United States House of Representatives, Select Committee on Energy Independence and Global Warming

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My expertise on climate change and its impacts stems from my core research program and multiple scientific publications on the biological impacts of recent climate change, from participating for the past 10 years as author and reviewer of reports by the Intergovernmental Panel on Climate Change (formed by the United Nations and the World Meteorological Organization), and from teaching a graduate-level course at the University of Texas in Global Environmental Change which covers relevant materials from atmospheric science, meteorology, climate modeling and carbon emissions scenarios as well as the biological impacts and projections of climate change on wild species.

I. Summary of the current state of climate science

1) global warming is unequivocal
2) > 90% certainty that humans are the main drivers of global warming

Greenhouse gases that have increased due to human activities include carbon-dioxide, methane, and nitrous oxide. Direct quotes from the recent Intergovernmental Panel on Climate Change (IPCC), 2007[1]:

"Warming of the climate system is **unequivocal**, as is now evident from observations of increases in global average air and ocean temperatures, widespread melting of snow and ice, and rising global mean sea level."

"Most of the observed increase in globally averaged temperatures since the mid-20th century is *very likely* **[>90% certain**] due to the observed increase in anthropogenic greenhouse gas concentrations. "

II. Summary of current, observed impacts on natural systems and human health

1) We don't have a lot of biological studies in the southern USA, but global analyses can help us to understand what is likely to be happening more regionally It's clear that everywhere there's been measurable climate change, it has impacted wild species. With relatively small changes in

[1] IPCC 2007. Climate Change 2007: The Physical Science Basis, Summary for Policy Makers. The Intergovernmental Panel on Climate Change Fourth Assessment Report. IPCC Secretariat, Geneva, Switzerland. Download pdf file available at: www.ipcc.ch

recent temperatures (a rise of 0.7 ° C over the 20th century), we've documented that half (50%) of all wild species for which we have long-term data have shown a response to local, regional or continental warming[2].

Global warming has affected every major biological group that has been studied (*e.g.* from herbs to trees, from plankton to fish, and from insects to mammals) and responses have been seen on all continents and in all major oceans[3,4]. In my most recent review, I surveyed biological impacts studies from major international English-language journals only and found an astonishing 866 papers representing data from thousands of species worldwide (Figure 1). There are hundreds of additional studies which were not included in this review because the journal were in a non-English language or not available at a U.S. university library. This and several other synthetic, global analyses published in the scientific literature have concluded that these observed changes in biological systems are indeed caused by climate warming. The consensus among biologists that climate change has impacted a large part of the natural world now mirrors the level of consensus among climate scientists that the warming is caused by humans (in IPCC terms, we're more than 90% sure on both fronts)[1,2,3,4,5,6].

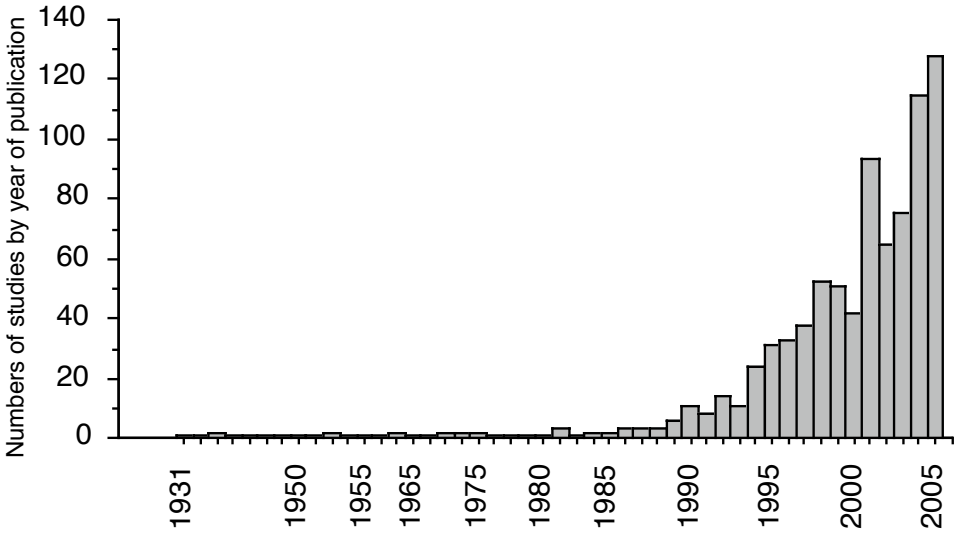

Figure 1. Numbers of papers by year of publication documenting a response of wild plants or animals to long-term changes in average temperature (from Parmesan 2006[4]).

