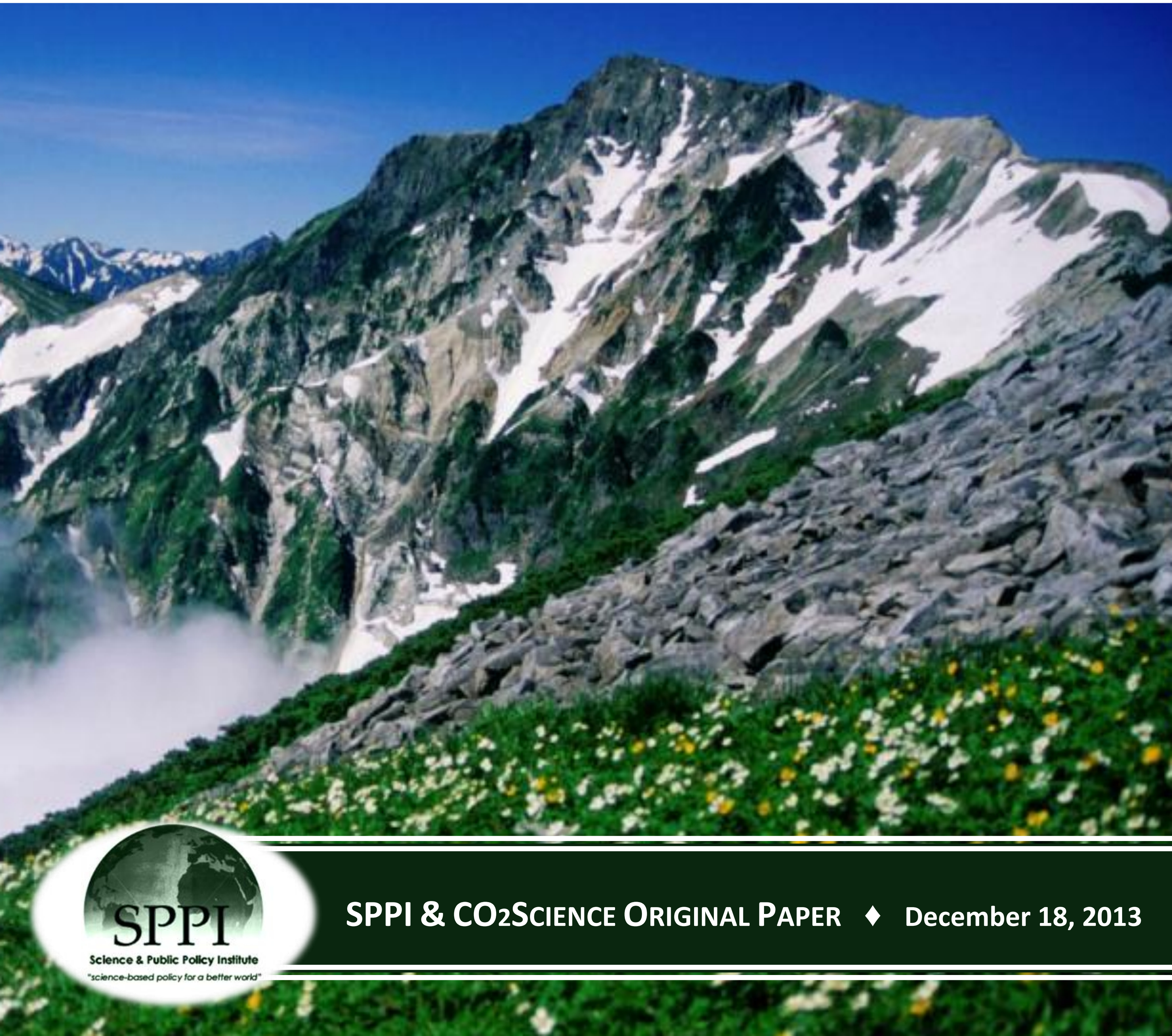
# Can Migrating Plants Move Fast Enough to Avoid Projected Extinctions from Global Warming?



