower after spending time outdoors because pollen may have collected on your skin and in your hair.
- Wash bedding frequently to remove pollen that settles on pillows and sheets, and vacuum regularly, preferably with a vacuum cleaner that contains a high-efficiency particulate (HEPA) filter.
- Minimize your family's exposure to other known allergens because of the cumulative effect of multiple allergens in producing symptoms.
- Try to save your most strenuous outdoor activities for days with relatively low ozone levels, or do them in the morning before ozone levels rise.

Ozone and Ragweed: Health Threats Likely to Worsen with Global Warming

Unfortunately for human health, ragweed pollen tends to increase with higher carbon dioxide concentrations; summertime ozone levels in many areas also tend to be higher, due in part to warmer temperatures. Hot, clear summer days with calm winds tend to increase both ozone and pollen concentrations. These increases will likely have serious negative health effects, particularly for people living in areas that are doubly hit by both ragweed and high concentrations of ozone pollution, and for those with allergies and asthma.

Ozone can worsen allergic reactions and impair lung function, especially among children, the elderly, and people already suffering from asthma.[14] Some studies have found that allergic reactions to pollen are more common among children who live closer to busy roads,[15, 16] and that traffic-related air pollution is linked to increased allergic symptoms.[17] Even at relatively low levels, air pollution, including ozone, has been related to breathing problems and decreased lung function in asthmatic children.[18] And even short-term exposure to ozone can worsen asthmatic responses to allergens (such as ragweed pollen) in people with mild allergic asthma or rhinitis.[19] One study suggests the possibility that high ozone levels and heavy outdoor exercise may contribute to the development of asthma in non-asthmatic children, but this warrants further research.[20]

Another component of air pollution from combustion sources, diesel exhaust particulates, represents a triple threat to the health of those living along major bus and truck thoroughfares. These particulates can damage health by helping to deliver pollen deep into the lungs, by stimulating the immune system, and by making people more likely to develop allergic sensitizations, allergy symptoms, and asthma.[21]

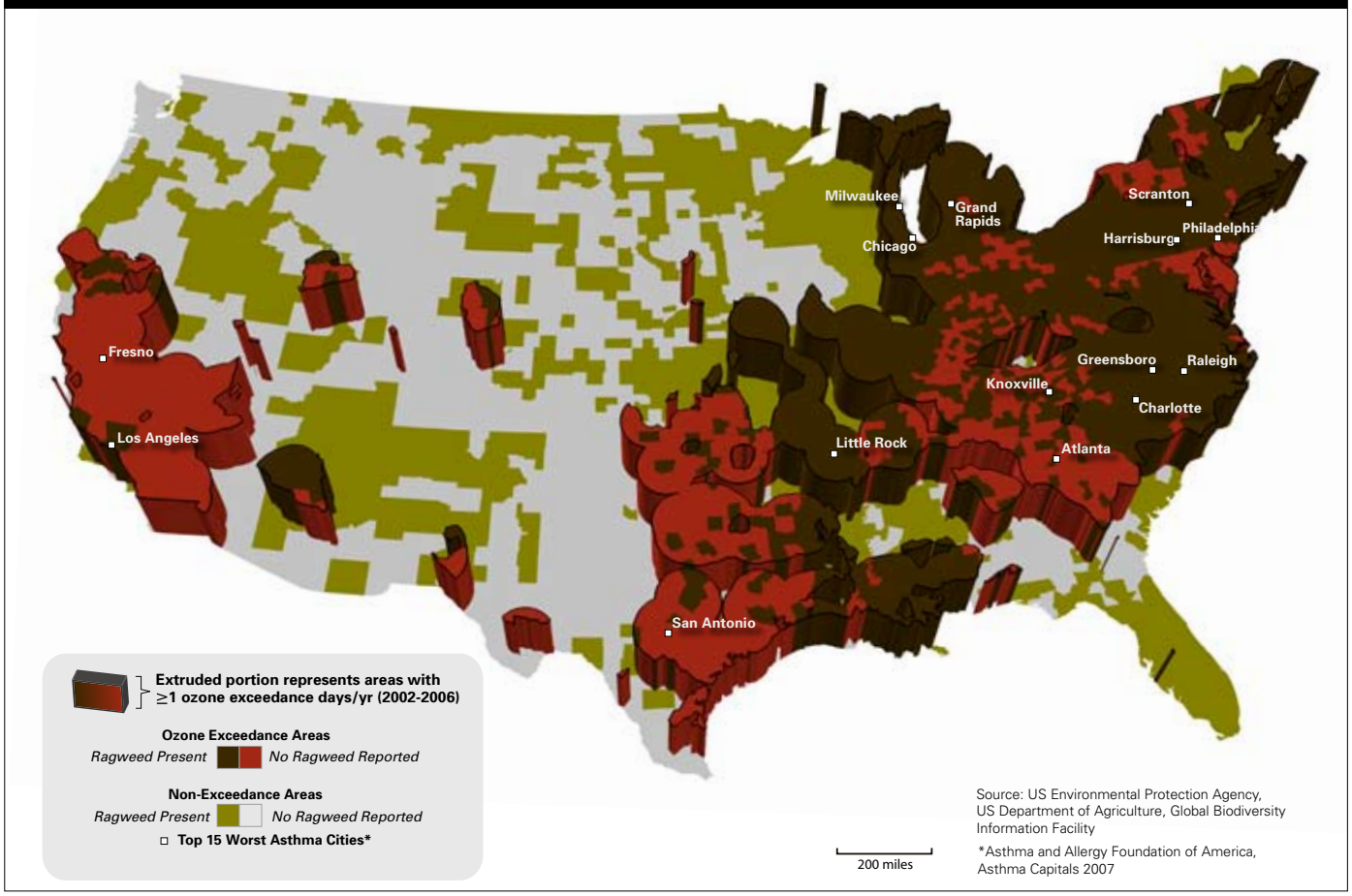
Atmospheric CO_2 concentrations have already increased more than 30 percent relative to preindustrial concentrations and by 22 percent since 1960, up from just under 315 parts per million (ppm) to the current estimate of 382 ppm. Since the late 19th century, global average surface temperatures have increased by 0.6°C, or 1°F.[22] The Intergovernmental Panel on Climate Change (IPCC) projects in its new Fourth Assessment Report that temperatures are likely to rise another 1.8° to 4.0°C (3.2° to 7.2°F) by 2100, with possible increases of up to 6.4°C (11.5°F).[23] It is important to remember that even when the average temperature increases only slightly, peak temperatures can increase significantly. That means that many more hot days will be in store in the future.

