

3. The Health Effects of Global Warming

Introduction

Many researchers, environmentalists, and politicians forecast that rising world temperatures in the next century will have devastating effects on human health (NRC 1991; Mitchell 1991; Cline 1992; Gore 1992; IPCC 1992). Referring to the world as a whole, Working Group II of the Intergovernmental Panel on Climate Change (1995b, SPM-10) asserted: "Climate change is likely to have wide-ranging and mostly adverse impacts on human health, with significant loss of life." The authors of the IPCC report feared that increases in heat waves would cause a rise in deaths from cardio-respiratory complications. They also foresaw a rise in vector-borne diseases, such as malaria and dengue and yellow fevers. The report did acknowledge briefly that, in colder regions, there would be fewer cold-related deaths.

Most of the causes of premature death have nothing to do with climate. Worldwide the leading causes are chronic diseases—accounting for 24 million deaths in 1996—such as maladies of the circulatory system, cancers, mental disorders, chronic respiratory conditions, and musculoskeletal disorders, none of which has anything to do with climate but everything to do with aging (*World Health Report 1997*, vol. 2, no. 1.). Another 17 million, most of them in poor countries, succumbed in the same year to disorders caused by infections or parasites, such as diarrhea, tuberculosis, measles, and malaria. Many of those diseases are unrelated to climate; most have to do with poverty.

Diarrheal diseases, such as cholera and dysentery, killed 2.5 million of the 52 million people who died worldwide in 1996. Through the provision of fresh water and proper sanitation, those diseases are easily preventable. Although a warmer climate might make the environment more hospitable for such afflictions as cholera, dysentery, and typhoid in areas without good sanitation or clean water, chlorination and filtration could halt their spread.

Both the scientific community and the medical establishment assert that the frightful forecasts of an upsurge in disease and early mortality stemming from climate change are unfounded, exaggerated, or misleading and do not require action to reduce greenhouse gas emissions. *Science* magazine reported that “predictions that global warming will spark epidemics have little basis, say infectious-disease specialists, who argue that public health measures will inevitably outweigh effects of climate” (Taubes 1997). It added: “Many of the researchers behind the dire predictions concede that the scenarios are speculative.” The American Council on Science and Health has recommended that spending to reduce greenhouse gas emissions will make societies poorer and that any additional outlays should go instead to such public health measures in developing countries as improving drinking water and sanitation, vector control, medical infrastructures, and systems of emergency response to extreme weather events (Shindell and Raso 1997).

This chapter examines the effect of climate and, in particular, temperatures on mortality in the United States. Anecdotal evidence suggests that warmer temperatures may actually promote health. Folklore alleges that physicians sometimes recommend that patients escape to a more clement climate, never to a colder one.

The few studies that have examined in depth the relation between warming and human health or mortality have focused either on increases in the number of days of very hot weather, which can increase mortality, or on the spread of infectious diseases by such vectors as mosquitoes, flies, and snails (Smith and Tirpak 1989; Kalkstein 1991; Stone 1995). Nevertheless, several major studies of the implications of global warming for the United States have neglected or claimed a lack of data on its effects on health or human welfare (NRC 1978; Nordhaus 1991; Cline 1992).

Other studies of the influence of climate change on human health have examined a rather narrow set of potential medical problems. The underlying research has generally referred to Lyme disease, malaria, dengue and yellow fevers, and encephalitis, none of which is a major health problem in the United States. The IPCC (1995b, p. SPM-10) has emphasized that the “geographical zone of potential malaria transmission in response to world temperature increases at the upper part of the IPCC-projected range (5° to 9°F by 2100) would increase from approximately 45 percent of the world population to approximately 60 percent by the latter half of the next century.”

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Concern about tropical and insect-spread diseases seems overblown. Inhabitants of Singapore, which lies almost on the equator, and of Hong Kong and Hawaii, which are also in the tropics, enjoy life spans as long as or longer than those of people living in Western Europe, Japan, and North America. Both Singapore and Hong Kong are free of malaria, but that mosquito-spread disease ravages nearby regions. Modern sanitation in advanced countries prevents the spread of many scourges found in hot climates. Such low-technology and relatively cheap devices as window screens can slow the spread of insect vectors. The World Health Organization (1990, 21) notes:

until recent times, endemic malaria was widespread in Europe and parts of North America and . . . yellow fever occasionally caused epidemics in Portugal, Spain and the USA. Stringent control measures . . . and certain changes in life-style following economic progress, have led to the eradication of malaria and yellow fever in these areas.

Under the stimulus of a warmer climate, insect-spread diseases might or might not increase. Many of the hosts or the insects themselves flourish within a relatively small temperature or climatic range. Plague, for example, spreads when the temperature is between 66° and 79°F with relatively high humidity but decreases during periods of high rainfall (White and Hertz-Picciotto 1995, 7-7-3). Higher temperatures and more rainfall are conducive to an increase in encephalitis. Malaria-bearing mosquitoes flourish under humid conditions with temperatures above 61° and below 95°F. Relative humidity below 25 percent causes either death or dormancy.