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# CAN MIGRATING PLANTS MOVE FAST ENOUGH TO AVOID PROJECTED EXTINCTIONS FROM GLOBAL WARMING?

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One of the great horror stories associated with predictions of $CO_2$-induced global warming is that the warming will be so fast and furious that many species of plants will not be able to migrate towards cooler regions - poleward in latitude, or upward in elevation - at rates that are rapid enough to avoid extinction. This claim may sound logical enough ... but is it true?

In a study that goes a long way towards providing a powerful negative answer to this important question, Cowling and Sykes (1999)[1] conducted a review of the literature relative to the interactive effects of concurrent increases in atmospheric $CO_2$ and air temperature on plant growth and development. While doing so, they concluded from what they learned that "increases in $CO_2$ from 350 to 650 ppm are estimated to result in an up to 5°C rise in Topt [plant optimal growth temperature] primarily because of a reduction in rate of photorespiration at high temperatures." And they also observed that "experiments with *Phaseolus vulgaris* exposed to low $CO_2$ indicate that Topt can decrease by approximately 4°-5°C with a reduction in $CO_2$ from 380 to 200 ppm," citing the work of Cowling and Sage (1998).

In light of this knowledge, it naturally follows that if the Earth did warm by a significant amount, for *whatever* reason, the best thing that could possibly happen to the planet would be for the air's $CO_2$ concentration to rise concurrently, or shortly thereafter; because there would then be either little need for the vegetation of the planet to migrate to cooler regions, or the required rate of migration and/or distance of travel would be much reduced from what overly-simplistic coupled climate-biology models have suggested. As the air

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[1] http://www.co2science.org/articles/V3/N16/B1.php.

temperature rose higher and higher, for example, so also would the temperature at which most plants function at their optimum rise higher and higher; and they would thus maintain the capability to grow and successfully reproduce in close proximity to where they grew when the air temperature first began to rise.

Interestingly, this is *exactly* how nature appears to operate during and after a glacial-to-interglacial transition. In response to the air temperature increase experienced in going from a glacial to an interglacial period, Earth's atmospheric $CO_2$ concentration has typically risen by an amount sufficient to enable Earth's plants to successfully cope with the warming of the globe; for the work of Cowling and Sage (1998) indicates that a typical 180-ppm rise in atmospheric $CO_2$ concentration from a base level characteristic of glacial conditions can raise plant optimum growth temperature by about 4°-5°C, which is the degree of temperature increase that is typically experienced during most glacial terminations. Indeed, with respect to the global warming that occurred at the end of the Younger Dryas (~13,000 to 11,500 years ago), Vegas-Vilarrubia *et al*. (2011)[2] have noted that it is one of the more powerful analogues of projected future global warming "because both magnitude and rates of change parallel those predicted for the present century." And although this prior real-world transformation "seems to have consisted of ecological reorganizations and changes in community composition because of differential species migration patterns and rates," the four researchers correctly pointed out that "so far, it has not been possible to associate large-scale extinctions to the Younger Dryas climatic reversal." Thus, rather than a model-inspired increase in atmospheric $CO_2$ triggering catastrophic changes in climate, real-world data from the past suggest that rising atmospheric $CO_2$ will help plants *avoid* climatic-induced extinctions.

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Additional support for this thesis comes from the study of Cannariato *et al*. (1999)[3], who investigated the character, magnitude and speed of biotic responses of benthic foraminifera to millennial-scale climate oscillations reconstructed from data obtained from a northeast Pacific Ocean sediment core that extended back in time some 60,000 years. This history revealed a number of rapid climatic switches throughout the course of the record, representing periods of what they called "extreme environmental variability." However, they reported that no extinctions were observed, and that the benthic ecosystems "appear to be both resilient and robust in response to rapid and often extreme [changes in] environmental conditions." In addition, they reported that faunal turnovers occurred within *decades* throughout the record "without extinction or speciation," which led them to conclude that "broad segments of the biosphere are well adapted to rapid climate change."

[2] http://www.co2science.org/articles/V15/N9/EDIT.php.
[3] http://www.co2science.org/articles/V2/N6/C4.php.

