Introduction

Global warming is defined as "the increase in the average measured temperature of the Earth's near surface air and oceans". For the past several decades scientists have documented multiple aspects of climate change, including rising surface air temperature, rising ocean temperature, changes in rain and snowfall patterns, declines in permanent snowpack and sea ice, and a rise in sea level. Through their research, scientists have been able not only to document changes in climate and the physical environment, but have also documented effects that this phenomenon is having on the world’s ecosystems and species, many of which are negative.

Although global warming can occur naturally as a result of variation in the amount of solar energy reaching the earth, the Intergovernmental Panel on Climate Change (IPCC) has concluded that climate change of the past 30 years is largely attributed to a human-caused increase in greenhouse gas emissions. As the research has progressed, the concern about greenhouse gas emissions has increased. In 1995, the second IPCC Assessment Report stated that "the balance of evidence suggests discernable human influence on global climate change." In 2001, the Third IPCC Assessment concluded that "most observed warming is likely due to the increase of greenhouse emissions." Finally in 2007, the Fourth IPCC Assessment report concluded that the "warming of the climate system is unequivocal" and "is very likely (>90% sure) due to observed increases in anthropogenic greenhouse gas concentrations." Based on these conclusions, many scientists and environmentalists have focused their efforts on sustainable living and are pushing for energy alternatives which produce little or no carbon-dioxide to reduce greenhouse gas emissions.

Effects of temperature change

Scientists have concluded that in the past 100 years, the Earth's average air temperature has risen 0.74°C (See Figure 2). This graph indicates that the temperature has been steadily rising since about 1975. It may not seem like a big change because the overall number is low, but in fact, this rise has had a dramatic effect on the environment and its inhabiting species. Of some 1592 species observed, 41% have shifted their ranges toward higher elevations or closer to the poles, while another 62% showed some sort of shift to earlier spring breeding, migrating, leafing, or blooming. Additionally, every major group that has been studied, whether trees, butterflies, mammals, birds, amphibians, fish, or marine coral, has been affected in some way.

Global warming has affected more than just...
animal species. The increase in ocean and air temperatures has also affected the Earth’s ice caps and glaciers. According to the World Meteorological Organization, in 2007 “a record low Arctic sea ice extent was observed which led to the first recorded opening of the Canadian Northwest Passage.” Additionally, “the largest single block of ice in the Arctic, the Ward Hunt Ice Shelf, had existed for 3000 years before it starting cracking in 2000. Within two years it had split all the way through and is now breaking into pieces.” Figure 2, taken from NASA satellites, depicts the shrinking of the Arctic ice cap as a whole. Scientists estimate that it has shrunk by about 20% since 1979.

A reduction of twenty percent over 30 years averages to a rate of more than 6% per decade. If this rate continues, the polar ice cap will no longer exist at the end of the century. Melting glaciers are expected to contribute to sea level rise over the next few centuries. Even recent sea level rise, which to date has largely been due to expansion of the water as it warms, has been sufficient to cause problems in low-lying coastal regions. Rise in sea levels is a problem because it increases beach corrosion, coastal flooding, and contamination of freshwater supplies. In 2001, an EPA study suggested that a rise in sea levels of 3 feet (a level for 2100 projected by multiple studies) would “inundate some 22,400 square miles of land along the Atlantic and Gulf coasts of the United States, primarily in Louisiana, Texas, Florida, and North Carolina.” Although the observed rise in the Earth’s temperature might seem slight, the effects are already apparent, and will become increasingly dramatic.

**Effect of global warming on species**

Global warming has proven harmful to many of the Earth’s species. Changes in temperature, rainfall and snowpack are affecting the way that many species live. Many are moving closer to the poles as the more equatorial parts of their range become climatically unsuitable, while others that live in mountain areas are moving to higher altitudes. A recent study of nearly 1,600 species of plants and animals discovered movement toward the poles at an average rate of 3.8 miles per decade. For instance, the purple emperor butterfly, which historically only went as far north as Estonia, has now begun inhabiting Sweden and Finland. Their rate of colonization has been rapid, a 100km expansion in just three years. A warm-adapted group of marine copepods, which once only went as far north as the Northeast Atlantic, has shifted up to 1000km northward over the past four decades and now is abundant in the northern part of the North Sea. With glacial retreat in the Andes, three species of frogs, along with their parasitic fungus, have shifted 400m higher in altitude over the past 70 years.