Parasitic diseases, such as AIDS, Lyme disease, yellow fever, malaria, and cholera, can usually be controlled through technology, good sanitary practices, and education of the public. Even without warming, it is certainly possible that dengue fever or malaria could invade North America. Unfortunately, some of the government's well-meaning environmental policies may make the vector more likely. The preservation of wetlands, although useful in conserving species diversity, also provides prime breeding grounds for mosquitoes that can carry the diseases. If the United States does in the future suffer from such insect-borne scourges, the infestation may have less to do with global warming than with the preservation of swampy areas.

Torrid Summers

Recent summers have sizzled. Newspapers have reported the tragic deaths of the poor and the aged on days when the mercury reached torrid levels. Prophets of doom forecast that rising temperatures in the next century portend a future of calamitous mortality. Scenes of men, women, and children collapsing on hot streets haunt our imaginations.

Happily the evidence refutes that dire scenario. First, however, let us review the documentation supporting the supposition that human mortality will rise with rising temperatures. Death rates during periods of very hot weather have jumped in certain cities, but above-normal mortality has not been recorded during all hot spells or in all cities. Moreover, research concerned with “killer” heat waves has generally ignored or downplayed the reduction in fatalities that warmer winter months would bring.

In a 1991 paper, Laurence Kalkstein, one of the most respected and careful scholars examining the health effects of climate change, finds that deaths are related to the length of the hot spell. He suggests that it takes an extended heat wave to raise the death rate. In a later work, he reports that heat spells early in the summer or quick rises in temperature trigger deaths; in other words, unseasonal or rapid warming produces mortality (Kalkstein 1992). But if rapid warming causes deaths, we should find that most of the mortality during heat spells occurs on the first day or so and that fatalities then taper off, rather than increase with the length of the warm spell. As indicated, Kalkstein finds the opposite: deaths go up after a long spell of hot weather.

Kalkstein also finds that a particular weather pattern—characterized by high temperatures, strong southeast winds, moderate humidity, and relatively clear skies with little cloud cover—is correlated with increased mortality in St. Louis. For other cities either no weather pattern was related to mortality or the patterns that correlated with extra deaths differed. Even in St. Louis, many of the days that exhibited the suspect weather showed no unusual number of fatalities. Moreover, very hot days, those with temperatures over 100°F, failed to show death rates higher than the rates on those days when the thermometer made it only to 95°F. In fact, the number of recorded deaths in St. Louis during that particular weather pattern varied considerably more than during other periods, which reduces our confidence in the results.

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Researchers analyzing hot days and deaths have found no constant relationship; even when extremes in weather and mortality are correlated, the relationship is inconsistent. Cities with the highest average number of summer deaths are found in the Midwest or Northeast while those with the lowest number are in the South (Kalkstein and Davis 1989, 56). Typically analysts have failed to find any relationship between excess mortality and temperature in southern cities, which experience the most heat (Kalkstein 1992, 372). Other studies have found that people who move from a cold to a subtropical climate adjust within a very short period (Rotton 1983). Moreover, Kalkstein and others have reported without explanation that the “threshold” between temperatures that lead to excess deaths and those that have no effect varies significantly among the cities. In some, such as Los Angeles, San Francisco, Boston, and Pittsburgh, the threshold was below 85° while in Phoenix and Las Vegas, it exceeded 110°F.

Scholars have also reported contradictory and implausible results. According to several analyses, air pollution is not correlated with premature deaths (Kalkstein 1991). Some studies have found that during hot spells mortality goes up sharply in females; other researchers have measured increased deaths among men (Kalkstein 1992 using Applegate et al. 1981, Bridger et al. 1976, Ellis 1972). Blacks are apparently more susceptible in St. Louis; whites, in New York. The lack of agreement on the effects of weather and on premature deaths again raises suspicions about the robustness of the results.

Measurement error may also foul up daily figures. In 1995, for example, Chicago suffered through an extraordinarily hot July that the press characterized as a harbinger of global warming. The coroner reported a marked increase in deaths. What was very curious was that on Friday, Saturday, and Sunday, July 14, 15, and 16, the reported deaths were way below the normal of 78 per day—only 14 people were reported to have died on Saturday—but on the two following days, Monday and Tuesday, fatalities were well above normal. The previous record low body count for any day in the last 30 years had been 46! Given that on Friday, July 14, a record temperature of 106°F was measured at Midway Airport, those numbers are not only remarkable but suspicious. Could it have been that most people in the coroner’s office took the hot weekend off and counted bodies on Monday and Tuesday?

