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The Specter of Species Extinction

Will Global Warming Decimate Earth's Biosphere?

Sherwood B. Idso, Craig D. Idso and Keith E. Idso

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Foreword

That humans have a profound impact on the natural environment is a foregone conclusion. The alteration of the natural environment began with the formation of the first social groups and the rise of agriculture. Today, two critical questions are whether species are becoming extinct at rates that exceed normal and the degree to which human activity is the predominant cause.

A recent Marshall Institute study, *Climate Change and Ecosystems*, looking at the claim that human-induced climate change will lead to significant increases in the rate of species extinction found that very little is actually known about the rate of species extinction. Without knowing how many species there are, what the rate of natural extinction is, or how many species are becoming extinct as a result of other human activities, discussion about the potential impact of climate change on species extinction is very difficult. Nevertheless, frequently claims are advanced that climate change will accelerate the rate of species extinction.

The Marshall Institute is pleased to partner with the Center for the Study of Carbon Dioxide and Global Change to further evaluate the question. *The Specter of Species Extinction* offers a comprehensive examination of the scientific basis underlying claims of human-induced climate change and species extinction.

After reviewing this body of work, the report concludes that the facts do not support claims of mass extinctions arising out of climate change. Whether through adaptation, acclimation, or migration, available research suggests that the threats may be overstated.

By reminding us of what is known, *The Specter of Species Extinction* provides a useful reference for critically evaluating and assessing the apocalyptic claims advanced during the policy debates on climate change.

Jeffrey Kueter
Executive Director, The George Marshall Institute

Executive Summary

Extinction is forever … and *forever* is a very long time. The mere mention of the possibility that CO_2-induced global warming could drive species to extinction engages the natural sympathies of people everywhere. Hence, preventing extinction has become a rallying cry to convince nations to dramatically reduce their CO_2 emissions, which are claimed to be responsible for 20th century warming.

It is said, for example, that CO_2-induced global warming will be so fast and furious that many species of plants and animals will not be able to migrate towards cooler regions of the planet (poleward in latitude and/or upward in elevation) rapidly enough to avoid extinction. *It is said* that the process has already been set in motion by the global warming of the past hundred and fifty years. *It is said*, that "a significant impact of global warming is already discernible in animal and plant populations," and that, as a result, "we're sitting at the edge of a mass extinction."

It is easy to make long-term predictions; but to substantiate them with facts is an entirely different matter. And even when the facts are largely in hand, one can still be blinded by preconceived ideas that make it difficult to comprehend the real meaning of what has been discovered. So it is with the specter of species extinction that hovers over the global warming debate. The vast majority of people who have studied the subject have not understood some of the issue's most basic elements; and they have consequently drawn conclusions that are not aligned with reality.

Proponents of what we shall call the *CO_2-induced global warming extinction hypothesis* seem to be totally unaware of the *fact* that atmospheric CO_2 enrichment tends to ameliorate the deleterious effects of rising temperatures on earth's vegetation. They appear not to know that more CO_2 in the air enables plants to grow better at nearly all temperatures, but especially at *higher* temperatures. They feign ignorance of the knowledge (or truly do not know) that elevated CO_2 boosts the optimum temperature at which plants grow best, and that it raises the upper-limiting temperature above which they experience death, making them much more resistant to heat stress.

The end result of these *facts* is that if the atmosphere's temperature and CO_2 concentration rise *together*, plants are able to successfully *adapt* to the rising temperature, and they experience no ill effects of the warming. Under such conditions, plants living near the *heat*-limited boundaries of their ranges do *not* experience an impetus to migrate poleward or upward towards cooler regions of the globe. At the other end of the temperature spectrum, however, plants living near the *cold*-limited boundaries of their ranges are empowered to extend their ranges into areas where the temperature was previously too low for them to survive. And as they move into those once-forbidden areas, they actually *expand* their ranges, overlapping the similarly-expanding ranges of other plants and thereby increasing local plant biodiversity.

Animals react in much the same way. Over the past century and a half of increasing air temperature and CO_2 concentration, many species of animals have significantly extended the cold-limited boundaries of their ranges, both poleward in latitude and upward in elevation, while they have *maintained* the locations of the *heat*-limited boundaries of their ranges. Consequently, individual animal species, like individual plant species, have measurably increased the areas of the planet's surface that they occupy, creating more overlapping of ranges, greater local species richness, and an improved ability to *avoid* extinction.

In view of these real-world *facts*, it is clear that if massive plant and animal extinctions – due to *any* cause – are to be prevented in a warming world, *it would be best if the air's CO_2 content rose in tandem with its temperature*.

I. Introduction

Will global warming decimate earth's biosphere? Many scientists who are concerned about global warming have long contended the increase in temperature predicted to result from the ongoing rise in the air's CO_2 content will be so great and occur so fast that many species of plants and animals will not be able to migrate poleward in latitude or upward in elevation rapidly enough to avoid extinction as they are forced to seek cooler living conditions:

Woodwell (1989): "The changes expected are rapid enough to exceed the capacity of forests to migrate or otherwise adapt."

Davis (1989): "trees may not be able to disperse rapidly enough to track climate."

Gear and Huntley (1991): "the maximum [migration] rates attainable by … long-lived sessile organisms [are] more than an order of magnitude less than those required to maintain equilibrium with forecast anthropogenically induced climate changes."

Root and Schneider (1993): "changes in global climate are expected to occur … too fast for evolutionary processes such as natural selection to keep pace. Such constraints … could substantially enhance the probability of extinction of numerous species."

Dyer (1995): "The magnitude of the projected warming is considerable; the rate at which it is predicted to occur is unprecedented. There is genuine reason for concern that the extent of range shifts will exceed the dispersal abilities of many plant species."

Malcolm and Markham (2000): "rapid rates of global warming are likely to increase rates of habitat loss and species extinction …. many species may be unable to shift their ranges fast enough to keep up with global warming."

Malcolm et al. (2002): "Migration rates required by the warming are unprecedented by historical standards, raising the possibility of extensive, and in many cases, catastrophic, species loss."

Root et al. (2003): "rapid temperature rise and other stresses … could … lead to numerous extirpations and possibly extinctions."

Parmesan and Yohe (2003) and Root *et al.* (2003) suggest that the CO_2-induced global warming extinction phenomenon is already underway, with its initial effects being manifest in numerous "mini-migrations" of plant and animal populations throughout the world. However, *when atmospheric CO_2 concentrations rise* *sufficiently fast concurrently*, many experiments have demonstrated that rising temperatures should not *force* plants to migrate, although they may provide them with the *opportunity* to do so. In addition, there are a number of other ways in which plants are able to *adapt* to rising temperatures without resorting to *migration*. Finally, nearly all of the real-world observations that are routinely cited as evidence for the validity of the CO_2-induced global warming extinction hypothesis not only do not support it, they actually *refute* it, as we demonstrate later in this report.

II. Physiological Reasons for Rejecting the CO_2-Induced Global Warming Extinction Hypothesis

A. The Adaptability of Plants to Rising Temperature

All else being equal, the global warming extinction scenario would appear to have merit. After all, if it gets "too hot" for a species of plant or animal where it currently lives, it is only logical that individuals of the heat-stressed species would have to move to a cooler location in order to survive. In many cases, however, *acclimation* can adequately substitute for *migration*, as has been demonstrated by several studies in which the temperatures at which plants grow best rose substantially (by several degrees Centigrade) in response to increases in the air temperature regimes to which they had long been accustomed (Mooney and West, 1964; Strain *et al*., 1976; Bjorkman *et al*., 1978; Seemann *et al*., 1984; Veres and Williams, 1984; El-Sharkawy *et al*., 1992, Battaglia *et al*., 1996). So how does it happen?

One possible way in which adaptation to warmer temperatures may occur is described by Kelly *et al*. (2003). In reference to the climate-alarmist view of the Intergovernmental Panel on Climate Change or IPCC (Watson and Team, 2001), they note that "models of future ecological change assume that *in situ* populations of plants lack the capacity to adapt quickly to warming and as a consequence will be displaced by species better able to exploit the warmer conditions anticipated from 'global warming'." In contrast to this *assumption*, they report finding individual trees within a naturally occurring stand of *Betula pendula* (birch) that are genetically adapted to a range of different temperatures. As they describe it, they discovered "the existence of 'pre-adapted' individuals in standing tree populations" that "would reduce temperature-based advantages for invading species," which finding, they say, "bring[s] into question assumptions currently used in models of global climate change."

Another perspective on the *adaptation* vs. *migration* theme is provided by the work of Loehle (1998), who notes (using forests as an example) that the CO_2-induced global warming extinction hypothesis rests on the assumption that the growth rates of trees rise from zero at the cold limits of their natural ranges (their northern boundaries in the Northern Hemisphere) to a broad maximum, after which they decline to zero at the warm limits of their natural ranges (their southern boundaries in the Northern Hemisphere). Loehle demonstrates that this assumption is only *half* correct. It properly describes tree growth dynamics near a Northern Hemispheric forest's *northern* boundary, but it is an inaccurate representation of tree growth dynamics near a Northern Hemispheric forest's *southern* boundary.

Loehle notes, for example, that in the Northern Hemisphere (to which we will restrict our discussion for purposes of simplicity), trees planted north of their natural ranges' northern boundaries are only able to grow to maturity within 50-100 miles of those boundaries. Trees planted south of their natural ranges' southern boundaries, however, often grow to maturity *as much as 1000 miles further south* (Dressler, 1954; Woodward, 1987, 1988). In fact, Loehle reports that "many alpine and arctic plants are extremely tolerant of high temperatures, and in general one cannot distinguish between arctic, temperate, and tropical-moist-habitat types on the basis of heat tolerances, with all three types showing damage at 44-52°C (Gauslaa, 1984; Lange and Lange, 1963; Levitt, 1980; Kappen, 1981)."