Examining an even longer period of time was Allen *et al*. (1999)[4], who analyzed sediment cores from a lake in southern Italy and from the Mediterranean Sea and developed high-resolution climate and vegetation datasets for this region covering the last 102,000 years. Their efforts similarly revealed that rapid changes in vegetation correlated well with rapid changes in climate, such that *complete shifts* in natural ecosystems would sometimes occur over periods of less than 200 years. They also found that over the warmest portion of the record (the Holocene), the total organic carbon content of the vegetation reached its highest level, more than doubling values experienced over the rest of the record, and that during the more productive woody-plant period of the Holocene, the increased vegetative cover also led to less soil erosion. Thus, they too discovered that the biosphere can - *and does* - respond to rapid changes in climate. Indeed, the fifteen researchers stated that "the biosphere was a full participant in these rapid fluctuations, contrary to widely held views that vegetation is unable to change with such rapidity." In fact, they learned that *warmer* was always *better* in terms of vegetative productivity.

Other studies from around the globe have continued to demonstrate the *un*likelihood of warming-induced plant extinctions based on more modern data. In July/August of 2003, for example, Walther *et al*. (2005)[5] resurveyed the floristic composition of the uppermost ten meters of ten mountain summits in the Swiss Alps, applying the same methodology used in earlier surveys of the same mountain tops by Rubel (1912), which was conducted in 1905, and Hofer (1992), which was conducted in 1985, so that their analyses covered the bulk of the Little Ice Age-to-Current Warm Period transition (1905-2003), which warming is claimed by climate alarmists to have been *unprecedented over the past millennium or more* in terms of both the *rate* of temperature rise and the *level* to which Earth's temperature rose.

**In spite of the apparent reasonableness of the global warming extinction hypothesis, Walther et al. could find *no sign* of this dire predicted consequence over an *entire century* of supposedly *unprecedented* warming in the Swiss Alps.**

These studies revealed that whereas the mean increase in species numbers recorded by Hofer (1992) for the time interval 1905 to 1985 was 86%, "species numbers recorded in 2003 were generally more than double (138%) compared to the results by Rubel (1912) and 26% higher than those reported by Hofer (1992)." Put another way, Walther *et al*. stated that "the rate of change in species richness (3.7 species per decade) was significantly greater in the later period compared to the Hofer resurvey (1.3 species per decade)." In addition, they said "the observed increase in species numbers does not entail the replacement of high alpine specialists by species from lower altitudes, but rather has led to an enrichment of the overall summit plant diversity." Consequently, and in spite of the

4 http://www.co2science.org/articles/V2/N18/C2.php.
5 http://www.co2science.org/articles/V9/N48/B1.php.

apparent reasonableness of the global warming extinction hypothesis, whereby high-altitude species are expected to be "squeezed out of existence" - or "pushed off the planet," as NASA's James Hansen once described it - by other species migrating upwards from lower altitudes to escape the increasing stress of rising temperatures, Walther *et al*. could find *no sign* of this dire predicted consequence over an *entire century* of supposedly *unprecedented warming* in the Swiss Alps.

Also working in a high mountain region was Kullman (2007)[6], who analyzed the changing behavior of alpine and subalpine plants, together with shifts in their geographical patterns over the past century (when air temperatures rose by about 1°C in the Scandes of west-central Sweden), based on "repeat photography, individual age determinations and analyses of permanent plots." This work revealed that "at all levels, from trees to tiny herbs, and from high to low altitudes," as he described it, "the results converge to indicate a causal association between temperature rise and biotic evolution," indicating that "this appears to be an ecosystem on the brink of profound and imminent transformation."

More specifically, Kullman reported that treeline advance since the early 20th century varied between 75 and 130 meters, depending on species and site, and that subalpine and alpine plant species had shifted upslope by an average of 200 meters. In addition, he reported that "present-day repetitions of floristic inventories on two alpine mountain summits reveal increases in plant species richness of 58 and 67%, respectively, since the early 1950s," and, most importantly, that "no species have yet become extinct from the highest elevations." Last of all, he indicated that his results "converge with observations in other high-mountain regions worldwide," citing the studies of Grabherr *et al*. (1994), Keller *et al*. (2000), Kullman (2002), Virtanen *et al*. (2003), Klanderud and Birks (2003), Walther *et al*. (2005) and Lacoul and Freedman (2006).