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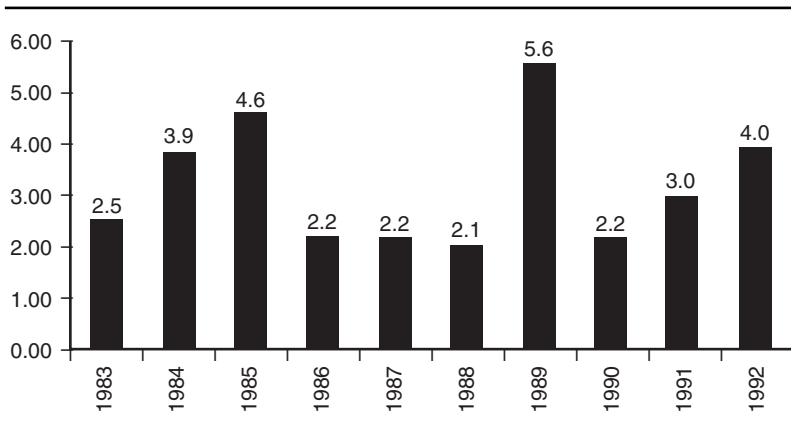
Researchers have attributed the absence of heat-related deaths in southern cities to acclimatization and the prevalence of housing that shields residents from high temperatures. In the North, the housing of the elderly and the poor is usually old and dilapidated. Over the next hundred years, if not sooner, most of those buildings will be torn down and replaced. Should the climate warm, builders will move toward structures that protect the inhabitants from extreme heat, as housing in the South allegedly does now.

These findings may imply simply that out-of-the-ordinary high temperatures increase the mortality of those in a weakened state. Studies have found that those most likely to die during heat spells are elderly (Kalkstein and Davis 1989, 62; Kalkstein 1992). Little attention has focused on the question of whether excess deaths represented only premature mortality of a few days among the old or sick or whether the excess deaths shortened lives significantly. Studies examining excess deaths by months fail to find any positive correlation with high temperatures, indicating that any daily excess is offset by a reduction in fatalities over the next few days. In the South, where temperatures are routinely very high during the summer, even the elderly adjust. Consequently, if the climate becomes warmer, no excess deaths can be expected.

Fear of killer heat waves appears exaggerated. If temperatures rise slowly over the next century, possibly by the 2° to 6°F currently predicted, people will become acclimated while housing can and, in the normal cycle, will be replaced. After all, half the housing stock in the United States has been built during the last 25 years. Consequently, if warming takes place, people and housing will adapt; even if extended warm spells occur, mortality should not rise sharply. Moreover, the models and the evidence to date suggest that most of the warming will take place in the winter and at night. Consequently extreme heat events are unlikely to become much more common.

Heat-stress does increase mortality; but it typically affects only the old and infirm, whose lives may be shortened by a few days or perhaps a week. There is no evidence, however, that general mortality rises significantly. The numbers of heat-stress-related deaths are very small; in the United States they are exceeded by the number of deaths due to weather-related cold. During the latest 10-year

Figure 3-1
PROPORTION OF WEATHER-RELATED COLD DEATHS TO
HEAT-STRESS MORTALITY



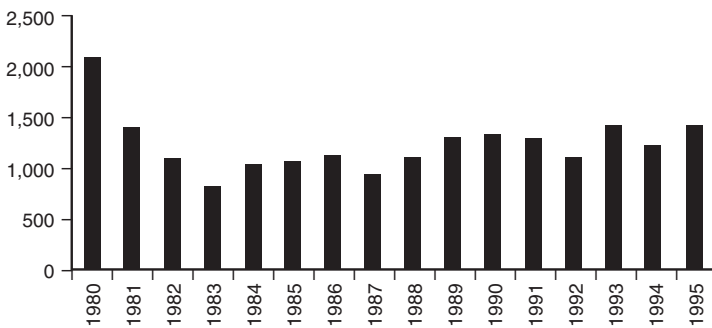
SOURCE: *Vital Statistics of the United States* (1983–1992).

period for which we have data (figure 3-1), which includes the very hot summer of 1988, the average number of weather-connected heat deaths was 132, compared with 385 for those who died from cold. Even during 1988, more than double the number of Americans died from the cold than passed on from the heat of summer. A somewhat warmer climate would clearly reduce more deaths in the winter than it would add in the summer.