Mapping the Most Vulnerable Regions

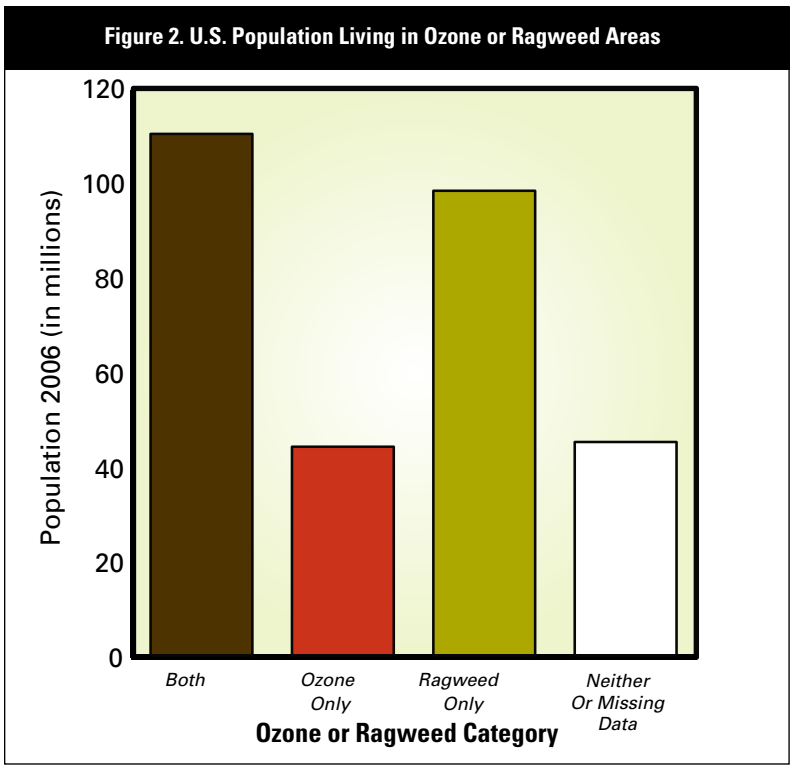
Because there is evidence that exposure to unhealthy levels of ozone can damage the lungs and worsen allergic responses to ragweed pollen, NRDC identified those areas of the United States where ragweed and ozone problems intersect. We overlaid the areas that experience an average of one or more days per year of unhealthy ozone conditions on a map base that shows U.S. counties where ragweed has been reported. There are 308 counties in the United States—home to 110 million people—that experience both ragweed pollen and unhealthy ozone days (Figure 1). Together, the two pollutants can interact to worsen respiratory health, making these areas especially vulnerable to increasing allergic and respiratory disease with global warming.

Figure 1 also shows the location of the 15 cities that top the list of "Asthma Capitals 2007—The Most Challenging Places to Live with Asthma," published by the Asthma and Allergy Foundation of America.[24] This is one list on which being in first place is no honor: The top spot each year is reserved for the metro area with the greatest concentration of negative factors that can potentially affect asthma patients.[25] The top 15 cities for 2007 are: Atlanta; Philadelphia; Raleigh, North Carolina; Knoxville, Tennessee; Harrisburg, Pennsylvania; Grand Rapids, Michigan; Milwaukee; Greensboro, North Carolina; Scranton, Pennsylvania; Little Rock, Arkansas; San Antonio, Texas; Los Angeles; Chicago; Charlotte, North Carolina; and Fresno, California. Thirteen of these top 15 "asthma capitals"[26] are located in areas where people's health is currently challenged by both ragweed and ozone. And as temperatures warm and carbon dioxide concentrations increase with global warming, both of these conditions could become even more severe.

Figure 1. Intersection of Ragweed-Positive and 8-Hour Ozone Exceedance-Positive Areas in the Continental United States



Note: Ragweed data as of 2007. Ozone data based on annual average of monitors with valid 8-hour data for at least 75 percent of required monitoring days in each year (2002-2006). Limited to areas with at least one monitor within 62 miles (100 km).



Based on U.S. Census 2006 population by county, http://www.census.gov/popest/datasets.html

The results are sobering: Figure 2 shows that in 2006 millions of Americans lived in counties where ragweed was reported or where unhealthy ozone levels occur. More than 150 million Americans live in counties where ozone violates the EPA's health-based standards at least once a year, on average, and a whopping 200 million people live in counties where ragweed has been reported.

How Ozone Is Hazardous to Your Health

Ozone (also known as smog) is an irritant that inflames the lungs.[27] Health effects related to ozone include increased respiratory symptoms, damage to cells of the respiratory tract, lung inflammation, diminished lung function in healthy adults, increased susceptibility to respiratory infections,[28] and exacerbation of asthma. These illnesses often lead to increased school absences and an increase in hospital admissions for respiratory ailments and emergency room visits.[29, 30] It has been estimated that more than 100 million Americans currently live in areas where ozone concentrations exceed the U.S. EPA 8-hour regulatory limit—a limit that the EPA scientific advisory board has recommended lowering because it is not sufficiently protective of health.[31]