What Loehle finds from his review of the literature and his experience with various trees in the Unites States, is that as temperatures and growing degree days rise from very low values, the growth rates of Boreal trees at some point begin to rise from zero and continue increasing until they either plateau out at some maximum value or drop only very slowly thereafter, as temperatures rise still higher and growing degree days continue to accumulate. Trees from the Midwest, by comparison, do not begin to grow until a higher temperature or greater accumulation of growing degree days is reached, after which their growth rates rise considerably higher than those of the colder-adapted Boreal species, until they too either level out or begin to decline ever so slowly. Last of all, southern species do not begin to grow until even higher temperatures or growing degree day sums are reached, after which their growth rates rise the highest of all before leveling out and exhibiting essentially *no* decline thereafter, as temperatures and growing degree days continue to climb.

In light of these observations, it is clear that although the northern range limit of a woody species in the Northern Hemisphere is indeed determined by growth-retarding cool growing seasons and frost damage, the southern boundary of a tree's natural range is not determined by temperature, but by *competition* between the northern species and more southerly-adapted species that have inherently greater growth rates.

Whenever significant long-term warming occurs, therefore, earth's coldest-adapted trees are presented with an opportunity to rapidly extend the cold-limited boundaries of their ranges northward in the Northern Hemisphere, as many studies have demonstrated they have done in the past and are doing now. Trees at the southern limits of their ranges, however, are little affected by the extra warmth. As time progresses, they may at some point begin to experience pressure from some of the faster-growing southern species encroaching upon their territory; but this potential challenge is by no means assured of quick success. As Loehle describes it:

> *Seedlings of these southern species will not gain much competitive advantage from faster growth in the face of existing stands of northern species, because the existing adult trees have such an advantage due to light interception. Southern types must wait for gap replacement, disturbances,*

> *or stand break up to utilize their faster growth to gain a position in the stand. Thus the replacement of species will be delayed at least until the existing trees die, which can be hundreds of years... Furthermore, the faster growing southern species will be initially rare and must spread, perhaps across considerable distances or from initially scattered localities. Thus, the replacement of forest (southern types replacing northern types) will be an inherently slow process (several to many hundreds of years).*

In summing up the significance of this situation, Loehle says that "forests will not suffer catastrophic dieback due to increased temperatures but will rather be replaced gradually by faster growing types."

Another possibility that must be seriously considered is that northern or high-altitude forests *will not be replaced at all* by southern or low-altitude forests in a warming world. Rather, the two forest types may *merge*, creating entirely *new* forests of *greater species diversity*, such as those that existed during the warmer Tertiary Period of the Cenozoic Era, when in the western United States many montane taxa regularly grew among mixed conifers and broadleaf schlerophylls (Axelrod 1994a, 1944b, 1956, 1987), creating what could well be called *super forest ecosystems*, which Axelrod (1988) has described as "much richer than any that exist today."

Possibly helping warmer temperatures to produce this unique biological phenomenon during the Tertiary were the higher atmospheric CO_2 concentrations of that period (Volk, 1987), as has been suggested by Idso (1989). It is a well known fact, for example, that elevated concentrations of atmospheric CO_2 significantly stimulate plant growth rates (Kimball, 1983) – especially those of trees (Saxe *et al.*, 1998; Idso and Kimball, 2001) – and that they also greatly enhance their water use efficiencies (Feng, 1999). Even more important, however, is how atmospheric CO_2 enrichment alters plant photosynthetic and growth responses to rising temperatures, as we discuss in the following section.

B. The Extra Help Provided by Rising Atmospheric CO_2 Concentrations

It has long been known that *photorespiration* — which can "cannibalize" as much as 40-50% of the recently-produced photosynthetic products of C_3 plants (Wittwer, 1988) – becomes increasingly more pronounced as air temperature rises (Hanson and Peterson, 1986). It has also been established that photorespiration is increasingly more inhibited as the air's CO_2 content rises (Grodzinski *et al.*, 1987). Hence, there is a greater potential for rising CO_2 concentrations to benefit C_3 plants at higher temperatures, as was demonstrated by the early experimental work of Idso *et al.* (1987) and Mortensen (1987) , as well as by the theoretical work of Gifford (1992), Kirschbaum (1994) and Wilks *et al.* (1995). In fact, in an analysis of 42 experimental data sets collected by numerous scientists, Idso and Idso (1994) showed that the mean growth enhancement due to a 300-ppm increase in atmospheric CO_2 concentration rises from close to zero at an air temperature of 10°C to 100% (doubled growth) at approximately 38°C, while at higher temperatures the growth stimulation rises higher still, as has also been shown by Cannell and Thornley (1998).

Several studies have additionally demonstrated that atmospheric CO_2 enrichment tends to alleviate high-temperature stress in plants (Faria, 1996; Nijs and Impens, 1996; Vu *et al.*, 1997); and it has been proven that at temperatures that are high enough to cause plants to die, atmospheric CO_2 enrichment can sometimes preserve their lives (Idso *et al.*, 1989, 1995; Baker *et al.*, 1992; Rowland-Bamford *et al.*, 1996; Taub, 2000), just as it can often stave off their demise in the very dry conditions that typically accompany high air temperatures (Tuba *et al.*, 1998; Hamerlynck, *et al.*, 2000; Polley *et al.*, 2002).

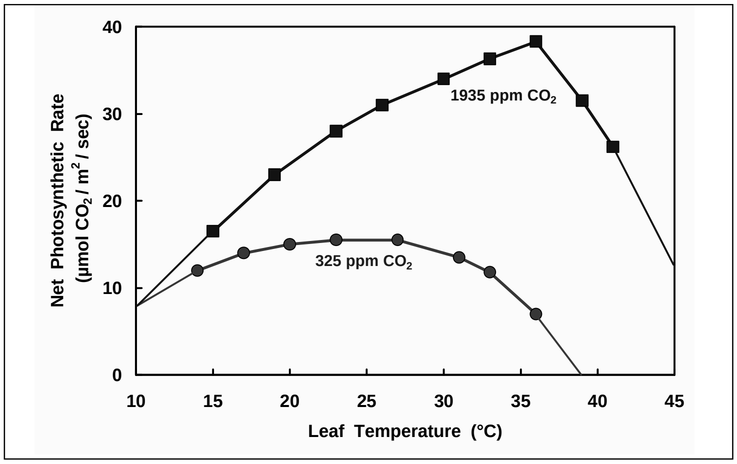
A major consequence of these facts is that the *optimum temperature* (Topt) for plant growth – the temperature at which plants photosynthesize and grow best – generally *rises* with atmospheric CO_2 enrichment (Berry and Bjorkman, 1980; Taiz and Zeiger, 1991). An example of this phenomenon is presented in Box 1 at the right, where it can be seen that the increase in atmospheric CO_2 concentration utilized in this particular study increases the optimum temperature for photosynthesis in this species from a broad maximum centered at 25°C in ambient air to a well-defined peak at about 36°C in CO_2-enriched air.

How much is plant optimum temperature typically increased by an extra 300 ppm of CO_2? Based largely on theoretical considerations, Long (1991) calculated that such an increase in the air's CO_2 concentration should increase Topt, in the mean, by about 5°C, while McMurtrie and Wang (1993) calculated that it should increase it by somewhere between 4 and 8°C. In Table 1, we report the results of all of the experimental determinations of this number that we could find in the scientific literature. As can be seen there, the mean increase in Topt for the eleven plants studied is 4.6 ± 1.2°C (3.4 to 5.8°C) for a 300-ppm rise in the air's CO_2 concentration. Hence, both theory and experiment appear to be in reasonably good agreement on this important point.

What is the ultimate implication of the finding that plant optimum temperature rises so dramatically in response to increasing atmospheric CO_2 concentration? It is that if the planet were to warm in response to the ongoing rise in the air's CO_2 content — even to the ungodly degree predicted by the worst-case scenario of the Intergovernmental Panel on Climate Change (5.8°C by 2100) — the vast majority of earth's plants would likely not feel a need (or only very little need) to migrate towards cooler parts of the globe. Any warming would obviously provide them an *opportunity* to move into regions that were previously too cold for them, but it would not *force* them to move, even at the hottest extremes of their ranges; for as the planet warmed, the rising atmospheric CO_2 concentration would work its biological wonders, significantly increasing the temperatures at which most of earth's C_3 plants — which comprise fully 95% of the planet's vegetation (Drake, 1992) — function best, creating a situation where earth's plant life would actually *prefer* warmer conditions.

Box 1: The CO2-Temperature-Growth Interaction

The growth-enhancing effects of elevated CO_2 typically increase with rising temperature. This phenomenon is illustrated by the data of Jurik et al. (1984), who exposed bigtooth aspen leaves to atmospheric CO_2 concentrations of 325 and 1935 ppm and measured their photosynthetic rates at a number of different temperatures. In the figure below, we have reproduced their results and slightly extended the two relationships defined by their data to both warmer and cooler conditions.



At 10°C, elevated CO_2 has essentially no effect on net photosynthesis in this particular species, as Idso and Idso (1994) have demonstrated is characteristic of plants in general. At 25°C, however, where the net photosynthetic rate of the leaves exposed to 325 ppm CO_2 is maximal, the extra CO_2 of this study boosts the net photosynthetic rate of the foliage by nearly 100%; and at 36°C, where the net photosynthetic rate of the leaves exposed to 1935 ppm CO_2 is maximal, the extra CO_2 boosts the net photosynthetic rate of the foliage by a whopping 450%. In addition, it is readily seen that the extra CO_2 increases the optimum temperature for net photosynthesis in this species by about 11°C: from 25°C in air of 325 ppm CO_2 to 36°C in air of 1935 ppm CO_2.