***Results demonstrated the tremendous capacity for Earth's vegetation to rapidly respond to climate change in dramatic ways that need not result in species extinctions, but that can lead to huge increases in ecosystem species richness, which is typically considered to be a desirable property of vegetative assemblages.***

In concluding, therefore, Kullman wrote that the rapidity with which the observed ecosystem transformations had occurred "contrasts with earlier assumptions and theoretical generalizations, stressing significant time-lags or inertial adaptations to changed climatic conditions." Indeed, his results demonstrated the tremendous capacity for Earth's vegetation to rapidly respond to climate change in dramatic ways that need *not* result in

6 http://www.co2science.org/articles/V10/N27/B1.php.

species extinctions, but that can lead to *huge increases* in ecosystem species *richness*, which is typically considered to be a desirable property of vegetative assemblages.

Three years later, Kullman reaffirmed his findings in additional works (Kullman, 2010a, 2010b, 2010c). In one of them (Kullman, 2010b[7]), he described how the post-Little Ice Age warming had, at long last, broken the back of "a multi-millennial trend of plant cover retrogression" and "floristic and faunal impoverishment, all imposed by progressive and deterministic neoglacial climate cooling." And as a result, he said that "alpine plant life is proliferating, biodiversity is on the rise and the mountain world appears more productive and inviting than ever."

Similar observations led Kullman to conclude - in yet another paper (Kullman, 2010c[8]) - that "the alpine flora appears to be more adaptive and responsive to climate change than generally believed," and that "overall, a richer, greener and more productive alpine world has emerged in the wake of the recent climate warming episode (Kullman, 2010a, 2010b)." And he made it very clear that "in contrast to model predictions, no single alpine plant species has become extinct, neither in Scandinavia nor in any other part of the world in response to climate warming over the past century" (Kullman, 2010b), *citing*, in addition to his own prior studies, the work of Pauli *et al*. (2001, 2007), Theurillat and Guisan (2001), and Birks (2008). As for the future, Kullman opined that "continued modest warming over the present century will likely be beneficial to alpine biodiversity, geological stability, resilience, sustainable reindeer husbandry and aesthetic landscape qualities" (Kullman, 2010b).

Another research team working in Switzerland was that of Holzinger *et al*. (2008)[9], who revisited areas of twelve mountains having summits located between elevations of 2844 and 3006 meters in the canton of Grisons. In 2004 they made complete inventories of all vascular plant species they encountered, which they compared with similar inventories made by other researchers in 1885, 1898, 1912, 1913 and 1958, following the ascension paths of the earlier investigators "as accurately as possible." As for *climate*, the four researchers reported that mean summer temperatures in the studied region increased by at least 0.6°C between the time of the first study and the one they conducted in in 2004.

The plant upward migration rates detected by Holzinger *et al*. (2008) were on the order of several meters per decade; and their data suggested that vascular plant species richness increased by 11% per decade over the last 120 years on the mountain *summits* (defined as the upper 15 meters of the mountains) in the alpine-nival ecotone. This finding, in their words, "agrees well with other investigations from the Alps, where similar changes have been detected (Grabherr *et al*., 1994; Pauli *et al*., 2001; Camenisch, 2002; Walther, 2003; Walther *et al*., 2005)." And with respect to the ominous prediction of "the extinction of a considerable number of high-alpine species" within "the context of climate warming," they thus concluded that this "outstanding threat for species to become out-competed 'beyond the summits' can neither be confirmed nor rejected with our data," suggesting that the threat may not be quite as "outstanding" as what climate alarmists have typically made it out to be.

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[7] http://www.co2science.org/articles/V14/N10/B2.php.

[8] http://www.co2science.org/articles/V14/N11/EDIT.php.

[9] http://www.co2science.org/articles/V11/N39/B1.php.