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[2] Parmesan C, Yohe G. 2003. A globally coherent fingerprint of climate change impacts across natural systems. ***Nature*** 421:37—42. pdf file available on request from author

[3] Parmesan, C. and H. Galbraith. 2004 *Observed Ecological Impacts of Climate Change in North America,* Pew Center on Global Climate Change. Download of pdf file available from: www.pewclimate.org

[4] Parmesan, C. 2006. Observed ecological and evolutionary impacts of contemporary climate change. ***Annual Reviews of Ecology and Systematics*** 37:637-669. pdf file available on request from author

[5] Root TL, Price JT, Hall KR, Schneider SH, Rosenzweig C, Pounds JA. 2003. Fingerprints of global warming on wild animals and plants. ***Nature*** 421:57--60

[6] IPCC 2007b. Climate Change 2007: Climate Change Impacts, Adaptation and Vulnerability, Summary for Policy Makers. ***The Intergovernmental Panel on Climate Change Fourth Assessment Report***. IPCC Secretariat, Geneva, Switzerland. Download pdf file available at: www.ipcc.ch

2) Globally, we're seeing a strong consistent pattern of northward movements of species ranges as well as upward movement in mountainous areas. Tropical species from Central America and Africa are moving into historically temperate zones of the USA and Europe, temperate species are moving into boreal zones of Alaska, Canada and Lapland, and true boreal species are losing total habitable area as woody shrubs invade the tundra, and sea ice disappears.

3) Some species that are adapted to a wide array of environments - globally common, or what we call weedy or urban species - will be most likely to persist. Rare species that live in fragile or extreme habitats are already being affected, and we expect that to continue. We are seeing stronger responses in areas with very cold-adapted species that have also had strong warming trends, such as in Antarctica and in the Artic. Species whose habitat is sea ice are showing drastic declines. This includes the polar bear and the ringed seal in the Arctic, and the Adelie and Emperor penguins in the Antarctic. Mountain-top species, like the pika, are dying off at their lower range boundaries, becoming more and more restricted to the highest elevations.

4) Tropical coral reefs world-wide have been killed off by recent high sea surface temperatures – often associated with El Niño – with nearly 30% of tropical coral reefs dead from multiple high temperature events. Caribbean reefs have suffered significantly. A coming danger is the increased acidity of the ocean due to increased absorption of carbon-dioxide. Ocean pH has already lowered from 8.2 to 8.1 in the tropics. At a only slightly lower pH (combined with warm temperatures) under lab conditions, animals such as corals and shellfish cannot build a hard shell. These conditions could be reached as early as 2050[7]. Massive loss of coral reefs is likely to hurt the economies of U.S. Caribbean islands that depend on reefs for fisheries and tourism.

5) Spring is earlier (by about two weeks) and fall is later (by about one week) throughout the northern hemisphere. Where sufficient precipitation exists, this has extended the growing season. While this effects is projected to increase agricultural production in Canada, Sweden and Finland, prime areas of U.S. agriculture – particularly the corn belt – are expected to experience continued drying conditions, which will negatively impact production as these areas currently do not irrigate but rely on natural rainfall.

6) Forestry has already seen large increases in pest outbreaks throughout the USA, Canada, Europe and Russia. This is both because of pest species moving northward and invading new territory (such as the white pine beetle in the western USA), and because warmer winters and extended growing seasons are allowing many populations to increase their generation time (such as for the mountain pine beetle in Colorado and the spruce bark beetle in Alaska).

7) We're seeing many tropical species moving into the Gulf Coast states – former migrants like the rufous hummingbird and the Mexican green jay have become year-around residents in Alabama and Texas, respectively. Florida has five new species of tropical dragonfly. Many tropical butterflies that are normally confined to Mexico are starting to breed as far north as Austin, Texas.

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[7] Hoegh-Guldberg, O. (2005), Low coral cover in a high-CO2 world, ***J. Geophysical Research***, 110-121.

8) Human health is already being affected. In a recent yearly report, the World Health Organization estimated that 6% of malaria infections, 7% of dengue fever cases and 2.4% of diarrhea could be attributed to climate change (principally increased frequency and intensity of flood events). The observed northward movements of tropical species has implications for human health. The parasites that cause people to get sick when the vacation in Mexico are just wild animals and microbes – just as we're seeing birds & butterflies coming up from Mexico, human parasites and their wild animal vectors are likely to be shifting northward as well.