Mosquito-Borne Diseases

A growing chorus has been chanting that global climate change will spread insect-borne diseases, such as malaria, dengue fever, and yellow fever, to temperate latitudes. In 1996, the health effects of global warming have been the subject of lengthy journal articles in the *Journal of the American Medical Association* (1996), and *Lancet* (1996), an international journal of medical science and practice. In September 1996, the Australian Medical Association sponsored a major conference on the subject. Professor Paul Epstein of the Harvard School of Public Health claimed that in the past few years mosquitoes carrying malaria and dengue fever had been found at higher altitudes in Africa, Asia, and Latin America. In North America, David Danzig (1995), in a Sierra Club publication, has

Figure 3-2
REPORTED CASES OF MALARIA IN THE UNITED STATES



SOURCE: Centers for Disease Control and the *Statistical Abstract of the United States*, 1984–1996.

contended that only the tip of Florida is currently warm enough to support malaria-carrying mosquitoes but that global warming could make most of us vulnerable. He should check his history.

Before the Second World War, malaria was widespread in the United States. The Centers for Disease Control and the *Statistical Abstract of the United States* for the relevant years reported that over 120,000 cases were reported in 1934; as late as 1940, the number of new sufferers totaled 78,000. After the war, reported malaria cases in the United States plunged from 63,000 in 1945 to a little over 2,000 in 1950 to only 522 in 1955. By 1960, DDT had almost eliminated the disease; only 72 cases were recorded in the whole country. In 1969 and 1970, the CDC reported a resurgence to around 3,000 cases annually, brought in by service personnel returning from Vietnam. Subsequently, immigrants from tropical areas have spawned small upticks in new cases.

In the 1980s and 1990s, as Figure 3-2 shows, the number of reported cases has averaged around 1,200 to 1,300 annually. The CDC reports that since 1985 approximately 1,000 of those cases have been imported every year, with visitors and recent immigrants accounting for about half. The rest come from travelers arriving from tropical countries, service personnel returning from infested areas, and a handful of individuals, typically those living near international airports, bitten by a mosquito that hitched a ride from a poor country.

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More stringent efforts to keep out the unwanted “immigrants” may be called for if the problem worsens.

Yellow and dengue fevers were both common in the United States from the 17th century onward. Epidemics of yellow fever ravaged New Yorkers and killed tens of thousands of people. In one year, 1878, of 100,000 cases reported along the East Coast, 20,000 people died. Between 1827 and 1946, eight major pandemics of dengue fever overran the United States. In 1922, the disease spread from Texas, with half a million cases, through Louisiana, Georgia, and Florida. Savannah suffered with 30,000 cases, of which nearly 10,000 had hemorrhagic symptoms, a very serious form of the disease. In contrast, in 1996 the CDC listed 86 imported cases of dengue and dengue hemorrhagic fever and eight local transmissions, all in Texas. There were *no* reported cases of yellow fever.

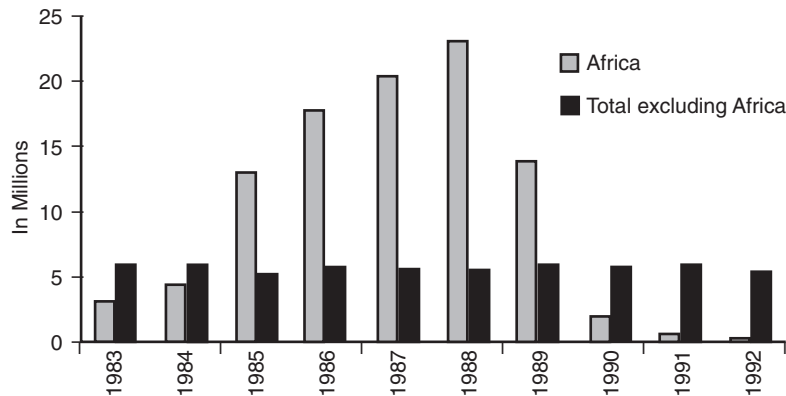
As a public health issue, those diseases, which did plague the United States in the reputedly colder 19th and early 20th centuries, have been largely exterminated. There is no evidence that a resurgence is imminent. Certainly the climate is not keeping the spread of the diseases in check. If it was warm enough in the cold 19th century for the mosquitoes to thrive, it is warm enough now!

Is there any basis at all for these scare-mongering prophecies? Is malaria rising worldwide? Not according to the World Health Organization. As Figure 3-3 shows, from 1983 to the latest year for which data exist, 1992, the number of cases of malaria reported in Africa, the most heavily infested section of the world, has fallen sharply, especially in the most recent years. For the rest of the world, reports are somewhat less encouraging. Malaria continues to be a problem, but there has been no increase in cases reported even though the world’s population has climbed. The good news is that the rate of malaria per 100,000 people has fallen for the whole world.

What brought an end to the scourges? The introduction of DDT clearly played a major role. From the end of World War II until it was banned in 1972, the pesticide worked wonders to eliminate harmful insects, especially mosquitoes. But it was not just insecticides that did the trick. Simple steps, such as screens on windows, the elimination of standing water, and the movement to the suburbs, which reduced population density and thus the risk of transmission, have played a critical role in eliminating mosquito-borne diseases.