In viewing the warm-temperature projections of the two relationships, it can also be seen that the transition from positive to negative net photosynthesis — which denotes a change from life-sustaining to life-depleting conditions — likely occurs somewhere in the vicinity of 39°C in air of 325 ppm CO_2 but somewhere in the vicinity of 50°C in air of 1935 ppm CO_2. Hence, not only was the optimum temperature for the growth of bigtooth aspen greatly increased by the extra CO_2 of this experiment, so too was the temperature above which life cannot be sustained increased, and by about the same amount, i.e., 11°C.

Table 1. The increase (Δ) in the optimum temperature for plant growth (Topt, °C) due to various increases in atmospheric CO_2 concentration (ppm), along with the increase in Topt due to a 300 ppm increase in atmospheric CO_2 concentration (ΔTopt/300) based on the values of ΔTopt and ΔCO_2.

Species	**Reference**	**ΔCO_2**	**ΔTopt**	**ΔTopt/300**
Arbutus unedo	Harley *et al.* (1986)	200	8.0	12.0
Camissonia brevipes	Seeman *et al.* (1984)	670	4.0	1.8
Chenopodium album	Sage *et al.* (1995)	400	0.0	0.0
Digitalis lanata	Stuhlfauth and Fock (1990)	650	13.0	6.0
Glycine max	Ziska and Bunce (1997)	350	-2.0	-1.7
Lycopersicon esculentum	Nilsen *et al.* (1983)	650	10.0	4.6
Nerium oleander	Bjorkman *et al.* (1978)	470	9.0	5.7
Phaseolus vulgaris	Cowling and Sage (1998)	187	5.0	8.0
Picea abies	Roberntz (2001)	350	4.1	3.5
Pinus radiate	McMurtrie *et al.* (1992)	350	10.0	8.6
Populus grandidentata	Jurik *et al.* (1984)	1610	11.0	2.0
Mean				**4.6**
Standard Error of the Mean				**1.2**

With respect to the C_4 and CAM plants that make up the remaining 5% of earth's vegetative cover, most of them are endemic to the planet's hotter environments (De Jong *et al.*, 1982; Drake, 1989; Johnson *et al.*, 1993), which according to the IPCC are expected to warm much less than the cooler regions of the globe. Hence, the planet's C_4 and CAM plants would not face quite as great a thermal challenge as earth's C_3 plants in a warming world. Nevertheless, the work of Chen *et al.* (1994) suggests that they too may well experience a modest increase in their optimum temperatures as the air's CO_2 content rises (a 1.5°C increase in response to a 350-ppm increase in atmospheric CO_2 concentration). Consequently, and in view of the non-CO_2-related abilities of earth's vegetation to adapt to rising temperatures discussed in the previous section, plants of all photosynthetic persuasions should be able to successfully adapt to any future warming that could possibly be caused by the enhanced greenhouse effect that may be produced by the CO_2 emitted to the air by mankind's burning of fossil fuels.

So what could we logically expect to happen to the biosphere in a world of both rising air temperature and atmospheric CO_2 concentration? We could expect that earth's plants would extend the current cold-limited boundaries of their ranges both poleward in latitude and upward in elevation, but that the heat-limited boundaries of the vast majority of them would remain pretty much as they are now, i.e., unchanged. Hence, the *sizes* of the ranges occupied by most of earth's plants would *increase*. We additionally hypothesize that many of the animals that depend upon those plants for food and shelter would exhibit analogous behavior. Hence, with respect to both plants *and* animals, we would anticipate that nearly everywhere on earth, local biodiversity or species richness would *increase* in a world of rising air temperature and atmospheric CO_2 concentration, as the expanding ranges of the planet's plants and animals overlapped those of their neighbors to an ever-increasing degree.

The implications of these observations are clear: if the planet continues to warm, even at what climate alarmists call "unprecedented rates," we need not worry about earth's plants and animals being unable to migrate to cooler regions of the globe fast enough to avoid extinction, *as long as the air's CO_2 content continues to rise at its current rate*. So obvious is this conclusion, in fact, that Cowling (1999) has bluntly stated that "maybe we should be less concerned about rising CO_2 and rising temperatures and more worried about the possibility that future atmospheric CO_2 will suddenly stop increasing, while global temperatures continue rising."

III. More Climate-Alarmist Claims of Extinction

Cowling is right on target with her assessment of the issue. Measures designed to slow the rate of rise of the air's CO_2 content would actually be counterproductive and *detrimental* to the biosphere, in that they would deprive earth's vegetation (and its associated animal life) of much of its capacity to adequately acclimate to rising temperatures forced by phenomena unrelated to the air's CO_2 content, such as variations in solar activity. However, the political pressure to respond to the counterfeit ethics of the CO_2-induced global warming extinction hypothesis is so great that both logic and facts count for little in the debate over what to do — or *not* do! – about the ongoing rise in the air's CO_2 content. Thus, the media onslaught continues, with each new scientific study that can possibly be construed to support a doom-and-gloom scenario being heralded as another important piece of evidence for the validity of the contention that earth's biosphere is already in process of being decimated by global warming.

But we hear so *many* stories of plants and animals being forced to move to higher latitudes and elevations over the past century and a half of increasing atmospheric CO_2 and temperature. Aren't at least *some* of them true? And what about the recent studies of Parmesan and Yohe (2003) and Root *et al.* (2003), numerous press reports of which conjure up ghastly visions of an imminent mass extinction? Don't they refute what we have just concluded?

Before answering these questions, it is important to note that the blame for the oft-repeated but false contention that global warming will decimate earth's biosphere cannot be laid solely at the feet of the popular press. Many of the scientists involved in the studies that have been construed to imply the validity of the CO_2-induced global warming extinction hypothesis have themselves been the sources of much of the rampant speculation. Root herself, for example, was quoted in one article describing her team's work (*post-gazette.com Health & Science*, 2 January 2003) as saying "animals and plants are being strongly affected by warming of the globe" and "in my opinion, we're sitting at the edge of a mass extinction," while in another article from the *New York Times* ("Global Warming Found to Displace Species," authored by Andrew C. Revkin, 2 January 2003), she was quoted as saying "it's really pretty frightening to think what we might see in the next 100 years."

Other scientists are also quick to promote the unholy vision of an impending biological apocalypse. In a related story (*CNN.com*, 2 January 2003), for example, it was reported that Alastair Fitter, a professor of biology at the University of York, said "the studies' conclusions that the ranges of hundreds of species are shifting northward in response to warming temperatures are disconcerting," adding that if temperatures rise as predicted, "it may drive some plant and animal species to extinction as their ranges shrink."

Still other reports put the "bad news" right up front in their titles. An *Environment News Service* report of 2 January 2003 declared "Hundreds of Species Pressured by Global Warming," while *Nature Science Update* trumpeted on 6 January 2003 that "Huge studies analyze climate change's toll on plants and animals across globe." Likewise, a *Rocky Mountain News* headline of 2 January 2003 declared "Species at risk as global warming spurs climate change," reporting in the body of the story that scientists said the studies "foretell the extinction of many species in the coming decades as rising temperatures force them to retreat from their historic ranges."

Although these reports may *seem* compelling, they do not live up to their dramatic billing when carefully analyzed. In fact, as we shall shortly demonstrate, the vast bulk of the scientific studies that prompted them actually do just the *opposite* of what climate alarmists claim they do. Rather than suggesting earth's biosphere is about to suffer irreparable damage as a result of past natural warming and future predicted warming, they actually *substantiate* nearly everything we have deduced from what is known about the effects of atmospheric CO_2 enrichment on plant physiology. Most importantly, they portray a biosphere of *increased species richness* almost everywhere on earth in response to the global warming and increase in atmospheric CO_2 concentration of the past century and a half that has promoted a great expansion of species' ranges throughout the entire world.

IV. Our Appraisal of the Root *et al.* (2003) Study

Root *et al.* (2003), by their own admission, examined "thousands of articles" in reaching their conclusion that "a significant impact of global warming," which they consider to be extremely negative, "is already discernible in animal and plant populations." However, most of this mountain of evidence was *rejected* by them. Why? It was rejected *because*, as they openly admit, they chose to include only those studies that "(1) examined a span of at least 10 years, (2) found that a trait of at least one species shows change over time, and (3) found either a temporal change in temperature at the study site or a strong association between the species trait and site-specific temperature."

Think about that. If a study did *not* indicate that "at least one species shows change over time" *or* that there was "a strong association between the species trait and site-specific temperature," *the study was ignored*. Talk about stacking the deck in favor of one's hypothesis! If a study showed that a species' population was *stable* over time or did *not* show a strong association between one of its traits and changing temperature patterns — such as we would predict for the heat-limited boundary of a species' range, which consequence would tend to refute the CO_2-induced global warming extinction hypothesis — *it was dropped from further consideration*.

So just how extensive was this stacking of the deck? Of the thousands of articles Root *et al.* examined, they selected a mere *one hundred and forty-three* for detailed scrutiny. Does this massive filtering of the data mean there could be hundreds upon hundreds — if not *thousands* — of studies that run *counter* to their hypothesis? There is a strong possibility that it does, especially in light of what we are about to learn about the studies they did use.

From among the 143 "qualifying" articles that survived their unique filtering process, Root *et al.* created two categories of studies. *Tier 1 studies*, of which there were 85, were "those demonstrating a statistically significant trend for at least one species examined." *Tier 2 studies*, of which there were 58, were "those in which statistical significance was not shown by the study's authors," which gives yet another indication of the paucity of pertinent data they employed in reaching their sweeping global conclusions.