Although some species have successfully shifted where they live and adapted to new areas, others have not. For example, “over the past 25 years, some Antarctic penguin populations have shrunk by 33% due to declines in winter sea ice habitat.” Many of the tiny organisms that the penguins feed on, like krill shrimp, feed off of the algae. It is believed that shrinking sea ice has led to declines in algae, which in turn has led to a decrease in krill shrimp, and thus a decline in the penguins’ food supply. Additionally, polar bears have even been drowning due to the longer swim lengths they must endure between ice flows. Also, the thinning of the ice caps “leaves fewer...
places for both the polar bears to hunt [for seals] and the seals to raise their young.\textsuperscript{13} Because polar bears need “2kg of fat per day,” land animals and berries will not be enough to keep them alive, thus they need an abundance of high fat foods, such as seals, for continued survival.\textsuperscript{2}

However, the most negatively affected terrestrial species have been high elevation cloud forest frogs. Of these, 74 species have become extinct over the past 30 years.\textsuperscript{14} Their extinctions are believed to be linked to climate change, because most have occurred only at particular elevations, and in relatively undisturbed areas. “According to this recent study, Earth’s rising temperatures are altering both temperatures and cloud cover on tropical mountains, leading to cooler days and warmer nights, both of which should favor the chytrid fungus, based on lab studies which indicated that the fungus grows and reproduces best at temperatures between 63 to 77° F (17 to 25° C).”\textsuperscript{15} Some scientists believe that climate change has improved conditions for this fungus at elevations where it previously non-optimal climatically, and that these changing conditions for the fungus has caused many species of frogs to become extinct.

Effects of global warming on human and animal diseases

Global warming will not only affect what species eat and where they live, it will also affect their health, including that of human beings. Some of the widespread health problems projected to affect humans are “devastating heat waves, poisonous plants producing more potent toxins, air quality plummeting on summer days, disease-carrying insects swarming mountain villages, and an increase in allergies and asthma.”\textsuperscript{16} Some health statistics are as follows:

“In the summer of 2003, an intense heat wave was blamed for an estimated 35,000 deaths across large swaths of Europe. A study says that global warming has doubled the likelihood of heat waves of this magnitude.

In 2008 scientists found that poison ivy vines have grown 10 times denser near Savannah, Georgia, over the last 20 years. Increased carbon dioxide in the atmosphere causes poison ivy to grow larger and produce stronger irritants.

Six young men and boys were killed by fatal parasites in 2007, after they swam in water at Arizona’s Lake Havasu that was infested with a heat-loving amoeba. The Centers for Disease Control and Prevention expect more of these illnesses as global temperatures rise.

Mosquitoes carrying malaria were found at previously unobserved elevations on Mount Kenya in 2006. As the temperatures rise, higher elevations become more hospitable for mosquitoes and more dangerous for local inhabitants.\textsuperscript{18}

These are not the only incidents recorded, nor will they be the last. Global warming will continue to have a negative effect on human life. However, these effects will not always be direct. Humans will also be at risk due to severe weather and flooding caused by the changes in temperatures and sea levels.

Additionally, humans can be affected by what they eat, as is the case with foods like oysters, which can contain deadly bacteria in warm waters. Several studies have explored the prevalence of this problem. The bacterium is found in marine and estuarine environments and thrives in warm seawater since it requires salt for growth.\textsuperscript{17} Of all the cases of infection by the vibrio vulnificus bacterium from the Gulf of Mexico, 89% occurred in humans eating seafood (primarily oysters) that were caught in warm waters. For patients admitted to hospital, the mortality rate was 30-48%. A continued rise in sea temperatures is expected to increase outbreaks of vibrio vulnificus, thus increasing the number of humans affected by the disease.

Effects of global warming on seasons

The changes in Earth’s temperature are also affecting the world’s seasons. Animals are breeding earlier than before, and trees, shrubs, and plants are blooming and leafing sooner than they used to.\textsuperscript{7} Figure 6 best illustrates the change in spring dates of different species.

Once again, the species most affected are the amphibians, with a nearly 30 day shift in dates.\textsuperscript{5}

This change in seasonal timing is also affecting seasons for human activities, crops, and vegetation. In one recent article, maple syrup producers in New Hampshire were blaming global warming for their earlier tap seasons. Producers claimed that “they [were] tapping their trees about a month earlier than their ancestors did.”\textsuperscript{19} One producer claimed that the maple syrup season began to change about 20 years ago and that the tapping season shifted from March to February during the last century. The rise in temperatures is so drastic that nature is beginning to react to the change, which is understandable when natural occurrences that once took place in March are now happening in February.