In 1995, however, a dengue pandemic afflicted the Caribbean, Central America, and Mexico, generating around 74,000 cases. Over

Figure 3-3
 REPORTED MALARIA CASES IN AFRICA AND IN THE REST OF
 THE WORLD



SOURCE: World Health Organization, Malaria Control Program, Geneva, Switzerland.

4,000 Mexicans living in the Tamaulipas state, which borders Texas, came down with the disease. Yet Americans living a short distance away remained unaffected. The contrast between the twin cities of Reynosa, Mexico, which suffered 2,361 cases, and Hidalgo, Texas, just across the border, is striking. Including the border towns, Texas reported only 8 nonimported cases for the whole state.

The only reasonable explanation for the difference between the spread of dengue in Tamaulipas and its absence in Texas is living standards. Where people enjoy good sanitation and public education, have the knowledge and willingness to manage standing water around households, implement programs to control mosquitoes, and employ screens and air-conditioning, mosquito-borne diseases cannot spread. If the climate does warm, those factors will remain. In short, Americans need not fear an epidemic of tropical diseases.

Cholera

A recent manifestation of fear-mongering about the health effects of global warming is a curious article in *Science*, taken from a modified text of Rita Colwell’s presidential address to the American

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Association for the Advancement of Science's 1996 annual meeting (Colwell 1996). This address presents a studious analysis of cholera and its recent resurgence in the Americas. What is most singular is not what is in Dr. Colwell's report but what she does not mention.

Despite the title of the address, "Global Climate and Infectious Disease: The Cholera Paradigm," climate change is scarcely broached, and the one reference to it comes in connection with malaria, not cholera. Certainly Colwell makes no effort to tie global warming to the spread of cholera. Moreover, in a section strangely entitled "Global Climate, Global Change, and Human Health," the word "climate" does not appear; nor do the words "warmer," "temperature," or "global"! Also puzzling for such a careful exposition is the absence of any reference to the role that the Environmental Protection Agency may have played in creating the conditions leading to the explosion of cholera in Peru in 1991. But more on that later.

First, a few dry facts about cholera, an infectious disease caused by *Vibrio cholerae*, a bacterium that can bring on diarrhea, vomiting, and leg cramps. Without treatment, a person can rapidly lose body fluids, become dehydrated, and go into shock. Death can come quickly. Treatment is simple, the replacement of the fluids and salts with an oral rehydration solution of sugar and salts mixed with water. Fewer than 1 percent of those who contract cholera and are treated die.

Cholera cannot be caught from others but comes from ingesting food or water that contains the bacterium. Eating tainted shellfish, raw or undercooked fish, raw vegetables, or unpeeled fruits can lead to infection. Drinking unpurified water can be dangerous as well. The bacterium thrives in brackish warm water but can survive, in a dormant state, both colder water and changes in salinity. *V. cholerae* is also associated with zooplankton, shellfish, and fish. It often colonizes copepods, minute marine crustaceans. Ocean currents and tidal movements can sweep the bacterium, riding on copepods, along coasts and up estuaries where *V. cholerae* can remain dormant until conditions are ripe for it to multiply.

In 1817, the British first identified this dreaded disease in Calcutta, whence it spread throughout India, Nepal, and Afghanistan. Ships carried it into Asia, Arabia, and the ports of Africa. It reached Moscow, its first port of call in Europe, in 1830, creating panic as locals fled the city. From there it traveled to Poland, Germany, and

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England. In the decade after it first appeared in Europe, it killed tens of thousands in Paris, London, and Stockholm. It reached North America in 1832, appearing first in New York and Philadelphia, then spreading along the coast to New Orleans. In that same year, the disease killed over 2,200 people in Quebec. Apparently cholera is not a tropical disease; it can kill and sicken in any climate, although in high latitudes it may do so only in the summer.

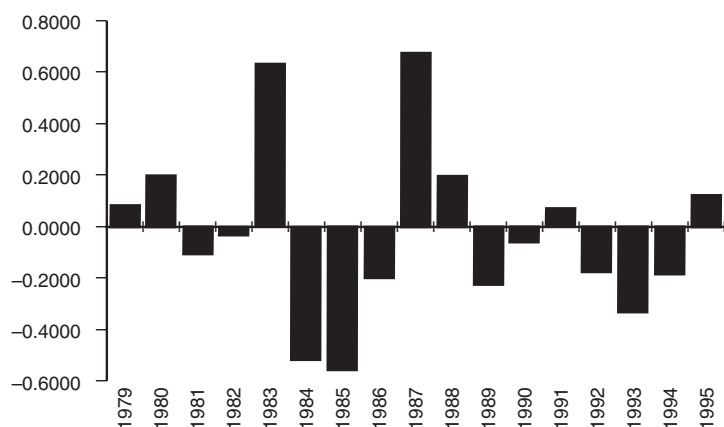
Before the most recent outbreak, the world suffered six cholera pandemics. By the end of the 19th century, however, Europe and North America were free of the disease. The solution was simple: filtration and chlorination of the water supply. Filtering alone not only reduces the spread of cholera but cuts typhoid significantly. Combining filtration with chlorination eliminates waterborne diseases. A warmer climate, if it were to occur, would not reduce the effectiveness of water purification measures.