Within these two tiers of papers, Root *et al.* evaluated changes in four species traits: (1) species densities at given locations and species ranges, (2) the timing of significant species life-cycle events, (3) species morphology, and (4) species genetic frequencies. However, only the first of these traits provide data that are appropriate for evaluating the hypothesis that CO_2-induced global warming will force plants and animals to migrate to cooler regions of the planet.

The impact of this last observation is such that of the 85 Tier 1 articles evaluated by Root *et al*. — again by their own admission — only eleven contain information on species range shifts; while of the 58 Tier 2 papers they evaluated, a mere thirteen deal with the subject. Hence, out of the thousands of articles they originally examined, only two dozen contain data that might be appropriate for evaluating the CO_2-induced global warming extinction hypothesis; and over half of them lay no claim to possessing any statistical significance, which truly speaks volumes about how *underwhelming* is the case their paper makes for Root's contention that "we're sitting at the edge of a mass extinction." Nevertheless, to complete our analysis, we next evaluate each of the 24 potentially pertinent papers in the order in which Root *et al*. list them in their Supplemental Appendices 1 and 2, dealing first with their Tier 1 studies and then their Tier 2 studies.

V. Root *et al.*'s Tier 1 Studies

T1.1 — Pounds *et al*. (1999)

This first of the eleven articles that are claimed by Root *et al.* to provide statistically significant evidence for the proposition that an impact of global warming "is already discernible in animal and plant populations" fails miserably, even in terms of their own "rules." In their 2003 paper, for example, they said they "focused on temperature change and ignored other climatic changes, such as precipitation." Yet the Pounds *et al.* study, which was conducted in highland forests at Monteverde, Costa Rica, dealt with biological changes that, in the authors' own words, were "all associated with patterns of dry-season mist frequency."

Root *et al.* apparently justified the bending of their caused-by-temperature-change exclusivity rule on the basis of Pounds *et al.*'s claim that the patterns of dry-season mist frequency they identified were "negatively correlated with sea surface temperatures in the equatorial Pacific" and were therefore ultimately caused by a warming of that region of the globe. As everyone knows, however — or *should* know — *correlation does not prove causation*; and, in fact, it was subsequently demonstrated by Lawton *et al.* (2001) that the changes in dry-season mist frequency that Pounds *et al.* claimed were due to "the increase in air temperatures that followed a step-like warming of tropical oceans in 1976" were in reality caused by *upwind deforestation of adjacent lowlands* that increased convective and orographic cloud bases, which resulted in a reduced moisture supply to Pounds *et al.*'s study area.

The drying of the air over the Monteverde site — which was thus due to local logging activity and neither global nor regional warming — did indeed lead to local decreases in lizard and amphibian populations; and that was perhaps the reason Root *et al.* strove so mightily to include the Pounds *et al.* results in their meta-analysis. But with respect to the birds they studied, a very different result was obtained. The number of bird species characteristic of lower elevations nearly doubled at an elevation of 1540 meters between 1979 and 1998, while the number of species characteristic of higher elevations — which climate alarmists typically claim will be forced to migrate upward in elevation until there is no place left for them to go (except extinct) — *changed not at all*. As a result, bird species richness in this region actually *increased*, which is about as opposite a condition to extinction as one could possibly conceive.

T1.2 — Hill *et al*. (1999)

The authors studied a "species of UK butterfly, the speckled wood, *Pararge aegeria* (L.)," finding that "after contraction of its distribution at the end of the 19th century," it *increased* its range. Specifically, they report that "*P. aegeria* has expanded its northern margin substantially since 1940." They also note that "changes in this species' distribution over the past 100 years are likely to have been due to climate change" and that "during this century climates in the study area have on average become warmer and drier."

What we have here is a clear-cut case of a Northern Hemispheric butterfly capitalizing on the *opportunity* to move northward at the northern boundary of its range in a warming climate, as is only logical it should do. However, this response says absolutely nothing about the CO_2-induced global warming extinction hypothesis, which requires that Northern Hemispheric species will be *forced* to move northward at their *southern* boundaries in response to global or regional warming if they are to avoid heat-induced death.

T1.3 — Hill *et al*. (2001)

The three authors of Hill *et al.* (1999) — publication T1.2 above — joined forces with four additional researchers in this publication to conclude pretty much the same thing ... about the same butterfly species ... over the same period of time ... in the same part of the world ... as they did in their 1999 publication. Thus, this publication, too, sheds absolutely no light on the CO_2-induced global warming extinction hypothesis, which requires information about the movement or non-movement of the *southern* boundary of a species' range in the Northern Hemisphere.

T1.4 — Parmesan *et al*. (1999)

The authors documented changes in the northern boundaries of 52 butterfly species over the past century in northern Europe, as well as concomitant changes in the southern boundaries of 40 butterfly species in southern Europe and northern Africa, over which period of time the majority of the studied region warmed by about 0.8°C. As to the range shifts they observed, the authors report that "nearly all northward shifts involved extensions at the northern boundary with the southern boundary remaining stable."

This finding is a *direct refutation* of the CO_2-induced global warming extinction hypothesis, in that it demonstrates that a significant increase in temperature *allowed* butterflies to expand their *northern* boundaries northward but did not *force* them to move their *southern* boundaries northward. Indeed, it is a strong vindication of *our* hypothesis, i.e., that heat-limited species' boundaries will *not* change in a region of both increasing temperature and atmospheric CO_2 concentration.

Not only is this butterfly behavior not *bad*, as Root *et al.* would have the world believe, it is *good*. The authors note, for example, that because of their stable southern boundaries and the northward movement of their northern boundaries, "most species effectively expanded the size of their range," which has helped to *protect* them against the possibility of extinction. The resultant range overlapping has also increased regional *biodiversity* by increasing regional butterfly *species richness*, which is precisely what we have predicted should occur in such situations.

T1.5 — Thomas and Lennon (1999)

The authors documented changes in the distributions of numerous British bird species that occurred between 1970 and 1990 — which they describe as "a period of climatic warming" — finding that the northern margins of southerly species' breeding ranges shifted northward by an average of 19 km, while the southern margins of northerly species' breeding ranges shifted *not at all*. This finding, like that of publication T1.4 above, is at one and the same time a *direct refutation* of the CO_2-induced global warming extinction hypothesis and a *striking confirmation* of our view of the subject.

T1.6 — Prop *et al*. (1998)

The authors documented changes in the distribution of spring staging barnacle geese (*Branta leucopsis*) in Norway, finding that they extended the northern boundary of their range further north between 1983 and 1992, when increasingly warmer spring temperatures may have made more northerly islands more readily accessible to them. However, the authors also say "the shift in distribution could have been induced by limited supplies of food on the traditional islands, leaving the growing numbers of geese no choice but to explore new areas." In either case, this finding has no bearing whatsoever on the CO_2-induced global warming extinction hypothesis, which to be viable requires a northward extension of the *southern* boundary of a species' range in the Northern Hemisphere.

T1.7 — Grabherr *et al*. (1994)

The authors "collected data on the state of the flora at 26 summits exceeding 3,000 m in the middle part of the Alps and compared the actual records on cover and abundance of vascular plant species with historical records," finding that "species richness has increased during the past few decades, and is more pronounced at lower altitudes."

This result, like the results of publications T1.4 and T1.5, also argues against the validity of the CO_2-induced global warming extinction hypothesis, as the 0.7°C warming of the mountainous region over the period of data comparison resulted in *no loss of species at upper elevations*, but led instead to significant *increases* in species richness at *lower* elevations, where plants from still lower elevations apparently capitalized on the opportunity to expand their ranges upward in response to the regional warming, both of which results are again in harmony with what we are predicting to occur in response to simultaneous increases in air temperature and atmospheric CO_2 concentration.

T1.8 — Pauli *et al*. (1996)

The authors documented temporal changes in the summit floras of 30 mountains spread throughout three regions of Europe: (1) the central European Alps of Switzerland and Italy, (2) the Otztaler Alpen of Austria and Italy, and (3) the Zillertaler Alpen and Rieserferner Gruppe of Austria and Italy. Dates of initial species counts ranged from 1895 to 1953, producing a mean date of 1920, while the modern assessments were made in 1992 and 1993.

Over the period studied, during which time Austrian air temperatures are claimed by the authors to have risen by 2°C, with an increase of 1.2°C in the last 30 years alone, little net change was observed in species numbers at 9 of the 30 summits, where there was, as they describe it, a "stagnation of species richness." At the other 21 summits, however, species numbers rose dramatically. The top-performing 11 summits, for example, gained an average of 59% more species, with one summit exhibiting a species increase of 143%, once again in confirmation of what we are predicting.

The contention of climate alarmists, however, is that this opportunistic march of lower-elevation species up the mountains will result in a loss of the species that initially lived at their summits. So far, the data show only the slightest hint of such an effect, with a mean loss of *less than a single species* (0.68) out of an original mean species number of 15.57 across all 30 mountains, for a mean species number decline of about 4.4%. However, this tiny decrease is probably due to something *other* than competition from invading species, since the loss of original species on the 11 summits showing the *greatest* species invasion from lower elevations was considerably *less* than the mean loss, at only 2.5%.

Once again, therefore, these data tend to argue *against* the validity of the CO_2-induced global warming extinction hypothesis, as concurrent increases in the air's CO_2 content and temperature have greatly increased species richness on the mountain tops surveyed in this study without any clear-cut indication of a negative impact on the indigenous species that lived there before the warming began.