9) Where are we going? It's clear climate is going to continue to show a major shift. From recent deep ice-cores, we know that current carbon-dioxide levels are way out of bounds from natural fluctuations over the past 800,000 years. We're currently at 380 ppm CO_2, which is about 30% higher than peak levels during any of the warm periods during the recent Pleistocene climate changes. Over the many glacial/interglacial cycles which has characterized Earth for the past million years, peak CO_2 levels – which match peak warm temperatures – have stayed in the range of 270-300 ppm (Figure 2). There is a long lag time in the climate system – it takes hundreds of years for global temperature to stabilize after greenhouse gases have increased, and it takes thousands of years for sea level to stabilize, so we know we haven't yet felt the full effect of what we've already put out[4].

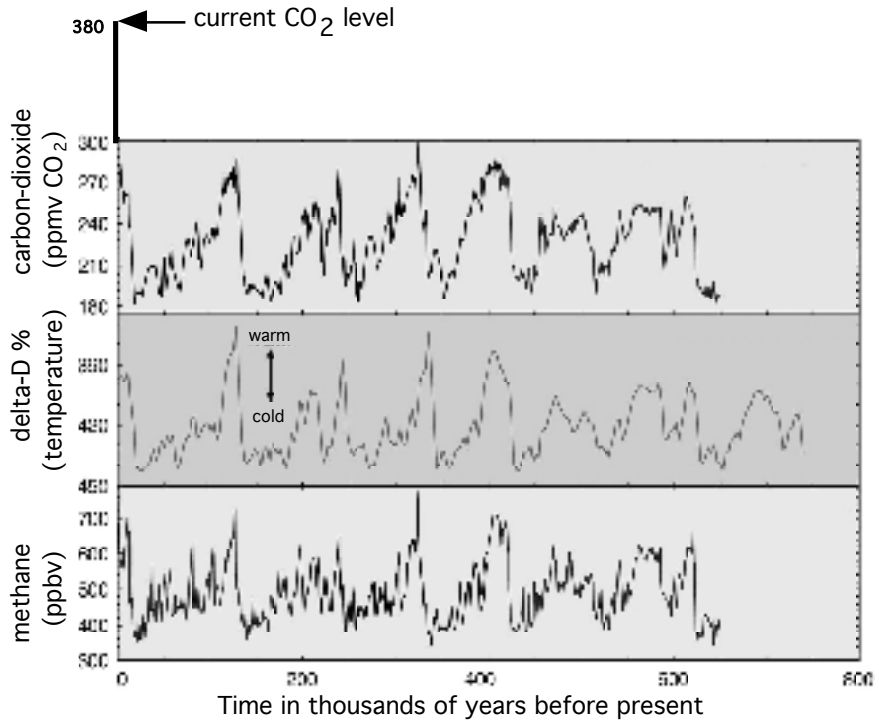

Figure 2: The ice core records from Antarctica. Top panel, carbon dioxide levels going back 600,000 years+. Heavy black line added to show current level of 380 ppmv CO_2. Middle panel, air temperatures going back 700,000 years+ (estimated from hydrogen/deuterium ratios). Bottom panel, methane levels going back 600,000 years+. Source: modified from EPICA

10) What are the implications of this for biodiversity and human health? All of the changes in natural systems that have been documented have occurred with only 0.7° C global average warming. This small amount of warming has already driven 74 species of frog extinct, has killed large areas of coral reef worldwide, has placed many boreal animals at high risk of extinction, and has begun to increase water borne diseases in humans[3,4,5]. Even the most optimistic minimum projections – of 1.8° C more warming - are more than twice what we've already seen (Figure 3). Under this "best case" scenario, projections of impacts on wild life have a large range depending on the species group, degree of habitat restriction, and geographic region. Examples on the low end are projected extinctions of 4% of birds and 7% of mammals in Mexico, to 6% of plants in Europe. On the upper end, projected extinctions with 2°C warming range from extinction of 70% of butterflies, 40% of birds and 40% of Proteacea plants in South Africa, to 79% of plants in the Amazon. (Table 1)