In January 1991, after many disease-free decades, cholera began sickening villagers in Chancay, Peru, a port less than 40 miles north of Lima. It then spread rapidly up and down the coast. From that outbreak to the end of 1995, Latin America reported over 1 million cases—many went unreported—and 11,000 deaths. The illness traveled from Peru to Ecuador, Colombia, then Brazil. Eight months after appearing in Peru, it reached Bolivia. By the end of 1992, virtually all of South and Central America, from Mexico to Argentina, had confirmed cases. In the early 1990s, cholera also entered the United States; however, with the exception of a few cases brought on from eating raw, tainted shellfish, virtually all cases were contracted abroad. Seventy-five cases, nearly half the total 160 reported to the CDC between 1992 and 1994, originated on a single flight from Lima in 1992!

What went wrong to bring an end to Latin America's 100 years of freedom from cholera? Rita Colwell theorizes that an El Niño* led to a plankton bloom that multiplied the hosts of *V. cholerae*. But El Niños have been occurring with some regularity for many years

*A warming of the ocean surface off the western coast of South America that occurs every 4 to 12 years when upwelling of cold, nutrient-rich water does not occur. It causes plankton and fish to die and affects weather over much of the world.

Figure 3-4
TEMPERATURE VARIATION FROM NORMAL OFF THE
PERUVIAN COAST



SOURCE: "EPA in the Time of Cholera," *World Climate Report 2*, no. 10 (February 3, 1997): 2.

without producing a cholera epidemic. As Figure 3-4 shows, the coast of Peru in 1991 was not even particularly warm compared with a number of other years. Even if El Niño were in part the culprit, the basic cause lies elsewhere. On the basis of EPA studies showing that chlorine might create a slight cancer risk, authorities in Peru decided not to chlorinate their country's drinking water (Anderson 1991). Perhaps they also thought they would save money. Chlorination, however, is the single most effective preventive of cholera and other waterborne diseases. After the fiasco in Peru, the EPA determined in 1992 that there was no demonstrable link between chlorinated drinking water and cancer. It was too late; the harm had been done. Peru's misplaced environmentalism led to more than 300,000 victims in that country alone.

Cholera is a disease of poverty, crowding, and unsanitary conditions. A warmer climate will not carry the disease to affluent countries; but in the Third World, economic growth can bring freedom from it and many other diseases. We should not impose costs on ourselves or others that would reduce the resources needed to bring clean water and good sanitation to Latin America, Africa, and Asia.

Overall Health Effects

A number of researchers have found a negative relationship between temperature and mortality and/or a correlation between season and death rates (Momiyama and Katayama 1967, 1972; Bull and Morton 1978). G. M. Bull and Joan Morton, British researchers, for example, reported that deaths from myocardial infarction, strokes, and pneumonia fell with higher temperatures in England and Wales. In New York, however, they fell only until the temperature reached 68°F and then rose with the heat. Momiyama (1963) found that deaths followed a seasonal path but that, in the United States, this pattern had been reduced in the period from the 1920s to the 1960s. Even though a regimen of increased deaths in the winter is apparent for all portions of the United States, England and Wales, and Japan, many subsequent researchers have emphasized summer deaths attributed to high temperatures.

Seasonal Effects

If climate change were to manifest itself as warmer winters without much of an increase in temperature during the hot months, which some climate models predict, the change in weather could be especially beneficial to human health (Gates et al. 1992). The IPCC reports that, over this century, the weather in much of the world has been consistent with such a pattern: winter and night temperatures have risen while summer temperatures have fallen (Folland et al. 1992).

A warmer globe would likely result in the polar jet stream's retreating toward higher latitudes; in the Northern Hemisphere, the climate belt would move north (Lamb 1972, 117, 118; Giles 1990). Thus an average annual 6.7°F increase in temperature for New York City, for example, would give it the climate of Atlanta. New York City's summertime temperatures, however, would not go up commensurably: the average high temperature in Atlanta during June, July, and August is only 4°F warmer than New York City's and the latter city has on record a higher summer temperature than does the capital of Georgia. Summer temperatures generally differ less than winter temperatures on roughly the same longitude and differ less than average temperatures.