T1.9 — Kullman (2001)

The author reviewed what has been learned from several studies of temporal changes in the vertical locations of mountain-side tree-limits that have been carried out over the past century in the southern Scandes of Sweden, based on data obtained from a network of more than 200 tree-limit sites spread over an area of approximately 8,000 km^2. His findings? (1) "Concurrent with fluctuating climate warming, tree-limits of different species in the Swedish Scandes have advanced upslope by 100-165 m during the 20th century." (2) "The major part of this displacement occurred prior to 1950, followed by stability or slight reversal for some colder mid-century decades." (3) "Signs of resumed advance were recorded during the 1990s." As these findings clearly relate to the upper cold-limited boundaries of the trees' ranges, they again tell us *nothing* about the CO_2-induced global warming extinction hypothesis, which requires lower elevation heat-limited boundaries to be moving upward also.

T1.10 — Vesperinas *et al*. (2001)

The authors systematically investigated the distribution of certain plant species in the northwest quadrant of the Iberian Peninsula and the Mediterranean coast over the past 30 years, finding a correlation between temperature increases detected in thermometric data series and an "expansion of native, thermophilic species (*Sonchus tenerrimus*, *Dittrichia viscosa*) towards colder inland areas where they were previously absent." They also documented similar expansions of "taxa from the neotropics and the Cape Province of South Africa which have colonized areas close to the Mediterranean coast."

Once again, these observations merely confirm the obvious: when temperatures rise and the climate warms, species are able to extend their ranges into areas where it was previously too cold for them to successfully grow and reproduce. This study thus has absolutely *no bearing* upon the question of what happens at the heat-limited boundaries of a species range, which is the crucial question for the CO_2-induced global warming extinction hypothesis.

T1.11 — van Herk *et al*. (2002)

The authors analyzed a database of approximately 70,000 lichen records that had been accumulated since 1979 in the province of Utrecht in the central part of the Netherlands. They found that "the total number of taxa present increased from 95 in 1979 to 172 in 2001, while the average number of taxa per site increased from 7.5 to 18.9." However, a clear response to warming was only evident from 1995 to 2001.

Since this finding is a consequence of the northern range boundaries of southerly taxa moving northward, it again tells us *nothing* about the CO_2-induced global warming extinction hypothesis; but it does indicate that the opportunistic northward march of more southerly lichens has greatly increased lichen species richness in the study area, as we predict. That this development is *good* is indicated by the authors' statement that "the Netherlands is regaining its original lichen flora, which was largely lost due to heavy air pollution" in earlier decades.

VI. Root *et al.*'s Tier 2 Studies

T2.1 — Emslie *et al*. (1998)

In this first of the thirteen articles that are acknowledged by Root *et al.* to *not* provide statistically significant evidence for *any* aspect of climate-modulated plant or animal behavior, the authors excavated six abandoned and three modern Adelie penguin colonies in the Palmer Station area of the Antarctic Peninsula. By careful analyses of these materials, they developed a 644-year history of penguin occupation of the region, which stretched back to just before the Little Ice Age.

Throughout the Little Ice Age, Emslie *et al.* noted there were both cool and warm periods, and that many penguin colonies periodically came and went, presumably because "the area may [periodically] have become too snow- or ice-covered for occupation by breeding birds." In addition, they found that "only recently [since 1957] have gentoo and chinstrap penguins expanded their breeding distribution to this region," noting that "it is possible that the relatively rapid regional warming now occurring in the Antarctic Peninsula has favored the expansion of these species southward."

These latter data demonstrate that, just as in the Northern Hemisphere, opportunistic species' range extensions occur in response to warming in the Southern Hemisphere. Below the equator, however, the cold-limited boundaries of species' ranges move *southward*, as is demonstrated by the recent arrival of gentoo and chinstrap penguins in the Palmer Station area of the Antarctic Peninsula. These extensions of the penguin species' southern range boundaries, however, tell us *nothing* about their critical heat-limited *northern* boundaries. Hence, the observations of this paper — like many of those comprising Root *et al.*'s Tier 1 set of papers — are *totally irrelevant* to the CO_2-induced global warming extinction hypothesis.

T2.2 — Pollard *et al*. (1995)

The authors studied temporal changes in the distributions of 18 butterfly species that "are widespread and, more or less, common in the British countryside," finding that "nearly all of the common species have increased in abundance more in the east of Britain than in the west." They then note that "the reasons for recent range expansion and increases in abundance of common butterflies are not known," stating in their concluding paragraph that "we are thus a long way from understanding the cause or causes of the expansions of butterfly ranges and the increases in abundance described in this paper."

In light of these observations, and the authors' admission that they do not know the cause of them, it is difficult to understand how Root *et al*. could possibly have cited this research as evidence for a warming-induced shifting of ranges. We also note that these range expansions and increases in abundance would appear to be welcome phenomena, not at all to be feared and far from implying imminent extinction. In addition, they appear to be part of a recurring cycle in which the authors suggest the participating species have merely been "regaining lost ground."

T2.3 — Ott (2001)

With respect to the warming-induced range expansions of dragonflies that have been observed since about 1980 in Europe, the author developed "an updated summary of a compilation of probably all relevant publications on this topic, including the so called 'grey literature'." The story told by this wealth of information is that of a "clear trend of expansion towards the north, the increase of population sizes and the colonization of biotopes in higher altitudes," which, again, is exactly what one would expect in response to regional warming.

Are these changes good or bad? The author notes that "mass invasion of one or more species along with a long term change of abiotic conditions, e.g. temperature and precipitation, may cause considerable alterations in the floral and faunal composition of whole coenoses." However, he rightly concludes that "a more diversified fauna in a particular area is not at all to be regarded as negative from the standpoint of nature conservancy," which is another way of saying that this phenomenon likely helps species to *avoid* extinction.

T2.4 — Thomas *et al*. (2001)

The authors begin their paper by stating the long-held belief that many animals are "relatively sedentary and specialized in marginal parts of their geographical distributions," citing Thomas (1993) and Thomas *et al*. (1999) as examples of that concept and noting that such animals are thus "expected to be slow at colonizing new habitats." This idea provides some of the basis for the chief contention of the CO_2-induced global warming extinction hypothesis, i.e., that plants and animals of many types will not be able to migrate either poleward in latitude or upward in elevation *fast enough* to avoid extinction as the earth warms in response to the rising CO_2 content of the atmosphere. "Despite this," the authors report, "the cool margins of many species' distributions have expanded rapidly in association with recent climate warming," citing a host of other studies as evidence of this phenomenon.

Why has this opportunistic response been so dramatic? One reason is revealed in what the scientists learned from the two butterfly species they studied: the butterflies "increased the variety of habitat types that they can colonize," which is something climate alarmists are loath to admit is possible, for it deals a strong blow to their contention that current plant-animal associations cannot be changed without debilitating consequences, as suggested by Root in interviews reported in several of the media reports associated with the publication of Root *et al.* (2003). Similarly, in Revkin's article in the 2 January 2003 issue of the *New York Times*, Richard P. Alley of Pennsylvania State University is quoted as saying that to survive a forced migration of the type described by the CO_2-induced global warming extinction hypothesis, species will "have to change what [they] eat," as if that were not possible. Yet Chavez *et al.* (2003) report that "recent theoretical work supports the idea that complex food webs can undergo substantial changes in response to subtle physical forcing (Taylor *et al.*, 2002)." The results of this study clearly demonstrate that not only is such a change possible, it's already occurring!

Another reason why the many opportunistic responses noted by Thomas *et al.* have been so rapid is revealed in what the scientists learned from the two species of bush cricket they studied. The crickets showed "increased fractions of longer-winged (dispersive) individuals in recently founded populations," which is something else climate alarmists are loath to admit is possible [see, for example, the quote from Root and Schneider (1993) in the Introduction of this report], for it deals a strong blow to their contention that animal physical characteristics cannot change fast enough to enable them to migrate as rapidly as they claim will be needed to escape the killing heat of a rapidly warming world. Here, too, Revkin quotes Alley as saying species will have to "travel farther to eat," as if that were also not possible. Yet the results of this study clearly demonstrate that species not only *will* do it, they *are* doing it.

As a consequence of these totally unanticipated but real-world observations, the authors report that "increased habitat breadth and dispersal tendencies have resulted in about 3- to 15-fold increases in [range] expansion rates, allowing these insects to cross habitat disjunctions that would have represented major or complete barriers to dispersal before the expansions started."

It is amazing that Root *et al.* ever included this paper in their list of Tier 2 studies, as almost everything its authors discovered contradicts one or more of the negative tenets of the CO_2-induced global warming extinction hypothesis.

T2.5 — Southward *et al.* (1995)

The authors documented marked changes in plankton community structure with latitudinal shifts of up to 120 miles and increases or decreases of 2-3 orders of magnitude in abundance in the western English Channel in response to the increase, then decrease, then increase in mean global air temperature experienced since the early 1920s. Over this 70-year interval, they report that "warm water species increased in abundance and extended their range during periods of warming while cold-water species declined or retreated," while "the reverse occurred during the period of cooling."

Is there anything new or earth-shaking here? No. Cyclical warmings and coolings with their associated "restructuring of planktonic, pelagic and benthic communities" have been a normal part of nature since the dawn of life itself. More recently, for example, Chavez *et al.* (2003) documented a whole host of such cycles throughout the Pacific Ocean in response to basin-wide "regime shifts" with a periodicity of about fifty years. As ocean waters warm and cool, different marine communities not only relocate themselves, they often *restructure* themselves, as Southward *et al.* report; and they do it very successfully, protestations of climate alarmists to the contrary notwithstanding [see also the discussion of publication T2.4].