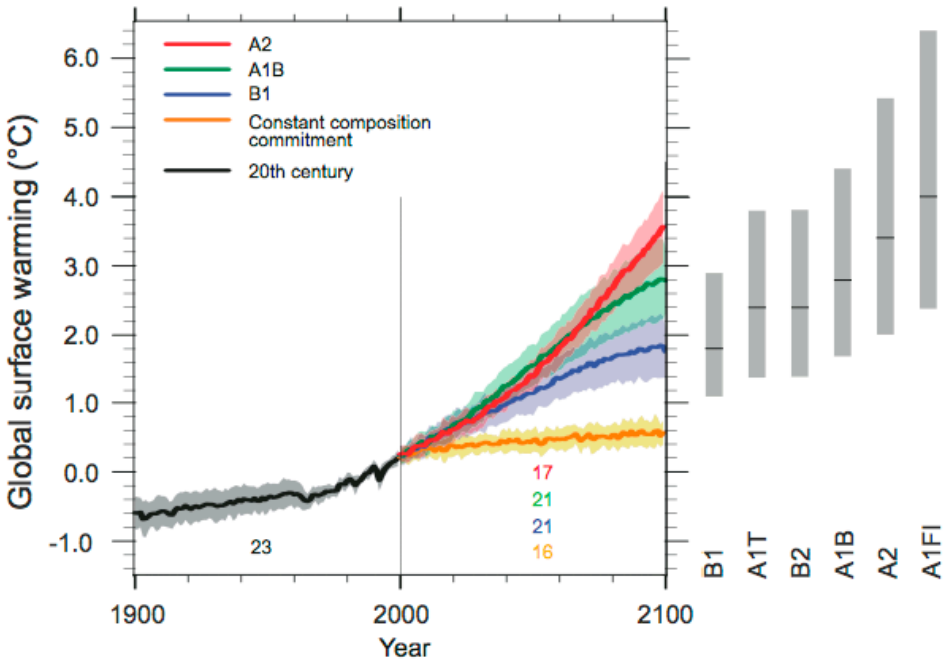

Figure 3: Temperature projections under different emission scenarios. Source: IPCC 2007

11) Business as usual projections lead to a 4°-5° C rise, with some models projecting as much as 6.8° C rise. This represents a climate the Earth hasn't seen in several million years – and an Earth humans, as a species, have never seen. The past million years or so has been a "cold Earth". Much of this time Earth has been heavily dominated by glaciers and sea ice. It is during this time that humans first appeared. For much of human history, we have lived as savage hunter/gathers in very small familial groups. It was only when we came out of these times of strong climate change – and no longer had to cope with repeated glacial/interglacial cycles – that we developed the modern trappings of humanity. Only when climate became relatively stable did we invent agriculture, the written language, art – everything we now associate with

"society". *(See figure in powerpoint presentation for timeline of climate over the past 65 million years)*

Under this "worst-case" scenario, projected impacts are severe for nearly every system studied. Worldwide mass extinctions are highly likely. Most cold-adapted species are expected to go extinct – those living in the Arctic and Antarctic and on mountaintops. Many tundra species, such as the caribou, are likely to go extinct. Large areas of boreal forest will die off, with obvious repercussions for the timber industry. Tropical diseases and parasites, along with their insect and mammalian vectors, will have shifted into the USA and Europe, with associated increased risk of human infection. (Table 1) Details of likely economic impacts can be found in the recent Stern Review[8].

III. Immediate strong action is required to prevent "dangerous anthropogenic interference with the climate system."

- The importance of acting now is because CO_2 is very stable in the atmosphere, and continues to have a strong effect on global climate for hundreds of years after it goes up into the atmosphere. 1/4 of the CO_2 we emit today will still be in the atmosphere 350 years from now

- We can't afford the worst case scenario – "business as usual" - either in terms of conservation of biodiversity, human health, or our economic stability[8]. We will see an enormous difference in life over the next 50 years regardless of which path we take (Table 1). Whether the impacts are ones for which we have some hope of devising adaptation strategies (*e.g.* physical movement of most sensitive species, industries and population centers, building barriers to sea level rise and higher intensity flooding), or whether we enter a climate era for which neither humans nor wild life have adaptation capacity, depends on what steps are taken now reduce emissions. It's only by implementing aggressive cuts in greenhouse gas emission immediately that we keep future global warming down to those lower projections we have some hopes of coping with – down to "just" another 1.8° C.