The Ozone and Global Warming Connection

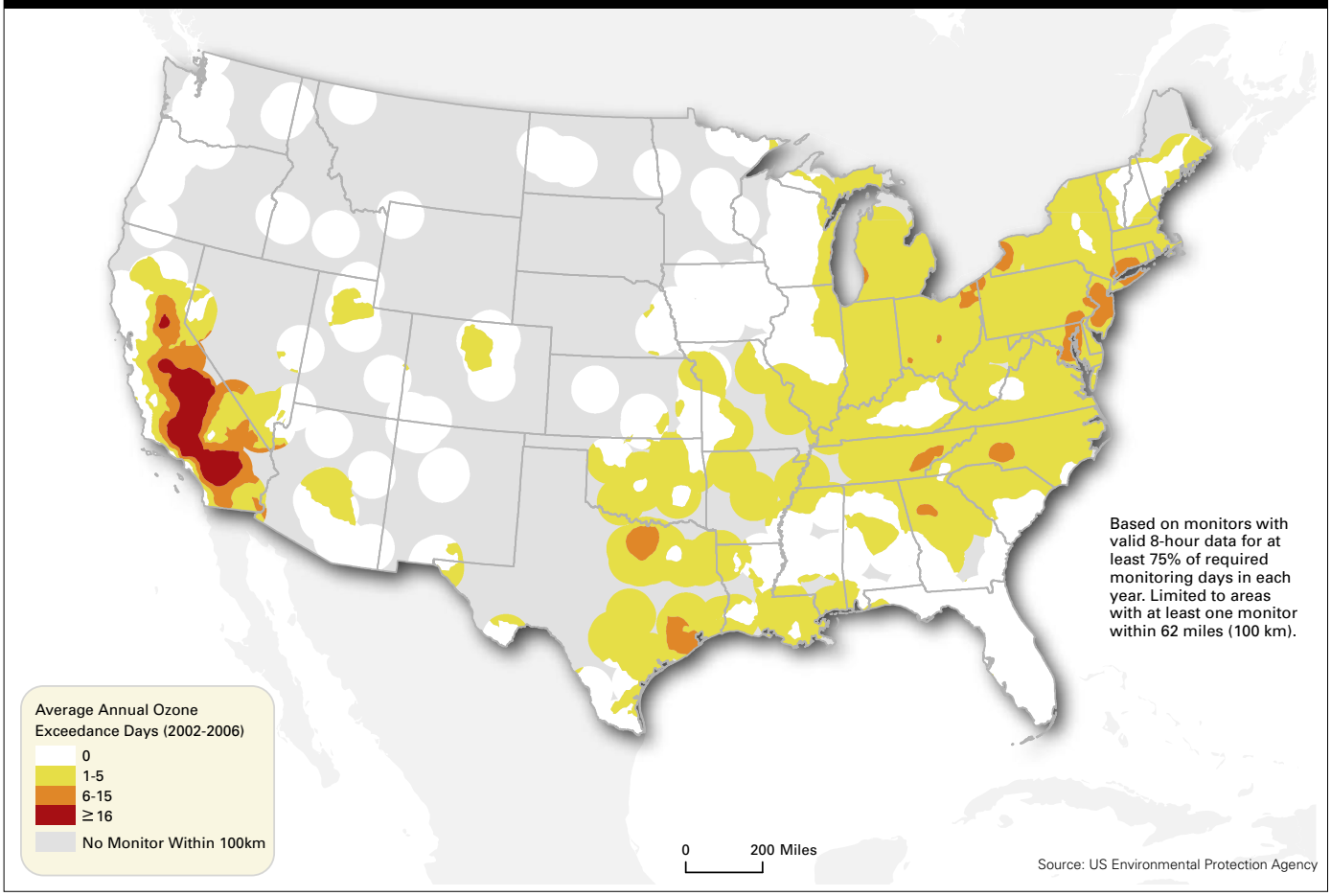
Ozone is formed at ground level by the combination of two types of pollutants, nitrogen oxides and volatile organic compounds (VOCs), in the presence of sunlight. Warmer temperatures enhance the reactions that form ozone in the air we breathe. As a result, maximum ozone concentrations typically occur during the hot summer months.[32]

Vehicle exhaust and emissions from power plants and certain industrial facilities contain nitrogen oxides. Volatile organic compounds are emitted from these same sources. VOCs also are emitted from plants, a phenomenon enhanced by higher summer temperatures. A number of U.S. studies have projected that global warming could increase ozone concentrations in already polluted areas in the absence of further efforts to reduce nitrogen oxides and VOC emissions.[33] Any increase in ozone concentrations will further contribute to respiratory illnesses already experienced by millions of Americans.

Many Regions Exceed EPA Health Standard for Ozone

Ozone levels in many areas of the country currently exceed standards set to protect public health. Ozone is a regional pollutant, and although there are gaps in data from existing monitoring stations, extrapolating from the existing monitoring stations shows that many regions of the country experience ozone levels that could be harmful to human health (Figure 3). The EPA's 8-hour ozone standard is exceeded on a widely varying average number of days in different regions of the United States, with a range from zero to more than 16 days per year. The two regions with the highest average values are in California and the Washington-Philadelphia-New York-Boston corridor in the Northeast, with some high values in the upper Ohio River Valley, the Southeast, Texas, and several western urban areas. More than 150 million people currently live in areas where ozone levels can be harmful, and these levels could worsen under global warming. A map showing the counties that contain ozone monitoring stations and those that exceed the ozone standard is shown in Appendix A.

Figure 3. Mean Number of 8-Hour Ozone Exceedance Days per Year, 2002-2006



How Ragweed Pollen Is Hazardous to Your Health

Pollen grains are the male reproductive structures of plants. Usually too small to see, they can be dispersed widely by wind, water, or insects. While most pollen grains are dispersed locally, some can be carried many miles into the surrounding countryside.[34] Pollen is a common substance that can trigger allergic reactions. An individual's tendency to develop allergies usually has a genetic component, but it is common for people to develop new allergies over their lifetime. The development of allergies also depends upon the total amount of allergen and the length of exposure.[35]

Many plants produce pollen that can be allergenic and harmful to human health, and comprehensive studies have not yet been conducted in the United States to evaluate the possible effects of higher CO_2 concentrations and warmer temperatures (projected with climate change) on growth and pollen production of most plants. Ragweed, however, has been studied because it is clinically an important allergen that causes seasonal symptoms in many Americans. Furthermore, while the springtime peak in tree pollen typically happens before most high ozone days occur, ragweed's late summer to early fall pollen season can coincide with high ozone levels.

Common Ragweed (Ambrosia artemisiifolia)

Source: USDA Crop Systems and Global Change Lab, Beltsville, MD.

In North America, ragweed makes pollen seasonally, beginning around mid-August and continuing into October. Ragweed (*Ambrosia artemisiifolia*), a widespread endemic weed, is commonly found in open, disturbed ground around homes, fields, roadsides, and vacant lots in the Northeast, Midwest, and South. Ragweed is considered to be a significant cause of summer and fall allergies.