T2.6 — Meshinev *et al.* (2000)

The authors documented a post-1970 "impressive invasion" of the higher slopes of the Central Balkan Mountain of Bulgaria by *Pinus peuce* Griseb., as it advanced "from the established timberline at 1760 m up to 2100 m," which advance was correlated with a concomitant increase in minimum winter temperatures. Again, this observation provides no pertinent data for evaluating the CO_2-induced global warming extinction hypothesis, as it deals with but one species' opportunistic movement up a mountain.

T2.7 — Walther (2000)

Rather than describing a latitudinal or elevational shifting of species, the author of this paper describes the proliferation of more than a dozen non-indigenous evergreen broad-leaved shrubs and trees throughout deciduous lowland forests of southern Switzerland. The invading species were imported from relatively warmer places such as Africa, the Far East and Australia. For more than 200 years these ornamental woody plants were grown in Swiss gardens and parks. Within the latter half of the 20th century, however, many of them began to spring up in adjacent natural habitat, becoming especially competitive over the last thirty years. The author attributes this phenomenon to concurrent warming. It is clear, however, that were the alien species not introduced to the region by human transplantation in the first place, this particular type of opportunistic ecosystem reorganization would not be occurring, with or without the help of global or regional warming. Hence, this study, too, has essentially nothing to say about the CO_2-induced global warming extinction hypothesis.

T2.8 — Wardle and Coleman (1992)

The authors looked for evidence of a rise in the upper limits of four native New Zealand forest trees at several South Island locations in response to the warming of the past century or more, obtaining results that were "consistent with the proposition that altitudinal limits of native trees have risen in response to climatic warming during recent decades." Again, this finding is irrelevant to the CO_2-induced global warming extinction hypothesis, being concerned with the cold-limited boundaries of the trees' ranges, which advance opportunistically and not because they are threatened by heat.

T2.9 — Catling (1996)

The author notes that sometime between 1959 and 1996 the northern boundary of the range of the damselfly *Enallagma civile* (Hagen) moved northward in southern Ontario, Canada by at least 200 km, concluding that "the northward spread of *E. civile* is probably related to climatic warming." He may well be right. But whether he is or he isn't sheds no light whatsoever on the robustness of the CO_2-induced global warming extinction hypothesis, for reasons we have now repeated over and over and over.

T2.10 — Ford (1996)

The author notes that from its discovery in 1949 until 1990, the oyster parasite *Perkinsus marinus* was found along the Atlantic coast of the United States from the Gulf of Mexico to Chesapeake Bay. In 1990 and 1991, however, it suddenly appeared in locations from Delaware Bay, New Jersey to Cape Cod, Maine. Ford describes "several hypotheses for the sudden appearance of the parasite in the northeastern United States," concluding that the pathogen probably "was repeatedly introduced, by many means over many years, into various northeast locations where it remained undetected and was stimulated to proliferate into an epizootic by a recent extreme warming trend."

Be that as it may — and who knows, for Ford describes even this idea as but an hypothesis — we again are dealing with a northward extension of a northern range boundary in the Northern Hemisphere, which does not allow for a critical evaluation of the CO_2-induced global warming extinction hypothesis.

T2.11 — Frey (2002)

The author recounts the life and work of George Divoky, who at enormous personal sacrifice and with great attention to detail, studied a colony of Arctic seabirds (black guillemots) on a remote barrier island off the northern coast of Alaska every year since 1972 to the time of the writing of this report. In addition to documenting the birds' behavior throughout this 30-year period, Divoky reconstructed their movements over the past 120 years from analyses of the $\delta^{13}C$ content of the feathers of specimens that had been "shot, stuffed and housed in museum collections." So what did he find?

According to Frey's report, the $\delta^{13}C$ content of 19th-century bird feathers indicated the birds "had to fly as far south as the Bering Sea in winter to find ice cracks in order to fish," but that the $\delta^{13}C$ content of more recent feathers indicated "the birds had been able to winter some 500 miles to the north," indicating that "guillemots [had been] tracking more than a century of warming." Once again, therefore, this study only confirms the obvious. As the earth recovered from the global chill of the Little Ice Age, this Arctic seabird successfully shifted its range hundreds of miles northward in response to the opportunity to do so.

T2.12 — Frey (1992)

The author documents a *cooling* trend from the 1930s to the 1960s and thermal stability from that point in time to the 1980s in Kansas and Nebraska, USA, together with a trend towards greater precipitation from the 1950s to the 1980s. She then documents expansions of the ranges of a certain group of Boreal mammals into the region that became progressively cooler and wetter. This opportunistic response is just the reverse of those described in most of the other studies we have discussed. It documents range expansions where *cooling* has made it possible for species to live where it was previously too warm for them; and, hence, it has nothing to do with the CO_2-induced global *warming* extinction hypothesis.

T2.13 — Nehring (1998)

The author conducted a review of phytoplankton species that have appeared in the North Sea over the last few decades, finding that 16 non-indigenous species have become permanently established immigrants. Of these, he reports that “13 have colonized the German Bight, corresponding to an increase of about 1% in the number of phytoplankton species found in this area.” Nehring suggests the influx of species, at least ten of which are normally found in more southerly and warmer waters, may be due to regional warming; but he notes that natural variability of temperature in this region is of such a magnitude that “a warming trend cannot be ascertained.”

Once again, it is clear that these data have nothing to say about the CO_2-induced global warming extinction hypothesis. They merely describe another example of opportunistic range expansions in response to warming, but only, of course, if there really was a concurrent warming of the water body where the species introductions were detected, of which Nehring admits he is not confident.

VII. Discussion of the Results of Root *et al.*'s Tier 1 and Tier 2 Studies

Of the twenty-four Tier 1 (T1) and Tier 2 (T2) studies analyzed by Root *et al.*, five of them, according to our analyses, *directly refute* the CO_2-induced global warming extinction hypothesis. In response to regional warming, two of these studies (T1.4, T1.5) describe opportunistic poleward extensions of the cold-limited range boundaries of a number of species that were accompanied by no forced changes in their heat-limited range boundaries, leading to actual range *expansions*, which should make extinction even *less* likely for the studied species than it was before the warming. Two other studies (T1.7, T1.8) describe upslope extensions of the cold-limited range boundaries of lower-elevation species that did *not* result in any loss of higher-elevation species. Another study (T2.4) demonstrated that certain species, when faced with a warming-induced impetus to migrate, dramatically changed both their behavior and physical characteristics in ways that no one had previously believed possible, allowing them to "cross habitat disjunctions that would have represented major or complete barriers to dispersal before the expansions started."

Over half of the T1 and T2 studies analyzed by Root *et al.* were simply examples of the opportunistic poleward or upward extensions of species' cold-limited range boundaries in response to regional or global warming, a phenomenon that reveals *absolutely nothing* about the responses of their heat-limited range boundaries, knowledge of which is critical to an evaluation of the CO_2-induced global warming extinction hypothesis. Nine of these studies dealt with latitudinal range extensions (T1.2, T1.3, T1.10, T1.11, T2.1, T2.5, T2.9, T2.10, T2.11), three with elevational range extensions (T1.9, T2.6, T2.8), and one with some of each (T2.3). These studies demonstrate what should be almost prenatal knowledge: if the climate warms, species of both plants and animals will expand into areas where it was previously too cold for them to live, a phenomenon that suggests an ability to *avoid* extinction rather than succumb to it.

The remaining six T1 and T2 studies analyzed by Root *et al.* were hybrids of sorts, which really did not address the subject of species' range responses to global warming. The upslope migrations discussed in T1.1, for example, turned out to be due to environmental changes induced by local logging practices rather than regional warming. Likewise, the cold-limited boundary extension of T1.6 may also have been caused by something other than warming; and the results of T2.2 were so complex that the authors could not decide what caused the range expansions. Somewhat similarly, the authors of T2.13, although demonstrating a latitudinal shifting of species, were not able to conclude unequivocally that it was due to regional warming; while the latitudinal heat-limited boundary extensions discussed in T2.12 were due to cooling and increased precipitation. Finally, the range expansions described in T2.7 would not even have occurred if the exotic species involved had not been transported into the area of study from half-way around the world.

In light of these observations, it is clear that the scientific articles studied by Root *et al.* that are most applicable to the CO_2-induced global warming extinction hypothesis fail to provide a single piece of evidence in support of it. In fact, most of the knowledge gleaned from them does not even address the subject; while that which is pertinent actually *contradicts* the hypothesis.

VIII. Our Appraisal of the Parmesan and Yohe (2003) Study

The Parmesan and Yohe study is much like the study of Root *et al*. It begins with the same initial filtering of data — Parmesan and Yohe say their "analyses ignore species classified as *stable*" — once again stacking the deck for success, as they would define it. It then proceeds to look intently at two, as opposed to Root *et al*.'s four, types of data: those dealing with *phenological shifts* and those dealing with *range-boundary changes* or, as they alternatively describe the latter subject, *distribution/ abundance shifts*.

With respect to the latter category, which is the one of pertinence to the CO_2-induced global warming extinction hypothesis, Parmesan and Yohe (PY) say they conducted "a quantitative assessment covering >1,046 species." Although this description of their work makes it sound incredibly comprehensive, it refers to the contents of but 19 scientific papers. Six of these articles were included in Root *et al*.'s Tier 1 group of studies (T1.1, T1.4, T1.5, T1.7, T1.9, T1.11), while one was included in their Tier 2 group (T2.5). Hence, we will next analyze PY's additional twelve papers of potential pertinence in the same way we did those of Root *et al*., i.e., in the order in which they appear in PY's list of references.