According to the National Climatic Data Center, a sample of 45 metropolitan areas in the United States shows that for each increase of a degree in the average annual temperature, July's average

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temperatures go up by only 0.5°F while January's average temperatures climb by 1.5°F. Since warming will likely exert the maximum effect during the coldest periods but have much less effect during the hottest months, the climate change should reduce deaths even more than any summer increase might boost them.

Deaths in the United States and most other advanced countries in the middle latitudes are higher in the winter than in the summer. Except for accidents, suicides, and homicides, which are slightly higher in the summer, death rates from virtually all other major causes rise in winter months; overall mortality from 1985 to 1990 was 16 percent greater when it was cold than during the warm season (Moore 1998). These data suggest that, rather than increasing mortality, warmer weather should reduce it; but that possibility is rarely discussed.

Earlier studies have also reported the relationship between season and death rates. Professor F. P. Ellis of the Yale University School of Medicine noted that deaths in the United States between 1952 and 1967 were 13 percent higher daily in the winter than in the summer (Ellis 1972, 15, table II). The difference is smaller than experienced during 1985–90, a period that included some of the hottest summers on record. Ellis's study covered a time during which recorded average temperatures in the United States were somewhat lower than during the 1985–90 period. If hot weather were detrimental to life, the differential between summer and winter death rates during the latter period should have been smaller, not larger.

The increase in average temperatures during this century has apparently been accompanied by a decline in hot weather deaths relative to winter mortality. Before the early or middle part of the century, deaths during the summer months were much higher relative to winter than is currently the case (Momiya 1977). Perhaps the decline in physical labor, which is afflicted with a much higher rate of fatal accidents than office work, helps to explain the change. One Japanese scholar, Masako Momiya, however, reports that for most advanced countries, such as the United States, Japan, United Kingdom, France, and Germany, mortality is now concentrated in the winter.

A number of studies, as indicated above, have examined death rates on a daily basis (Bull and Morton 1978; Kalkstein and Davis 1989; Kalkstein 1991). This allows the authors to compare extreme temperatures with mortality. Although the research has shown that it is typically the elderly or the very sick who are affected by temperature extremes, the analyses ignore the degree to which this shortens

life. Is it a few days or a few weeks? That cities in the South fail to show any relationship between deaths and high temperatures suggests that the correlation in the North may stem from deaths of the most vulnerable when the weather turns warm. One way to parse out whether climate extremes shorten lives by only a few days, or whether they lead to more serious reductions in the life span, is to consider longer periods.

Monthly data on deaths and temperatures, for example, show that deaths peak in the cold period. My research finds that monthly figures on various measures of warmth are correlated with monthly deaths in Washington, D.C. (Moore 1998). The results support the proposition that climate influences mortality.

Although deaths peak in the winter, factors other than cold, such as less sunlight, could induce the higher mortality. The peaking itself does not prove that warming would lengthen lives; it could be that the length of the day affects mortality. The day's length is closely correlated with temperature, of course, but, unlike the amount of sunlight, which remains constant each year, temperature fluctuates from year to year. My research, however, indicates that the length of the day is correlated with the death rate but is less statistically significant than temperature (Moore 1998). Moreover, if measures of temperature are combined with the length of the day, the amount of sunlight loses its statistical significance. Temperature remains the most important variable.

The District of Columbia study probably underestimates the relationship of deaths to temperature because some elderly from the capital winter in warm climates and die there. Nevertheless, the results imply that a 4.5°F warming—the “best estimate” of the IPCC under a CO₂ doubling—would cut deaths for the country as a whole by about 37,000 annually (IPCC 1992, 16).

Climatic Effects

Comparing death rates in various parts of the United States can provide evidence about how humans are affected by different climates. Within the continental United States, people live in locales that are subtropical, such as Miami, and cities that are subject to brutally cold weather, such as Minneapolis. The contrast between American cities makes the climate variables stand out. Within the United States, most people residing in big cities eat a more or less

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similar diet, live roughly the same way, and employ the same currency. Differences among the populations of various parts of the United States are confined largely to the age distribution, ethnic concentrations, income, and, of course, weather.

In a recent study, I expanded the research from a single city to the effect of climate on death rates around the country. Clearly many factors affect mortality. Within any population the proportion that is old influences death rates. Since African-Americans have lower life expectancies than whites, the proportion that is black affects mortality rates. Income and education also are related closely to life expectancy. As is well known, smoking shortens lives. Severe air pollution has pushed up mortality, at least for short periods.

As expected, age had the largest effect on death rates. The proportion of African-Americans is also highly significant in explaining death rates across counties. The higher the median income, the lower the death rate. Holding demographic and economic variables constant, I found that death rates are lower in warm climates. Various measures of climate demonstrate that warmer is healthier or at least extends life expectancies—once the age structure is held constant, there is a well established direct relationship between death rates and life expectancies. The analysis implies that if the United States were enjoying temperatures 4.5°F warmer than today, 41,000 fewer people would die each year (Moore 1998). That saving in lives is close to the number I estimated based on monthly Washington, D.C., data for the period 1987 through 1989.