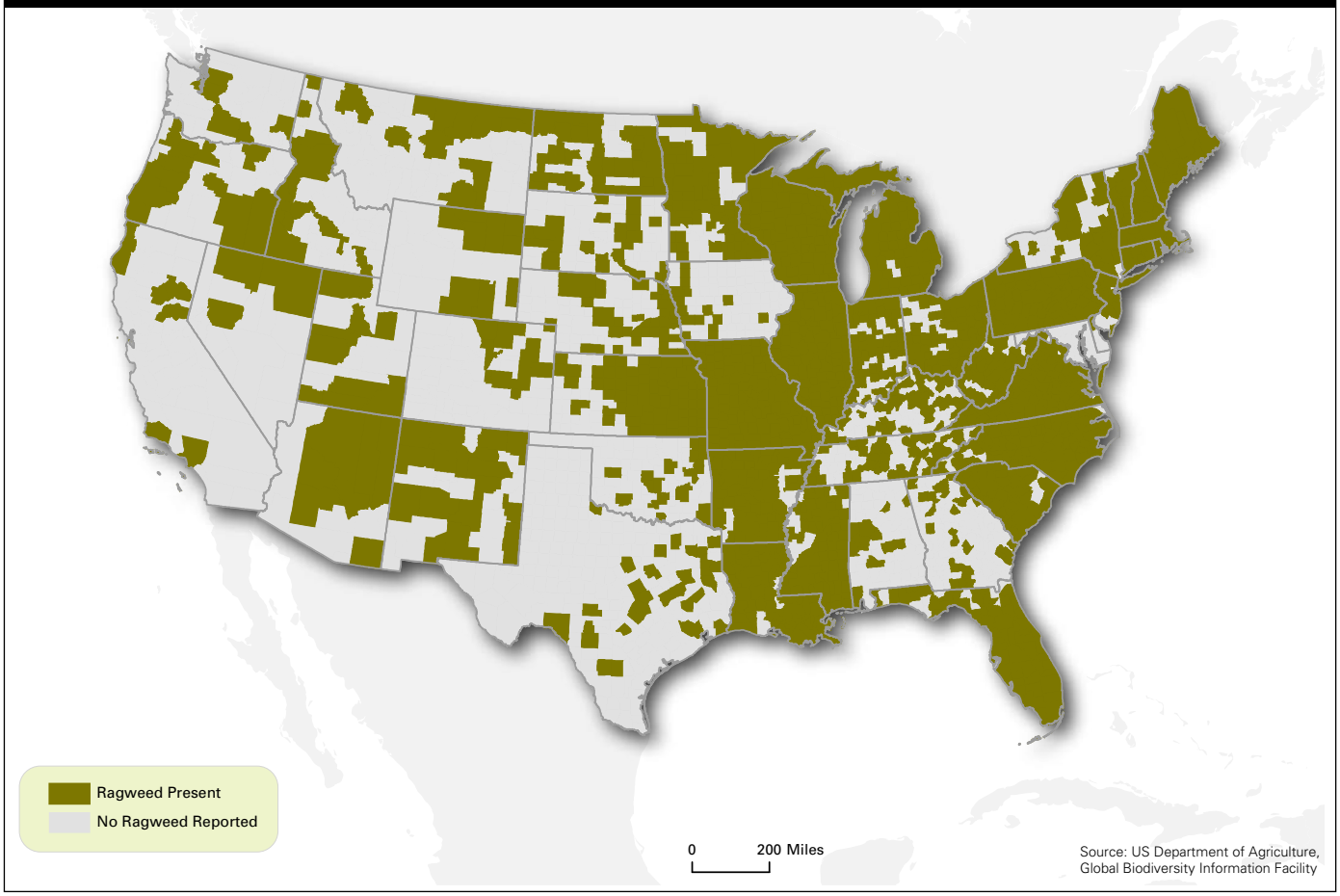
Pollen allergies can have particularly severe health consequences for people with asthma. In one study, weed pollen levels were linked to autumn peaks in children's asthma hospitalizations.[36] There are important connections between warming temperatures, higher concentrations of dioxide (the main global warming pollutant), and the allergenic pollen produced from plants like ragweed.

The Ragweed and Global Warming Connection

A growing number of laboratory and field tests have shown that when there is more carbon dioxide (CO_2) in the environment, ragweed produces significantly more pollen.[37] In one study, ragweed plants grown under approximately current CO_2 conditions (which were then 370 ppm) and conditions predicted to hit by the mid- to late 21st century (600 ppm) produced 131 percent and 320 percent more pollen, respectively, than did ragweed plants grown at preindustrial levels of CO_2 (280 ppm).[38] Along with ragweed, many other pollen-producing plants, including birch, oak, and pine trees, tend to produce pollen earlier, for a longer time, and in greater total amounts under higher CO_2 and temperature conditions—the kinds of conditions associated with global warming.[39] Weeds such as ragweed, dandelion, and poison ivy are expected to proliferate as carbon dioxide levels in the atmosphere continue to rise.

Ragweed thrives in urban and suburban environments where disturbed soils are common and where vehicle and industrial emissions from fossil fuel combustion create "CO_2 domes" over cities. In one study, ragweed pollen concentrations were higher in an urban environment (with warmer temperatures and 30 to 31 percent higher CO_2 levels) than in surrounding rural areas.[40] Furthermore, temperatures tend to be higher in urbanized areas because building and pavement materials capture and re-radiate heat more slowly than natural vegetated areas, creating an urban heat-island effect that could contribute to higher pollen and ozone production in cities.[41]

Figure 4. Ragweed Occurrence by County (reported as of 2007)



As Figure 4 shows, ragweed is found in many areas of the country. In particular, it is widely reported in Eastern and Midwestern states as well as in smaller areas of the desert Southwest and West. Some states in the Mississippi Valley, the Northeast, and the mid-Atlantic region have nearly continuous coverage of reported ragweed. This is no surprise given the highly adaptable nature of this weed species. In fact, it is likely that more counties than those shown in Figure 4 may have ragweed but have not yet reported it to agencies like the U.S. Department of Agriculture (USDA). We estimate that more than 200 million people currently live in areas with ragweed pollen that is likely to worsen under global warming.

Recommendations

Governments must act quickly to institute comprehensive controls on sources of global warming pollution. The good news is that we already know what needs to be done. In order to protect public health, Congress must address global warming through mandatory legislation that reduces global warming pollution on the order of 20 percent by 2020 and 80 percent by 2050.

In addition:

- The U.S. EPA should lower the allowable standard for ozone in air to a level that will adequately protect public health, and then require states to comply by reducing pollution.

- Government agencies should establish a network of daily pollen collection sites and share the information with local health practitioners and researchers to inform allergy and asthma sufferers about environmental conditions that could adversely affect their health.