IX. Parmesan and Yohe's Additional Studies

PY.1 — Smith *et al*. (1999)

The authors review what is known about marine ecosystem sensitivity to climate change on the Antarctic Peninsula, focusing on its penguin populations. Noting that "Adelie penguins are obligate inhabitants of pack ice, whereas their congeners, the chinstrap penguins, occur almost exclusively in ice-free waters," they describe pretty much the same historical shifts in these species' habitats (and, consequently, their populations) as do Emslie *et al*. (1998) in paper T2.1. Hence, with the Antarctic Peninsula currently warming but the rest of Antarctica cooling, the authors of this study find that "optimum sea ice conditions for Adelie penguins no longer exist in the west Antarctic Peninsula region and populations continue to decline, whereas in the Ross Sea region optimum sea ice and habitat conditions have not yet occurred and populations are increasing."

So what did the authors learn? Different penguin populations in Antarctica tend to follow the climatic conditions that suit them best, clearly *avoiding* extinction and alternately replacing one another as the climate either warms or cools. So it has ever been; so it shall ever be.

PY.2 — Grabherr *et al*. (1995)

The authors of this chapter in a book devoted to the study of arctic and alpine biodiversity present essentially the same data as are discussed by Grabherr *et al*. (1994) and Pauli *et al*. (1996) in papers T1.7 and T1.8. Although their report is filled with dire *predictions* of species extinctions, and they say that upslope migration rates of plant species "may not be adequate to keep pace with climate warming," so that "in high mountain areas an extensive reduction in biodiversity may occur," their own real-world data show just the *opposite* to be occurring. With respect to various mountains in the Alps of Europe, they report that "species richness has increased on most of the summits" and "most of the species have increased in abundance," which is exactly what we predict should be occurring in response to concurrent increases in atmospheric temperature and CO_2 concentration. Truly, life is *proliferating* and local biodiversity is on the *rise*, thanks to the ongoing increases in atmospheric CO_2 and temperature.

PY.3 — Sagarin *et al*. (1999)

The authors documented changes in the abundance of macroinvertebrate species in a rocky intertidal community at Hopkins Marine Station, Pacific Grove, California, USA, between surveys conducted in 1931-33 and 1993-96, over which time interval the average shoreline water temperature at the site warmed by 0.8°C. The scientists found that "most southern species (10 of 11) increased in abundance, whereas most northern species (5 of 7) decreased." Cosmopolitan species, on the other hand, "showed no clear trend, with 12 increasing and 16 decreasing."

Although these observations clearly suggest that regional warming was responsible for the observed species abundance changes at the site of the study, they obviously tell us nothing about the overall well-being of the species studied. Hence, they are *totally irrelevant* to the CO_2-induced global warming extinction hypothesis.

PY.4 — Beaugrand *et al*. (2002)

The authors "provide evidence of large-scale changes in the biogeography of calanoid copepod crustaceans in the eastern North Atlantic Ocean and European shelf seas" over the period 1960-1999. In particular, they note that east of 20°W, they "found a significant poleward movement of warm species associated with a clear decrease in the number of subarctic and arctic species in the north." West of the mid-Atlantic ridge, however, especially in the Labrador Sea, they report "the trend is opposite and the number of arctic species has clearly increased," confirming a "shift of marine ecosystems toward a colder dynamic equilibrium in the Subarctic Gyre." The authors then note that the various range shifts they identified appeared to be correlated with concomitant changes in temperature. Again, however, their data tell us little about the overall health of the species studied or the total sizes of their populations. That both warm-adapted and cold-adapted species tend to track temperature changes is all that was learned, which most anyone could probably have told them in advance.

PY.5 — Hersteinsson and Macdonald (1992)

The authors describe the geographical distributions of red and arctic foxes in the tundras of North America and Eurasia, noting that during the early 20th century "red foxes expanded the northern limits of their distribution into higher latitudes and altitudes," driven primarily, in the authors' opinion, by the positive consequences of the warming of that period for red fox *prey availability*. The subsequent competition the invading red foxes provided for arctic foxes then resulted in a northward shift of the latter species' southern range boundary, which was obliged to recede no further, however, than the northward extension of the red foxes' northern boundary. Hence, as with the previous study (PY.4), this study, too, provides evidence for climate-induced range shifts but no indication that these shifts were in any way detrimental to the overall vitality of any of the species involved.

PY.6 — Holbrook *et al*. (1997)

The authors studied changes in assemblages of nearshore reef fishes in the Southern California Bight over the period 1974-93. Near the beginning of this period, during 1976-77, the mean surface temperature of the region rose by nearly 1°C above the mean of the previous 15 years, coincident with a change in the basic state of the atmosphere-ocean climate system of the North Pacific Ocean. Thereafter "dominance shifted from cold-affinity species to those with affinity for warmer water" as "abundances of Northern species declined and those of Southern species increased."

This finding is much like the findings of many of the studies we have already considered. Species tend to "go with the flow" of changing climatic conditions (especially marine species), shifting their ranges and often creating new biotic associations with other species. In all instances, however, there are no indications of anything that would support the CO_2-induced global warming extinction hypothesis, in that the range shifts do not lead to the demise of any of the species involved nor, in most cases, even to decreases in the sizes of their populations.

PY.7 — Sturm *et al*. (2001)

In July of 1999 and 2000, the authors re-photographed 66 sites located between the Brooks Range and the Arctic coast of Alaska that had been photographed between 1948 and 1950. At over half of these locations they found "distinctive and, in some cases, dramatic increases in the height and diameter of individual shrubs, in-filling areas that had only a scattering of shrubs in 1948-50, and expansion of shrubs into previously shrub-free areas."

The scientists attributed this northward shifting of shrubs to the significant simultaneous warming of the region. It is also possible that the northward march of the woody plants may have been aided by the concomitant increase in the air's CO_2 content, as described by Idso (1995), who assembled a wealth of literature citations describing the invasion of grasslands by woody plants on all continents of the globe (except Antarctica, of course) and explained why such a phenomenon should be expected in response to increasing atmospheric CO_2 concentrations. In any event, whether driven by increases in the air's CO_2 content, its temperature or *both* phenomena, it is clear that the woody-plant range expansions described in this study are *opportunistic* responses to environmental change that in no way imply the impending demise of the migrating species that is predicted by the CO_2-induced global warming extinction hypothesis.

PY.8 — Smith (1994)

The authors report that data obtained by several researchers over a period of 27 years – during which time the Antarctic Peninsula experienced rapid and significant warming – have revealed "a significant and relatively rapid increase in numbers of individuals and populations at two widely separated localities in the maritime Antarctic" of "the only two native Antarctic vascular plant species (*Colobanthus quitensis* and *Deschampsia antarctica*)." This observation provides yet another example of *opportunistic* plant response to regional warming, which in this case would appear to be the *absolute antithesis* of impending extinction.

PY.9 — Parmesan (1996)

Citing a number of scientific sources, the author says that in response to global warming, "species' ranges should move both polewards in latitude and upwards in elevation." Testing this hypothesis as it pertains to Edith's checkerspot butterfly (*Euphydryas editha*), Parmesan says she "censused 115 sites with historical records to classify their current status as extinct or intact, and for 36 additional sites determined current status."

With respect to potential latitudinal range shifting, she found "a striking latitudinal cline in net extinction rates," with previously-viable *local* populations in much-warmer Mexico four times more likely to be currently *locally* extinct than those in much-cooler Canada, which is what would be expected in a warming world. However, it is important to note that *local extinctions occurred across the entire latitudinal range investigated*, which stretched from hundreds of kilometers into Mexico to hundreds of kilometers into Canada.

Even more important was the fact that *living* populations of the butterfly were found scattered across the same vast distance, indicating that they can — and do! — survive and reproduce across a *very* wide range of thermal conditions. Hence, even if Parmesan's conclusion was correct — which is highly debatable, based on these latter observations — it would suggest that the heat-limited southern boundary of the butterfly's range would never be able to move fast enough or far enough to overtake its cold-limited northern boundary in a warming world, which is what would be required for the total extinction of the species that is predicted by the CO_2-induced global warming extinction hypothesis.

But what about potential *elevational* range shifting, where much smaller distances separate a species' cold- and heat-limited range boundaries? Here, Parmesan was forced to report that "although a predicted result of climate warming is an increased extinction rate at the very lowest elevations, *no such trend appears in the data* [our italics]." Hence, her claim that her field work and analysis represents "the first study to provide evidence of the predicted range shifts" is vastly overstated. Indeed, it *fails outright* in one of its two tests (the elevational response) and is *far* from convincing in the other one (the latitudinal response).

PY.10 — Payette *et al*. (1989)

The authors investigated vegetation response to long-term climate change in northern Canada, based on tree-ring and growth-form analysis of spruce subfossils. Their data suggest, in their words, that "vegetation responses to global warming are not as straightforward as one may expect." Specifically, they note that "although recent climatic data indicate sustained global warming during this century, no conclusive evidence of a positive vegetation response to such warming has yet been identified at these exposed tree-line sites." How Parmesan and Yohe could thus have cited this study as evidence for their claim that the temperature increase of the past century "is already affecting living systems" is difficult to understand.

PY.11 — Ross *et al*. (1994)

The authors began their study by noting that Alexander (1976) interpreted the presence of dead pine tree trunks in mangrove swamps of the Lower Florida Keys as evidence of 20th century sea-level rise, which was presumed to have killed the pine trees. They then extended and updated Alexander's work by examining aerial photos and field evidence "to learn how the 15-cm rise in local sea level over the last 70 years had affected the distribution of pines." Their ultimate conclusion was that "the salinization of ground- and soil-water that occurs as sea level rises is a major factor in the reduction of [local] pine forests."

But what about *warming*, the *direct* effects of which are supposed to be responsible for the "distribution/abundance shifts" Parmesan and Yohe claim are evident in living systems? In the words of Ross *et al.*, "over the periods of record (temperature: 1850-1986; precipitation: 1886-1986) *there was no directional trend in either of the climatic parameters* [our italics]."