Table 1 *(next page)*: Observed and projected impacts on natural and human systems of different levels of global warming. Sources: 30+ studies published in scientific literature and IPCC 2007 report (bibliography available upon request).

[8] The Stern Review on the Economics of Climate Change, 2006. Her Majesties Treasury, United Kingdom. Pdf file downloadable from: www.hm-treasury.gov.uk/independent_reviews/stern_review_economics_climate_change/stern_review_report.cfm

Observed impacts of 0.7° warming over the past century

- 50% of species studied worldwide show measurable response
- Every major group studied has been affected, and impacts have occurred on every major continent and in every major ocean
- Northward range shifts from 30 - 600 miles, and upward shifts of 300 - 2,000 feet have occurred
- Parasites and their vectors have also shifted northward, some of these affect human health as well as wildlife.
- Spring events (breeding, migratory arrival, emergence from hibernation) are earlier by 2 weeks on average since 1970, with some frogs breeding a month earlier per decade.
- Warmer winters, northward ranges shifts of moths and beetles, and extended growing seasons have resulted in increased pest outbreaks, tree deaths, and associated loss of productivity in forests across the lower USA, Alaska, Canada and Russia.
- 74 species of highland cloud forest frogs have been driven extinct by climate change
- ~ 30% of tropical coral reefs have been killed by rising sea temperatures
- Cold-adapted and severely range-restricted species have lost habitat and are reaching "endangered" status because of loss of climatically-suitable space. Examples come from sea-ice habitats (polar bears & penguins) and from montane habitats (mountain-restricted frogs, mammals and butterflies)

Projected impacts of another 2°C warming

- Extinctions of most sensitive species – estimated species losses range from 4% for common, widespread trees and birds to 40% for sensitive species with small ranges.
- Large contractions of tundra and sea ice habitats, likely extinctions of associated species (*e.g.* caribou, polar bear, ringed seal)
- Major bleaching of most tropical coral reefs
- Overall projected extinction of 20% of species worldwide
- Increased incidences of tropical diseases in USA and Europe
- Lower agricultural productivity at lower latitudes (incl. some of USA), but increases at higher latitudes (Canada).

Projected impacts of > 4°C warming

- Complete loss of suitable climate space for a large number of species (*e.g.* from polar bears to montane tree possums in Australia) and whole ecosystems (*e.g.* the fynbos in South Africa)
- Mass extinction of wild species worldwide (on the order of >70%)
- High ocean temperatures combined with increased acidity lead to complete loss of tropical coral reefs with associated loss of fisheries and tourism
- Loss of much of boreal forests and associated lumber industries
- Lowered agricultural production at all latitudes

IV. Emission reductions options compatible with biodiversity preservation goals

- There is no single action that can bring greenhouse gas emissions down to levels which would prevent dangerous consequences. While increased production and use of renewable energy is admirable in theory, in practice many "green" energy schemes are counter-productive. For example, use of existing agricultural lands in the USA to grow crops for biodiesal is a good idea, but cutting down pristine rainforest in Indonesia to plant oil palms for biodiesal export (as is currently happening) is not a good idea. Likewise, schemes to plant forests over native grassland not only destroy an entire biome, but the benefits are short-lived – once the forest matures it ceases to take up large amounts of carbon from the atmosphere. This can happen in as little as 30 years. Wind power is fine in some areas, but in others has led to high bird mortality, often of endangered species, both from directly being killed when hitting the blades in-flight, and from creating fright behavior in open-meadow species (ground-nesting meadow birds appear to mistake the large moving blades for hawk and eagle predators).

- Solar panels are perhaps the single renewable energy source with no negative biodiversity consequences. Requiring roof solar panels on all new homes in appropriate areas (*i.e.* most of the western USA) would add little to overall housing costs (from $5,000 - $10,000 total upfront cost), which pays for itself in just a few years by money saved from reduced consumption from the grid.

- The policy options which would have the most direct and immediate effect on greenhouse gas emissions involve incentives for industry as well as individuals to produce less emissions. These could range from higher electricity prices which would provide incentive for improved energy conservation by homes and businesses (*e.g.* turning off heat or air-conditioning when the building is not occupied) to gasoline taxes which would encourage buying lower fuel-consumption cars. In Britain, yearly car registration fees are based entirely on absolute CO_2 emissions, with current fees ranging from $0 for the smallest cars to $400 /year for large family cars. Recent government announcements are to increase the maximum to $800/year. This is easy to implement and would have immediate impacts on individual car purchases.