- The U.S. Department of Agriculture (USDA), National Institutes of Health (NIH), or the National Science Foundation (NSF) should establish a comprehensive reporting and tracking system for ragweed and other potentially harmful weed species. Currently available information on ragweed occurrence may be overreporting the presence of ragweed in areas with more active and educated communities, while underreporting its presence in areas with less community involvement. The same would hold true for other pollen-bearing allergenic species that could be affected by higher CO_2 concentrations and warmer temperatures under a changing climate.

- The U.S. EPA should locate more ozone monitoring stations in many areas of the country where none now exist, to track local ozone conditions that can contribute to health-harming smog.

- The Centers for Disease Control and Prevention (CDC) should create a national initiative to help state and county health agencies prepare for the health impacts of global warming.

If you or someone in your family has ragweed allergies, it is helpful to start antihistamines or other allergy and asthma medications 10 to 14 days before the arrival of your area's peak ragweed pollen season. If you think you have symptoms,

you may want to visit an allergist or immunologist who can help you get an accurate diagnosis and work with you to develop an effective treatment plan.[42]

What you can do:

- If you or someone in your family has been diagnosed with asthma, be sure to follow the treatment plan you and your physician have designed.
- Ask your physician if he or she can suggest other strategies for minimizing ozone and pollen exposure.

APPENDIX A

Methodology Used in Mapping Ragweed and Ozone

To map ozone and ragweed conditions in the continental United States, we first surveyed current publicly available data sources. Our goal was to create maps for the entire continental United States, showing locations where residents are exposed to unhealthy levels of ozone, where ragweed is known thrive, and where people may be exposed to both ragweed pollen and ozone.

Ozone Data and Maps

All ozone maps are derived from publicly available data from the U.S. Environmental Protection Agency website (http://www.epa.gov/air/data/geosel.html). We selected "monitor values" data for ozone for the years 2002–2006 and used a precalculated field in the EPA data that represents the "number of days in the year when an 8-hour average concentration exceeded the level of the 8-hour standard." We calculated an average number of ozone exceedance days per year for only those monitors with at least 75 percent data completeness and those with data for all five years. Multiple monitors at a single site were treated as separate monitors.

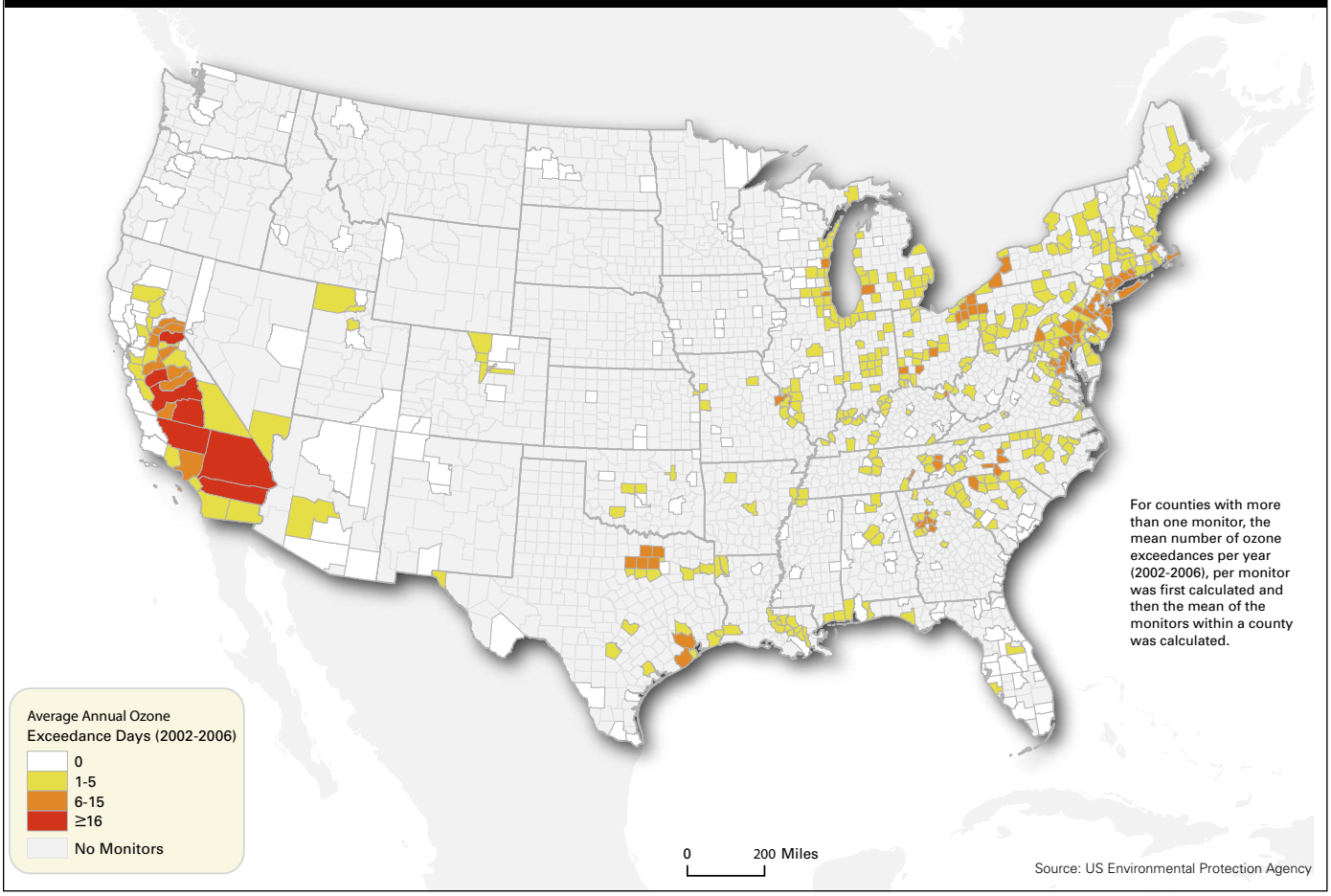
County-Level Maps

Counties with a single monitor were assigned that monitor's average number of ozone exceedance days per year. For counties with multiple monitors, the county was assigned a mean of the monitor-level means (Appendix Figure A1).