In terms of sea level rise, of course, it is not regional but *global* warming that is of pertinence; and the globe has indeed been warming, in the mean, since the middle of the 19th century (Esper *et al.*, 2002). But migrating to escape rising sea levels is *not* the mechanism upon which the CO_2-induced global warming extinction hypothesis is based. Hence, this study, too, is essentially irrelevant to any attempt to validate that concept.

PY.12 — Johnson (1994)

The author, "using as a baseline the distributional literature of the late 1950s-early 1960s," says he "compiled records for 24 species of birds from *Audubon Field Notes*, *American Birds*, and other sources which document massive pioneering and large-scale expansion of nesting distributions over the last three decades in the contiguous western United States." Specifically, he reports finding "four northern species have extended their ranges southward, three eastern species have expanded westward, 14 southwestern or Mexican species have moved northward, one Great Basin-Colorado Plateau species has expanded radially, and two Great Basin-Rocky Mountain subspecies have expanded westward."

What is responsible for these *all-directional* range expansions? Johnson concludes that "although climatic warming is probably involved, especially for those southwestern species that are invading northward, it is probably *neither the sole explanation nor even the primary cause* [our italics] for range adjustments among the expanding species as a group." As an alternative cause, he suggests that "many of these species are responding primarily to a decades-long increase of *summer rainfall* [our italics] in regions beyond their former ranges." Again, one wonders how Parmesan and Yohe could possibly have cited these findings as evidence for their claim that the global *warming* of the past century "is already affecting living systems."

X. Discussion of the Results of Parmesan and Yohe's Additional Studies

Of the twelve studies analyzed by Parmesan and Yohe, above and beyond those analyzed by Root *et al.*, two appear to *directly refute* the CO_2-induced global warming extinction hypothesis (PY.2, PY.9). The first of these studies describes opportunistic upslope migrations of plants that do not displace higher-elevation species and therefore end up *increasing* mountain species richness. The second study describes both latitudinal and elevational distributions of a butterfly species that is *not* precluded from living across a range of temperatures comparable to those found hundreds of kilometers south of the United States' border with Mexico to those found hundreds of kilometers north of the United States' border with Canada.

Three studies describe opportunistic extensions of cold-limited range boundaries in response to regional warming (PY.5, PY.7, PY.8). The first deals with foxes in North America and Eurasia, the second with shrubs in Alaska, and the third with vascular plants in Antarctica. All of the range extensions appear to have benefited the species in question and none appears to have threatened any other species with extinction, although one species of fox forced another species of fox to move further north as it encroached upon its territory. As earth's climate alternately warms and cools in natural cycles, however, this shifting of the foxes' competition-determined boundary is but a part of the natural scheme of things; and as it has been *considerably* warmer over much of the current interglacial than it is now — by 2 to 6°C, in fact (Taira, 1975; Porter and Orombelli, 1985; Huntley and Prentice, 1988; Korotky *et al.*, 1988) — the simple *existence* of both species today is *living proof* that even the most cold-adapted of them can "take the heat" of a major climate warming.

Four studies document *shifts* of species' ranges in response to changes in climate (PY.1, PY.3, PY.4, PY.6). The first deals with populations of Adelie and chinstrap penguins in Antarctica that follow the climatic conditions to which they are each best suited, alternately replacing one another in different locations as the climate either warms or cools. The second deals with macroinvertebrates in a rocky intertidal community just off the California coast, where warming between 1931-33 and 1993-96 led to the replacement of many "northern" species by "southern" species. The third deals with certain crustaceans in the eastern North Atlantic Ocean and European shelf seas, some of which shifted north in parts of the region that warmed between 1960 and 1999 and some of which shifted south in parts of the region that cooled over the same time period. The fourth deals with near-shore reef fishes in the Southern California Bight, where dominance shifted from cold-affinity species to warm-affinity species after a 1°C increase in temperature centered on 1976-77. In all four cases, there were no indications that any species suffered as a result of the temperature-induced range shifts; they merely appeared to move from one location to another.

The final three studies reviewed by Parmesan and Yohe are a mixed bag of oddities. Although the globe is known to have warmed substantially over the past century, a study of exposed tree-line sites in Canada (PY.10) could find "no conclusive evidence of a positive vegetation response." In another study (PY.11), it was determined that pine trees on islands of the Lower Florida Keys died as a result of "the salinization of ground- and soil-water that occurs as sea level rises." With respect to the CO_2-induced global warming extinction hypothesis, therefore, which says rising *temperatures* will force species to migrate faster than they are capable of doing, these investigations have little relevance. Finally, the study of Johnson (PY.12) describes species of birds extending their ranges in *every direction imaginable* in the western United States and concludes that climatic warming is *not* the primary cause of the range expansions, making one wonder how this and many of the other studies cited by Parmesan and Yohe could possibly be used to support irrational fears of impending species extinctions driven by CO_2-induced global warming.

XI. Discussion of Real-World Observations

Are significant impacts of global warming "already discernable in animal and plant populations," as Root *et al*. claim? Is climate change "already affecting living systems," as Parmesan and Yohe contend? The answer to both of these questions in *many* but not *all* of the cases they cite is a definite *yes*. Much of the biosphere has indeed responded to the global warming of the past century and a half that has transformed what we have come to call the Little Ice Age into what can now be called the Modern Warm Period. But it has *not* — we repeat *not* — brought us to the verge of biospheric disintegration, as the world's climate alarmists would have everyone believe. In fact, it has done just the *opposite*, aided in no small part by the concomitant rise in the air's CO_2 content.

To substantiate this fact, ironically, we need look no further than to the very papers that are used by Root *et al*. and Parmesan and Yohe to suggest, as Root has claimed, that "we're sitting at the edge of a mass extinction." And when we do, we find that the studies they cite do not imply anything of the kind.

It is true that some species of plants and animals have indeed moved poleward and upward in response to 19th and 20th century warming; but they have not been *forced* to do so. The poleward and upward extensions of the cold-limited boundaries of these species' ranges have been *opportunistic* movements, movements that have enabled them to inhabit regions that previously were too cold for them. But where it has been predicted that species would either be *compelled* to move towards cooler regions *or suffer death*, i.e., at the *heat*-limited boundaries of their ranges, they have in many instances, if not *most* instances, succumbed to neither alternative. As a result, instead of suffering range *contractions*, indicative of *advancement* towards extinction, these species have experienced range *expansions*, indicative of a propensity to *avoid* extinction.

We note also, with respect to latitudinal movements, that it is not necessary for the heat-limited boundary of a species' range to remain *totally stationary* for the CO_2-induced global warming extinction hypothesis to be found null and void. If the heat-limited boundary merely moves *slower* than the cold-limited boundary in response to an increase in temperature, a range expansion will occur that makes extinction even less likely than it was before the warming occurred. What is more, the viability of species in a warming world can be maintained by relaxing even this condition; for if a species' heat-limited boundary moves at the *same speed* as its cold-limited boundary, its range size will remain fairly constant (depending upon local geographical constraints, of course), which also precludes the possibility of extinction. In fact, if the cold-limited and heat-limited boundaries of a species' range are widely separated, as in the case of the butterfly studied by Parmesan (1996), even if the heat-limited boundary were to move *faster* than the cold-limited boundary, the large temperature difference between the two boundaries would prevent the heat-limited boundary from ever merging with the cold-limited boundary for the degree of warming that would be likely to occur in the real world. Hence, there is currently not the slightest shred of evidence that what is "already discernable in animal and plant populations," in the words of Root *et al.*, and "already affecting living systems," in the words of Parmesan and Yohe, portends the eminent or even far-distant extinction of a single species of plant or animal.

XII. Conclusions

The CO_2-induced global warming extinction hypothesis claims that as the world warms in response to the ongoing rise in the air's CO_2 content, many species of plants and animals will not be able to migrate either poleward in latitude or upward in elevation fast enough to avoid extinction as they try to escape the stress imposed by the rising temperature. With respect to plants, however, we have shown that as long as the atmosphere's CO_2 concentration rises in tandem with its temperature, most of them will not "feel the heat," as their physiology will change in ways that make them better adapted to warmer conditions. Hence, although earth's plants will likely spread poleward and upward at the cold-limited boundaries of their ranges in response to a warming-induced opportunity to do so, their heat-limited boundaries will probably remain pretty much as they are now or shift only slightly. Consequently, in a world of rising atmospheric CO_2 concentration, the ranges of most of earth's plants will likely *expand* if the planet continues to warm, making plant extinctions even *less* likely than they are currently.

Animals should react much the same way. In response to concurrent increases in atmospheric temperature and CO_2 concentration, they will likely migrate poleward and upward, where cold temperatures prevented them from going in the past, as they follow earth's plants. Also as with earth's plants, the heat-limited boundaries of their ranges should in many cases be little affected, as has been observed in several of the real-world studies that have been wrongly cited as providing evidence for impending species extinctions, *or* their entire ranges may simply shift with the rising temperature, as has been observed in many real-world studies of marine ecosystems.

To summarize, both theory and observation paint the same picture. A goodly portion of earth's plants and animals should actually *expand* their ranges and gain a *stronger* foothold on the planet as the atmosphere's temperature and CO_2 concentration continue to rise. If the air's CO_2 content were suddenly to *stop* increasing, however, the biosphere could find itself facing a significant challenge, as the world's plants would cease acquiring the extra physiological protection against heat stress that is afforded them by rising atmospheric CO_2 concentrations. Consequently, the end result of curtailing anthropogenic CO_2 emissions might well be just the *opposite* of what many people are hoping to accomplish by encouraging that policy, i.e., many species might actually be *driven* to extinction, rather than being *saved* from such a fate.

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