In one final alpine region study, Erschbamer *et al*. (2009)[10] documented and analyzed changes (from 2001 to 2006) in plant species number, frequency and composition along an altitudinal gradient crossing four summits from the treeline ecotone to the subnival zone in the South Alps (Dolomites, Italy), where minimum temperatures increased by 1.1-2.0°C during the past century with a marked rise over the last decades. And what did they find?

In the words of the four researchers, "after five years, a re-visitation of the summit areas revealed a considerable increase of species richness at the upper alpine and subnival zone (10% and 9%, respectively) and relatively modest increases at the lower alpine zone and the treeline ecotone (3% and 1%, respectively)." In addition, with respect to threats of extinction, they reported that "during the last five years, the endemic species of the research area were hardly affected," while "at the highest summit, one endemic species was even among the newcomers." And given such findings, the Austrian scientists concluded that "at least in short to medium time scales, the southern alpine endemics of the study area should not be seriously endangered."

Moving down somewhat in elevation and climate from that experienced in alpine regions, Kelly and Goulden (2008)[11] compared two vegetation surveys (one made in 1977 and the other in 2006-2007) of the Deep Canyon Transect in Southern California's (USA) Santa Rosa Mountains that spans several plant communities and climates, rising from an elevation of 244 meters to 2560 meters over a distance of 16 km, while "climbing through desert scrub, pinyon-juniper woodland, chaparral shrubland, and conifer forest." In doing so, they found that "the average elevation of the dominant plant species rose by ~65 meters," when the 30-year mean temperature measured at seven stations around Deep Canyon rose by 0.41°C between 1947-1976 and 1977-2006, and when the same metric rose by 0.63°C in the climate regions straddled by the transect, and by 0.77°C at the two weather stations nearest Deep Canyon. As a result of these findings, therefore, they concluded that "surprisingly rapid shifts in the distribution of plants can be expected with climate change."

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Concentrating their efforts on the Svalbard Archipelago - the islands of which were almost entirely glaciated during the last glacial maximum of 20,000 years ago (which phenomenon excluded the contemporaneous survival of "most, if not all, species") - Alsos *et al*. (2007)[12] analyzed DNA fingerprinting (amplified fragment-length polymorphism) of 4439 samples from most of the geographic ranges of nine plant species native to the Arctic, after which they used the genetic data thereby obtained to reconstruct past plant colonization patterns. More specifically, they "determined the frequency of effective long-distance dispersal events,

[10] http://www.co2science.org/articles/V12/N39/B3.php.
[11] http://www.co2science.org/articles/V11/N41/B1.php.
[12] http://www.co2science.org/articles/V10/N38/B1.php.

identified the source areas, and assessed whether dispersal ability is more limiting than establishment in a new area."

This work revealed, in the words of the nine researchers, that long-distance colonization of the Svalbard Archipelago "has occurred repeatedly and from several source regions," with probable propagule dispersal vectors being "wind, drift wood and drifting sea ice, birds, and mammals." In addition, they found that "the genetic effect of restricted colonization was strongly correlated with the temperature requirements of the species, indicating that establishment limits distribution more than dispersal."

Given the likelihood that dispersal mechanisms in existence during the early and mid-Holocene (i.e., from 9500 to 4000 years Before Present, when Alsos *et al*. report "the climate was 1 to 2°C warmer than today") are probably "still operating," as they described it, they went on to conclude that "Arctic species seem to be able to track their potential niche and that unlimited dispersal models may be appropriate to estimate long-term range shifts for Arctic regions." In other words, getting viable plant propagules to Arctic lands made newly-suitable for plant growth by global warming - no matter how rapid that warming might have been - appears not to have been a problem, which means that as soon as new Arctic lands are capable of supporting the growth and reproduction of various plants, *they will do so*.