Interpolated (Smoothed) Map

The smoothed map (Figure 3) was created using an interpolation technique known as kriging. Kriging, in this case, makes use of the statistical relationship between the ozone exceedance data and distance from a monitor to impute values at unmonitored locations. To help project regional ozone conditions for people living in counties without ozone monitoring stations, kriging was used to construct a smoothed surface of ozone concentrations from stations within at least 62 miles (100 kilometers). In terms of technical specifications, variography was conducted using the GSTAT library in R-statistical software. We used a cutoff of 250,000 meters and bin breaks of 5,000 meters. A spherical model (nugget = 3.14, partial sill = 57.39, range = 131 km) fit the variograms well, and the resulting parameters were used in ArcGIS Geostatistical Analyst to conduct the (ordinary) kriging.

Figure A1. Mean Number of 8-Hour Ozone Exceedance Days by County Per Year, 2002-2006



Note on Differences Between County-Level and Interpolated Maps

The county-level maps use, in some cases, an average of several monitors for a single county, whereas the interpolation uses monitor-level data more directly. Therefore, small differences in the maps can occur. An individual county, for example, may have a monitor with an average number of exceedances greater than 1, but if all the monitors in that county average out to less than 1, the county will be assigned to the zero category. In kriging, however, the small geographic area at and around the monitor with more than 1 exceedance will be assigned a value above 1. As a result, the two maps may categorize a few small areas differently.

Ragweed Data

Counties with ragweed (Figure 4) were identified using two publicly available databases. We downloaded and cross-referenced data from the USDA Natural Resources Conservation Service PLANTS database (http://plants.usda.gov/index.html),[43] and the Global Biodiversity Information Facility (http://www.gbif.org/).[44] If ragweed was reported in a particular county in either (or both) of these databases, that county was assigned to the "ragweed present" category. Any non-ragweed county that was completely surrounded by ragweed-present counties was also assigned to the "ragweed present" category.

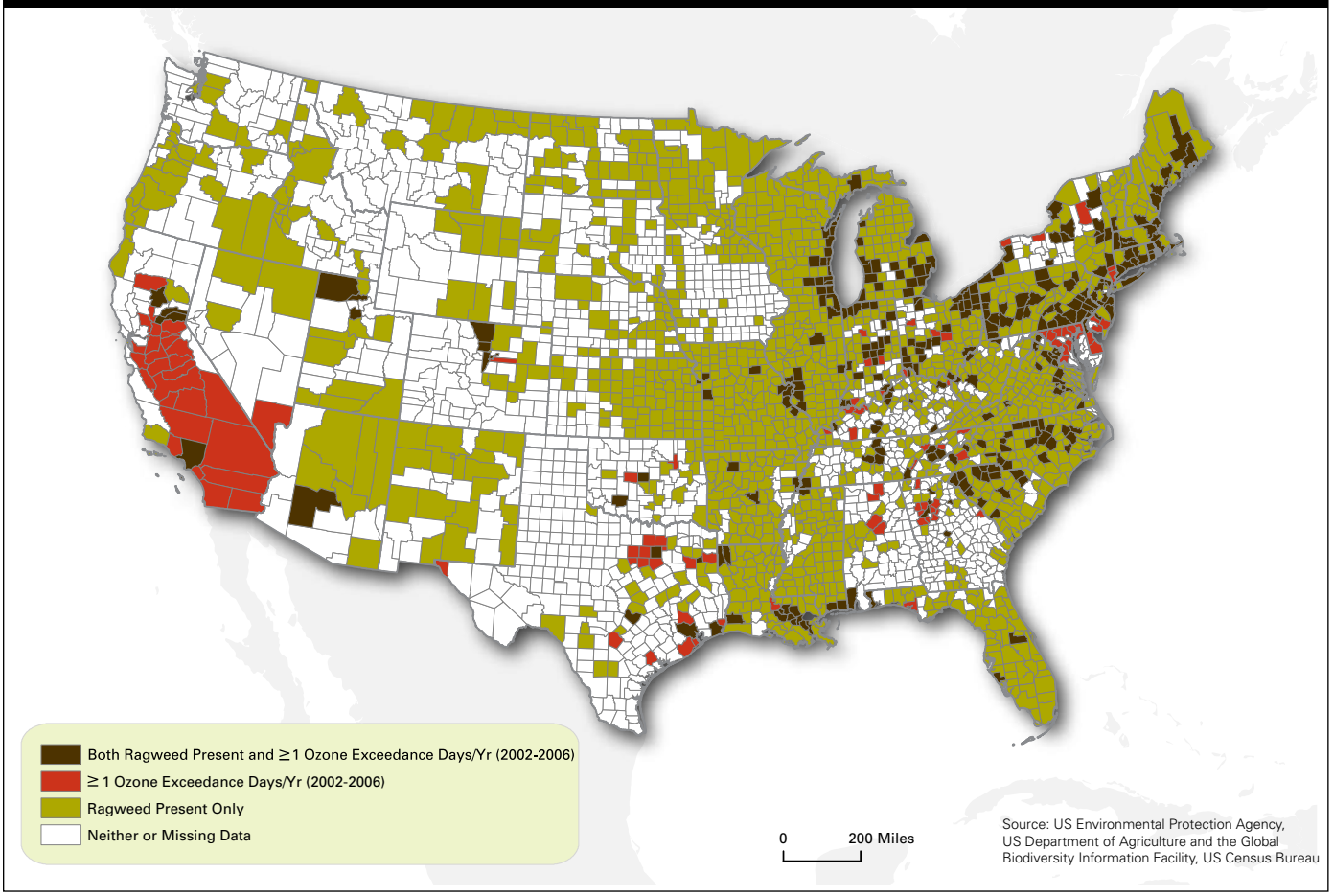
Combining the Ozone and Ragweed Maps

Because there is evidence that exposures to unhealthy levels of ozone can harm the lungs and make allergic responses to ragweed pollen worse, we wanted to evaluate those areas of the United States that experience an average of one or more days per year of unhealthy ozone conditions on the same map base that shows U.S. counties where ragweed has been reported. Two different maps were prepared. The first (Appendix Figure A2) shows four vulnerability levels:

- areas with neither unhealthy ozone nor ragweed reported (or for which no data exist)
- areas with ragweed only
- areas with an average of one or more ozone-exceedance days per year
- areas with both ragweed and an average of one or more unhealthy ozone days annually

Figure 2 gives a tally of the numbers of Americans who lived in the counties in each of these four categories as a bar graph, using 2006 county population estimates from the U.S. Census Bureau.[45] The second map version (Figure 1) shows the same type of information on a bilevel map that uses the kriged ozone surface to provide a more regional sense of areas where the two potentially health-damaging conditions coincide. Reported ragweed is shown in green; ozone exceedance areas are shown in red on an extruded map surface; and areas with both conditions are shown in brown on the extruded surface. Figure 1 also shows the location of the top 15 from "Asthma Capitals 2007—The Most Challenging Places to Live with Asthma," published by the Asthma and Allergy Foundation of America.[46]