Warmer winters have also caused moth and beetle populations to expand and to shift toward the poles. “Extended growing seasons have resulted in increased forest pest outbreaks and loss of wood productivity.”\textsuperscript{20} The most notable example of this phenomenon is the Spruce bark beetle epidemic that has killed some 3.8 million acres of trees in Alaska. Growths of Mountain pine beetles in Colorado and British Columbia and of pine processionary moths in Italy and France have also damaged large stands of timber.\textsuperscript{7}

Projected impacts of global warming

Global warming is just beginning, and will only worsen if alternatives are not implemented. From this report, one can begin to
understand the magnitude of the impact that climate change has had on the environment and its inhabiting species. These results have occurred without even a full 1°C rise in temperature. What will become of the world if the temperature continues to rise? Will the Earth and its ecosystems be able to adjust? Many Researchers and scientist believe that they may not.

Some scientists predict that a 2°C increase in temperature would cause an overall “projected extinction of 20% of species worldwide.” There would also be an increase in the incidence of tropical diseases, which would lead to an increase in the number of human deaths worldwide. Additionally, there would be a decline in the production of agriculture and farming at lower latitudes, and an increase in production for higher latitudes, i.e. Canada. Large concentrations of tundra and sea ice habitats would likely become scarce, thus leading to extinction or near extinction of many of polar animals such as polar bears, seals, and caribou.

To emphasize the negative effects of global warming further, scientists also predicted the impacts of a 4°C rise in temperature. At this level, the world would begin to see mass extinctions of species, up to 70% of those currently existing. A complete loss of suitable climate space for a large number of species and ecosystems would also be likely. The coral reefs of the world would likely become extinct because of the rise in ocean temperatures and increasing ocean acidity due to increased carbon-dioxide. As a result, both tourism and fishing industries would be negatively affected. Furthermore, agriculture production would decline for all latitudes throughout the world. This decline in production would result in a large reduction of the food supply for the world’s population; subsequently the world’s population would suffer increased malnutrition and even starvation.

**Recommendations for reducing global warming**

Global warming is affecting the Earth at an alarming rate and changes must be made to reduce these effects. Although adaptation can occur within a margin of +2°C, beyond that, it becomes increasingly unlikely. The only way to prevent an increase of this magnitude is to decrease the emission of greenhouse gases. Scientists believe that greenhouse gases are the primary cause of temperature increases, so to combat the problem, society must find ways to reduce greenhouse gases through conservation and use of those renewable sources of energy which do not emit carbon-dioxide or other substances that cause warming. One way to reduce greenhouse gases is to use alternative energy sources. For instance, switching the fuel used in power plants from coal to gas would decrease the amount of CO₂ that is released into the atmosphere. Other forms of power could come from renewable sources such as wind, solar, and hydroelectric power. The use of nuclear power, which has proven successful in Europe, could also be considered. Most biofuels actually emit more carbon during farming and energy-production processes than they capture through plant growth, and so should be considered on a case-by-case basis.

Although using these forms of energy would decrease the amount of greenhouse gases emitted into the atmosphere, they each raise other issues that must be considered. For instance, the use of nuclear power brings up questions about where and how the waste would be stored. Some places would be opposed to storing waste in their nearby surroundings. Others would be concerned about attacks on the power plants themselves or on the waste sites. Wind power also introduces problems. Already, rare and endangered species have been hurt and killed by windmills. The windmills pose a threat to birds, especially during migratory seasons. Additionally, some birds mistake the shadows of the mills for larger predators and thus do not nest near them out of fear of being destroyed.
Energy efficiency and conservation are an essential part of any strategy for reducing the emission of greenhouse gases. Improved efficiency of home appliances and cars is one way to reduce the effects. Also, knowledge about conservation and consumption can improve the situation. Programming air conditioning and heating is one form of energy conservation. Unplugging appliances and turning off lights when they are not in use will conserve energy. Building green buildings and improving the efficiency of current homes and buildings will also help. Improved natural lighting and use of better insulation increase building efficiency. Ensuring that doors and windows are properly caulked and sealed conserves energy.