Also working on an island, Le Roux and McGeoch (2008)[13] examined patterns of altitudinal range changes in the totality of the native vascular flora of sub-Antarctic Marion Island (46°54'S, 37°45'E) in the southern Indian Ocean, which warmed by 1.2°C between 1965 and 2003. The work of these South African researchers revealed that between 1966 and 2006, there was "a rapid expansion in altitudinal range," with species expanding their upper elevational boundaries by an average of 70 meters. And *because*, as they described it, "the observed upslope expansion was not matched by a similar change in lower range boundaries," they emphasized the fact that "the flora of Marion Island has undergone range expansion rather than a range shift." In addition, they appropriately noted that "the expansion of species distributions along their cooler boundaries in response to rising temperatures appears to be a consistent biological consequence of recent climate warming," citing references to several other studies that have observed the same type of response.

Another consequence of the *stability of **lower** range boundaries* together with *expanding **upper** range boundaries* is that there is a *greater **overlapping** of ranges*, resulting in greater local *biodiversity* everywhere up and down various altitudinal transects of the island. And as a further consequence of *this* fact, Le Roux and McGeoch reported that "the present species composition of communities at higher altitudes is not an analogue of past community composition at lower altitudes, but rather constitutes a historically unique combination of species," or what could be termed a "brave new world" that is significantly *richer* - ecologically speaking - than that of the old one.

As for why plants in the real world would tend to behave in the manner demonstrated above, i.e., undergo a *proliferation*, as opposed to *extinction* of species, as both atmospheric

[13] http://www.co2science.org/articles/V12/N12/EDIT.php.

temperature and $CO_2$ concentration rise, some insight can be gleaned from the work of Stocklin *et al*. (2009)[14]. Working in the Swiss Alps, this group of researchers studied the consequences of the highly structured alpine landscape for evolutionary processes in four different plants (*Epilobium fleischeri*, *Geum reptans*, *Campanula thyrsoides* and *Poa alpina*), testing for whether genetic diversity *within* their populations was related to altitude and land use, while simultaneously seeking to determine whether genetic differentiation *among* populations was more related to different land use or to geographic distances.

According to the three Swiss scientists, the results indicated that *within*-population genetic diversity of the four species was high and mostly not related to altitude or population size. They also found that genetic differentiation *among* populations was pronounced and strongly increasing with distance, implying "considerable genetic drift among populations of alpine plants." Based on these findings, as well as the observations of others, Stocklin *et al*. concluded that "phenotypic plasticity is particularly pronounced in alpine plants," and that "because of the high heterogeneity of the alpine landscape, the pronounced capacity of a single genotype to exhibit variable phenotypes is a clear advantage for the persistence and survival of alpine plants." Hence, they stated that "the evolutionary potential to respond to global change is mostly intact in alpine plants, even at high altitude." And these results make it much easier to understand *why* - even in the face of significant 20th-century global warming - there have been no species of plants that have been observed to have been *pushed off the planet*, especially in alpine regions.

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Another view of why the climate-alarmist extinction-based hypothesis is way off-base was described in an invited paper in *Quaternary Science Reviews* by Vegas-Vilarrubia *et al*. (2011)[15], who said that "current extinction estimates for the near-future should be revised in light of palaeoecological information," which in their view, "shows that spatial reorganizations and persistence in suitable microrefugia have been more common than extinction during the Quaternary." And as a result of this fact, the four researchers concluded that "an interesting

[14] http://www.co2science.org/articles/V13/N7/B3.php.

[15] http://www.co2science.org/articles/V15/N9/EDIT.php.

consequence is the possibility of new unknown species combinations with no modern analogues."

Two phenomena that come into play in these ecosystem transformations, according to the Spanish scientists, are *acclimation* and *adaptation*, "with the first relying on phenotypic plasticity and the second involving genetic changes of potential evolutionary significance," which have been proposed as "possible reactions to future global warming and as alternatives to extinction by habitat loss." And as a result of these and other considerations, Vegas-Vilarrubia *et al*. noted that "some authors propose that spatial reorganizations without extinction will be the dominant biotic response to the near-future global changes." But they indicated that "it is also possible that ecosystems never attain equilibrium," and that "transient states perpetuate because of the recurrent action of environmental change." In fact, they suggested that one of the main lessons to be learned from these considerations is that ecosystems may express their resilience when confronted with environmental shifts by attaining several possible equilibrium states, as manifested in changes in biodiversity and/or composition, without losing their ecological functions."