Figure A2. Intersection of Ragweed-positive and Ozone Exceedance-positive Areas in the Continental United States, by County



Blank Page 17

Endnotes

1 G. D'Amato, et al., "On the Interrelationship Between Outdoor Air Pollution and Respiratory Allergy." *Aerobiologia* 16 (2000), pp. 1-6; G. D'Amato, et al., "The Role of Outdoor Air Pollution and Climatic Changes on the Rising Trends in Respiratory Allergy," *Resp Med* 95 (2001), pp. 606-611; G. D'Amato, et al., "Outdoor Air Pollution, Climatic Changes and Allergic Bronchial Asthma," Eur Resp J 20 (2002) , pp. 763-776; G. D'Amato, "Environmental Urban Factors (Air Pollution and Allergens) and the Rising Trends in Allergic Respiratory Diseases," *Allergy* 57 (2002), suppl. 72, pp. 30-33.

2 Certified Allergy and Asthma Consultants, *Allergic Rhinitis* (Albany, New York, 2003), available at http://www.certifiedallergy.com/pdf/allergicrhinitis.pdf.m3 "Sniffles and Sneezes: the AAAAI Offers Tips to Prepare for Ragweed Season." American Academy of Allergy, Asthma & Immunology (2007), Available online at http://www.medicalnewstoday.com/articles/78618.php.

4 G. D'Amato, et al., 2000.

5 G. D'Amato, 2002.

6 Certified Allergy and Asthma Consultants, *Asthma Facts and Figures* (Albany, New York, 2003), available at http://www.certifiedallergy.com/asthma.asp.

7 J. Grossman, "One Airway, One Disease," Chest 111 (1997), suppl. 2, pp. 11S-16S.

8 *Ibid.*

9 D.M. Mannino, et al., "Surveillance for Asthma Prevalence: United States, 1960-1995." *Morbidity and Mortality Weekly Report (MMWR)* 47 (1998), SS-1, pp. 1-28.

10 K.L. Ebi and J.A. Paulson, "Climate Change and Children," *Pediatr Clin N Am* 54 (2007), pp. 213-226; S. Bunyavanich, et al., "The Impact of Climate Change on Child Health," *Ambulatory Pediatrics 3*, no. 1 (2003), pp. 44-52.

11 P.J. Beggs and H.J. Bambrick, "Is the Global Rise of Asthma an Early Impact of Anthropogenic Climate Change?" *Environ Health Perspect* 113 (2005), pp. 915-919.

12 L.H. Ziska, "*Sensitivity of Ragweed (Ambrosia artemisiifolia)* Growth to Urban Ozone Concentrations," *Functional Plant Biol* 29 (2002), pp. 1-5.

13 "Sniffles and Sneezes: the AAAAI Offers Tips to Prepare for Ragweed Season." American Academy of Allergy, Asthma & Immunology (2007), Available online at http://www.medicalnewstoday.com/articles/78618.php.

14 H.S. Koren and P.A. Bromberg, "Respiratory Responses of Asthmatics to Ozone," *Int Arch Allergy Immunol* 107, no. 1-3 (1995), pp. 236-238.

15 N.A.H. Janssen, et al., "The Relationship Between Air Pollution from Heavy Traffic and Allergic Sensitization, Bronchial Hyperresponsiveness, and Respiratory Symptoms in Dutch Schoolchildren," *Environ Health Perspect* 111 (2003), pp. 1,512-1,518.

16 C. Wyler, et al., "Exposure to Motor Vehicle Traffic and Allergic Sensitization," *Epidemiology* 11, no. 4 (2000), pp. 450-456.

17 U. Kramer, et al., "Traffic-Related Air pollution Is Associated with Atopy in Children Living in Urban Areas," *Epidemiology* 11 (2000), pp. 64-70.

18 K.M. Mortimer, et al., "The Effect of Air Pollution on Inner-City Children with Asthma," *Eur Respir J* 19 (2002), pp. 699-705.

19 R. Jorres, et al., "The Effect of Ozone Exposure on Allergen Responsiveness in Subjects with Asthma or Rhinitis," *Am J Respir Crit Care Med* 153 (1996), pp. 56-64. 20 R. McConnell, et al. "Asthma in Exercising Children Exposed to Ozone: a Cohort Study," *Lancet* 359 (2002), pp. 386-391.

21 R.B. Knox, et al., "Major Grass Pollen Allergen Lol p 1 Binds To Diesel Exhaust Particles: Implications for Asthma and Air Pollution," *Clin Exp Allergy* 27 (1997), pp. 246-251; D. Diaz-Sanchez, et al., "Diesel Exhaust Particles Directly Induce Activated Mast cells to Degranulate and Increase Histamine Levels and Symptom Severity," *J Allergy Clin Immunol* 106 (2000), pp.1,140-1,146; R.J. Pandya, et al., "Diesel Exhaust and Asthma: Potential Hypotheses and Molecular Mechanisms of Action," *Environ Health Perspect* 110 (suppl 1) (2002), pp. 103-112; R. Hauser, et al., "The Upper Airway Response to Pollen Is Enhanced by Exposure to Combustion Particulates: A Pilot Human Experimental Challenge Study," *Environ Health Perspect* 111 (2003), pp. 472-477.

22 P.J. Beggs, "Review: Impacts of Climate Change on Aeroallergens, Past and Future," *Clin Exp Allergy* 34 (2004), pp. 1,507-1,513.

23 IPCC, "Summary for Policymakers," *In Climate Change 2007: The Physical*

Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. S. Solomon, et al., eds., (Cambridge U.K.: Cambridge University Press, 2007) p.13.

24 Asthma and Allergy Foundation of America "Atlanta Named 2007 Asthma Capital" (2007), available online at http://www.asthmacapitals.com/.

25 Asthma and Allergy Foundation of America, "Asthma Capitals Ranking Methodology," (2007) available online at http://www.aafa.org/print.cfm?id=8&sub=104&cont=570

26 *Ibid.*

27 M. Beniston, "Climate Change: Possible Impacts on Human Health," *Swiss Med Wkly* 132 (2002), pp. 332-337.

28 American Lung Association (ALA). *Annotated Bibliography of Recent Studies of the Health Effects of Ozone Air Pollution 1997-2001* (Washington, D.C,:ALA, 2001), p. 10.