In summary, the monthly figures for the city of Washington, between 1987 and 1989, indicate that a 4.5°F warmer climate would cut deaths nationwide by about 37,000; the analysis of climate in counties around the United States points toward a saving in lives of about 41,000. Those data sets produce roughly the same conclusion: a warmer climate would reduce mortality by about the magnitude of highway deaths, although the latter deaths are more costly in that they involve a much higher proportion of young men and women.

Morbidity

Presumably, if a warmer climate reduced deaths, it would also cut disease. In the early 1970s, the U.S. Department of Transportation sponsored a series of conferences on climate change that examined, among other things, the effect of climate on preferences of workers

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for various climates and on health care expenditures. At that time, the government and most observers were concerned about possible cooling of the globe. The department organized the meetings because it planned to subsidize the development and construction of a large fleet of supersonic aircraft that environmentalists contended would affect the world's climate.

The third gathering, held in February 1974, examined the implications of climate change for the economy and people's well-being and included a study of the costs to human health from cooling, especially any increased expenses for doctors' services, visits to hospitals, and additional medication (Anderson 1974). For that meeting, the Department of Transportation asked the researchers to consider a cooling of 2° Celsius (3.6° Fahrenheit) and a warming of 0.5°C (0.9°F). Robert Anderson Jr., the economist who calculated health care outlays, made no estimate of the costs or savings should the climate warm; but his numbers show that for every 5 percent reduction in the annual number of heating degree days, a measure of winter's chill, health care costs would fall by \$0.6 billion (1971 dollars).[†] In a paper summarizing the various studies on economic costs and the benefits of climate change, Ralph D'Arge (1974), the principal economist involved in the DOT project, indicated that a 10 percent shift in heating degree days would be equivalent to a 1°C change in temperature. Thus the gain in reduced health costs from a warming of 4.5°F would be on the order of \$3.0 billion in 1971 dollars or \$21.7 billion in 1994 dollars, adjusting for population growth and price changes (using the price index for medical care).

In a more recent study, I examined the relationship between the number of hospital beds per 100,000 and the number of physicians per 100,000 and the average annual temperature. Although the number of physicians is only weakly related to climate, the number of hospital beds is significantly inversely related. In other words, holding income, race, and age constant, the warmer the climate, the lower the number of hospital beds or doctors. Assuming that the numbers of hospital beds and physicians reflect correctly the health care needs

[†]Each degree that the average temperature for a day falls below 65° Fahrenheit produces one heating degree day. If the mean temperature on a particular day were 60°, for example, the number of degree days would be 5. If the high for a day were 60° and the low 40°, the average would be 50° and the number of degree days would be 15.

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of their communities and are an index of health care costs, the numbers suggest that, had the climate been 4.5°F warmer, private expenditures on health care would have been lower by \$19 billion to \$22 billion in 1994. Those numbers are remarkably close to the updated figures reported by Professor Robert Anderson (\$22 billion). Assuming that government health expenditures would be affected comparably, the total national savings in medical costs would be about \$36 billion.

That figure understates the benefits of warming because it does not include the gains from a reduction in suffering or from a cut in working days lost through disease. A minimum estimate of those gains would include the wage-cost of people with jobs who, in the absence of warming, would not have been at work because of illness. The \$36 billion also neglects the gain to those who, because of the better climate, remain healthy and are not in the paid workforce or would have come to work in spite of suffering from a cold or the flu. If we assume that a 4.5°F warmer temperature would reduce illness by the same amount it is estimated to reduce deaths (1.8 percent) and apply the average workers' compensation, the savings come to around three-quarters of a billion dollars (*Statistical Abstract of the United States 1994*, 404, table 631; 427, table 660). These numbers also do not include any lowering of government expenditures on health care. Conservatively, health care saving would amount to about \$37 billion per year.

Conclusion

Although it is impossible to measure the gains exactly, a moderately warmer climate would be likely to benefit Americans in many ways, especially in health. At the same time, let me stress that the evidence presented here is for a *moderate* rise in temperatures. If warming were to continue well beyond 4.5°F, the costs would mount and at some point the health effects would undoubtedly turn negative.[‡] Contrary to many dire forecasts, however, the temperature increase predicted by the IPCC, which is now less than 4.5°F, under a doubling of greenhouse gases would yield health benefits for Americans.

[‡]Adding minimum temperature squared or average temperature squared to regressions produced coefficients that were not only negative but insignificantly different from zero.

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In summary, a warmer climate should improve health and extend life, at least for Americans and probably for Europeans, the Japanese, and people living in high latitudes. High death rates in the tropics appear to be more a function of poverty than of climate. Thus global warming is likely to prove positive for human health.