The list of improvements is infinite and a multitude of variations can always be improvised. The key is to start now. Ideally, the overall goal is to lower total consumption of energy and resources. However, people must realize that even with a reduction in greenhouse gas emissions, it will still take time for the world to reach equilibrium (See Figure 7). The change will not happen overnight, but it must be set in motion if we are to prevent further rise of the earth’s temperature.

Conclusion

Global warming has begun and will continue to negatively affect the world around us unless society can find ways to prevent it through alternative lifestyles and mindsets. Even with just a 0.74°C increase in temperature, the world has begun to see negative effects: species are migrating toward the poles, plants and animals are blooming and breeding sooner, farmers are seeing an trend toward earlier crop production, and human diseases and health problems are increasing. With a continued rise in greenhouse emissions, the effects of global warming will only get worse. The world will still be able to adapt within a +2°C margin, however, any variation beyond that would be catastrophic and irreversible.

In order to avoid these catastrophic situations, people must change the way that they live. Societies must consider the use of alternative resources, preferably renewable resources that do not deplete the world’s natural stores. Using these renewable resources will also serve to minimize the emission of greenhouse gases. It will not be enough just to switch from coal to natural gas, because eventually that resource will also be depleted. Renewable resources such as solar and wind are essential. Furthermore, architects and engineers must find ways to incorporate sustainable living into their designs and buildings. Designers must make use of natural lighting and thermal or solar energy. New construction should comply with LEED and other energy related standards and all appliances need to be energy efficient. It is the responsibility of professionals to educate owners and clients about the use of alternative energy sources. Lastly, it is also the responsibility of politicians and world leaders to enforce sustainable living through public policy and education. People and businesses will need incentives to live sustainably and it is the government’s job to offer those incentives. New buildings need to meet higher standards and older buildings need to be updated to comply with codes. What the world needs is a change in lifestyle. Without it, the effects of global warming will continue to multiply, bringing disastrous consequences.

Notes
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**Figures**

Figure 1: NASA.gov

Figure 2: Instrumental Record of Global Average Temperatures as compiled by the Climatic Research Unit of the University of East Anglia and the Hadley Centre of the UK Meteorological Office. Data set TaveGL2v was used. The most recent documentation for this data set is Jones, P.D. and Moberg, A. (2003) “Hemispheric and large-scale surface air temperature variations: An extensive revision and an update to 2001”. Journal of Climate, 16, 206-223. <http://en.wikipedia.org/wiki/Image:Instrumental_Temperature_Record.png>.

Figure 3: Comparison of extent of arctic polar ice cap, from 1979 to 2003. <http://www.nrdc.org/globalWarming/thinice.asp>.

Figure 4: Cloud Forest Frog. The World Conservation Union (IUCN) has listed this frog as Critically Endangered and facing an extremely high risk of extinction in the wild, because most of them have disappeared since 1988. <http://ecopreservationsociety.wordpress.com/tag/rainmaker/>

Figure 5: Close-up of an Aedes aegypti female mosquito sucking blood from a man’s arm. (Credit: James Gathany, Centers for Disease Control and Prevention, Atlanta, GA) < http://uanews.org/node/17643

Figure 6: Trends in Timing of Spring Events. Parmesan, Camille. 2007a.

Figure 7: Time to Reach Equilibrium. Source: Intergovernmental Panel on Climate Change (IPCC)

**References**

Intergovernmental Panel on Climate Change www.IPCC.ch/ See specific references above.

Parmesan, Camille. 2006. “Ecological and Evolutionary Responses to Recent Climate Change.” See full reference above


**Biography**

Dr. Camille Parmesan is an associate professor in Integrative Biology at the University of Texas at Austin. Dr. Parmesan received her PhD in Zoology from the University of Texas in 1995 and then did a post-doc at the National Center for Ecological Analysis and Synthesis, Santa Barbara.

Parmesan’s early research focused on multiple aspects of population biology, including the ecology, evolution, and behaviors of insect/plant interactions. For the past several years, her work has focused on impacts of 20th century climate change on wildlife. Her work on butterfly range shifts has been highlighted in many scientific and popular press reports, such as Science, Science News, New York Times, London Times, National Public Radio, and the recent BBC film series “State of the Planet” with David Attenborough.

The intensification of global warming as an international issue led her into the interface of policy and science. Parmesan has given seminars in DC for the White House, government agencies, and NGOs (such as IUCN and WWF). As a lead author, she was involved in multiple aspects of the Third Assessment Report of the IPCC (Intergovernmental Panel on Climate Change, United Nations).