29 M.L. Bell, et al., "Ozone and Short-term Mortality in 95 U.S. Urban Communities, 1987-2000," *Journal of the American Medical Association* (JAMA) 292 (2004), pp. 2,372-2,378; P.J.M Koken, et al., "Temperature, Air Pollution, and Hospitalization for Cardiovascular Diseases Among Elderly People in Denver," *Environ Health Perspect* 111 (2003), pp. 1,312-1,317; P.L. Kinney, "The Pulmonary Effects of Outdoor Ozone and Particle Air Pollution," *Sem Resp Crit Care Med* 20 (1999), pp. 601-607; P.L. Kinney and H. Ozkaynak, "Associations of Daily Mortality and Air Pollution in Los Angeles County," *Environ Res* 54 (1991), pp.99-120; G.D. Thurston, et al., "A Multi-Year Study of Air Pollution and Respiratory Hospital Admissions in Three New York State Metropolitan Areas: Results for 1988 and 1989 Summers," *J Expo Anal Environ Epidemiol 2* (1992), pp. 429-450; A. Galizia and P.L. Kinney, Long-term Residence in Areas of High Ozone: Associations with Respiratory Health in a Nationwide Sample of Nonsmoking Young Adults. *Environ Health Perspect* 107 (1999), pp. 675-679.

30 R.B. Devlin, et al., "Inflammation and Cell Damage Induced by Repeated Exposures of Humans to Ozone," *Inhal Toxicol* 9

(1997), pp. 211-235; L.J. Folinsbee, J.F. Bedi, and S.M. Horvath, "Respiratory Responses in Humans Repeatedly Exposed to Low Concentrations of Ozone," Am Rev Respir Dis 121 (1980), pp. 431-439.

31 M. Bell, et al., "Climate Change, Ambient Ozone, and Health in 50 U.S. Cities," *Climatic Change* 82 (2007), pp. 61-76.

32 J.A. Patz, "Climate Change and Health: New Research Challenges," *Ecosyst Health* 6 (2000), pp. 52–58; J.H. Seinfeld and S.N. Pandis, *Atmospheric Chemistry and Physics: from Air Pollution to Climate Change* (New York: Wiley, 2006).

33 Bell, et al., "Assessing Ozone-related Health Impacts Under a Changing Climate," *Environ Health Perspect* 112 (2004), pp. 1,557-1,563; C. Hogrefe, et al., "Simulating Changes in Regional Air Pollution over the Eastern United States Due to Changes in Global and Regional Climate and Emissions," *J Geophys Res* 109 (2004), D22301, doi:10.1029/2004JD004690; K. Murazaki and P. Hess, "How Does Climate Change Contribute to Surface Ozone Change over the United States?" *J Geophys Res 111* (2006), D050301, doi:10.1029/2005JD005873.

34 AAAAI, *Ragweed: What's Really Behind Your Seasonal Allergies?* (August 1, 2007, 2007a), available at: http://www.aaaai.org/patients/topicofthemonth/0807/; P.D. Moore, "How Far Does Pollen Travel?" *Nature 260* (April 1, 1976) pp. 388-389.

35 Certified Allergy and Asthma Consultants, *Allergy* FAQs, Available at http://www. certifiedallergy.com/allergies.asp.

36 W. Im and D. Schneider, "Effect of Weed Pollen on Children's Hospital Admissions for Asthma During the Fall Season," *Arch Environ Occup Health* 60, no. 5 (2005) pp. 257- 265

37 P. Wayne, et al., "Production of Allergenic Pollen by Ragweed (*Ambrosia artemisiifolia L.*) Is Increased in CO2-enriched Atmospheres," *Ann Allergy Asthma Immunol* 88 (2002), pp.279-282; L.H. Ziska and F.A. Caulfield, "The Potential Influence of Rising Atmospheric Carbon Dioxide (CO2) on Public Health: Pollen Production of the Common Ragweed as a Test Case," *World Res Rev* 12 (2000) pp. 449-457; C.A. Rogers, et al., "Interaction of the Onset of Spring and Elevated Atmospheric CO2 on Ragweed (*Ambrosia artemisiifolia L.*) Pollen Production," Environ Health Perspect 114 (2006) pp. 865-869.

38 L.H. Ziska and F.A. Caulfield, Rising CO2 and Pollen Production of Common Ragweed (*Ambrosia artemisiifolia*), a Known Allergy-inducing Species: Implications for Public Health," *Aust J Plant Physiol* 27 (2000), pp. 893-898. 39 C.A. Rogers, "Carbon Dioxide and Aeroallergens," *In Climate Change Futures: Health, Ecological and Economic Dimensions. Center for Health and the Global Environment*, (Boston, Mass: Harvard Medical School, 2005), pp.48-52; F.T.M. Spieksma, et al., "Atmospheric Birch (betula) Pollen in Europe: Trends and Fluctuations in Annual Quantities and the Starting Date of the Seasons," *Grana* 34 (1995), pp. 51-57; T. Frei, "The Effects of Climate Change in Switzerland 1969-1996 on Airborne Pollen Quantities from Hazel, Birch and Grass," *Grana* 37 (1998) pp. 172-179.

40 L.H. Ziska, et al., "Cities as Harbingers of Climate Change: Common Ragweed, Urbanization, and Public Health," *J Allergy Clin Immunol* 111 (2003), pp. 290-295.

41 C.P. Lo and D.A. Quattrochi, "Land-use and Land-cover Change, Urban Heat Island Phenomenon, and Health Implications: A Remote Sensing Approach," *Photogrammetric Engineering and Remote Sensing* 69, no. 9 (2003), pp. 1,053-1,063.

42 *Ibid.*

43 USDA, NRCS. The PLANTS Database, (September 17, 2007), National Plant Data Center, Baton Rouge, LA, online at http://plants.usda.gov.

44 Global Biodiversity Information Facility (GBIF), available online at http://www.gbif.org (accessed September 17, 2007).

45 U.S. Census Bureau, National Population Datasets (2007), available online at http://www.census.gov/popest/datasets.html.

46 Asthma and Allergy Foundation of America, "Atlanta Named 2007 Asthma Capital" (2007), available online at http://www.asthmacapitals.com/.

Blank Page 20