In another impressive and enlightening review of the subject from the same time period, Willis and MacDonald (2011)[16] began by noting that key research efforts have focused on extinction scenarios derived from "a suite of predictive species distribution models (e.g., Guisan and Thuiller, 2005)" - which are most often referred to as *bioclimatic envelope models* - that "predict current and future range shifts and estimate the distances and rates of movement required for species to track the changes in climate and move into suitable new climate space." And they wrote that one of the most-cited studies of this type - that of Thomas *et al*. (2004) - "predicts that, on the basis of mid-range climatic warming scenarios for 2050, up to 37% of plant species globally will be committed to extinction owing to lack of suitable climate space."

*It is important to note that this approach, in contrast to the approach typically used by climate alarmists, relies on empirical (as opposed to theoretical) data-based (as opposed to model-based), reconstructions (as opposed to projections) of the past (as opposed to the future).*

In contrast, Willis and MacDonald wrote that "biotic adaptation to climate change has been considered much less frequently." And this phenomenon - which is sometimes referred to as *evolutionary resilience* - they described as "the ability of populations to persist in their current location and to undergo evolutionary adaptation in response to changing environmental conditions," citing Sgro *et al*. (2010). In addition, they noted that this approach to the subject "recognizes that ongoing

[16] http://www.co2science.org/articles/V15/N24/EDIT.php.

change is the norm in nature and one of the dynamic processes that generates and maintains biodiversity patterns and processes," citing MacDonald *et al*. (2008) and Willis *et al*. (2009).

The aim of Willis and MacDonald's review, therefore, was to examine the effects of significant and rapid warming on earth's plants during several previous intervals of the planet's climatic history that were as warm as, or even warmer than, what climate alarmists typically predict for the next century. These intervals included the Paleocene-Eocene Thermal Maximum, the Eocene climatic optimum, the mid-Pliocene warm interval, the Eemian interglacial, and the Holocene. And it is important to note that this approach, in contrast to the approach typically used by climate alarmists, relies on *empirical* (as opposed to theoretical) *data-based* (as opposed to model-based), *reconstructions* (as opposed to projections) *of the past* (as opposed to the future).

And what were the primary findings of the two researchers?

As they described them, "persistence and range shifts (migrations) seem to have been the predominant terrestrial biotic response (mainly of plants) to warmer intervals in Earth's history," while "the same responses also appear to have occurred during intervals of rapid climate change." In addition, they made a strong point of noting that "evidence for global extinctions or extinctions resulting from reduction of population sizes on the scale predicted for the next century owing to loss of suitable climate space (Thomas *et al*., 2004) is not apparent." In fact, they stated that sometimes an actual *increase* in local biodiversity has been observed.

Shortly thereafter, Feurdean *et al*. (2012)[17] wrote that species distribution models run at either *finer* scales (Trivedi *et al*., 2008; Randin *et al*., 2009) or including representations of plant demography (Hickler *et al*., 2009) and more accurate dispersal capability (Engler and Guisan, 2009) appear to predict a much smaller habitat and species loss in response to climate model predictions than do more *coarse*-scale models (Thomas *et al*., 2004; Thuiller *et al*., 2005; Araujo *et al*., 2008)," and these observations prompted the German and Romanian researchers to conduct their own real-world empirical study of the subject. So what did they do?

In the words of Feurdean *et al*., "seven fossil pollen sequences from Romania situated at different elevations were analyzed to examine the effects of climate change on community composition and biodiversity between 15,000 and 10,500 cal. yr BP in this biogeographically sensitive region of Europe," because this period, as they described it, "was characterized by large-amplitude global climate fluctuations occurring on decadal to millennial time scales (Johnsen *et al*., 1992; Jouzel *et al*., 2007)," which enabled them to explore "how repeated temperature changes have affected patterns of community composition and diversity" and to analyze "recovery processes following major disruptions of community structure."

In so doing, the four scientists reported discovering that (1) "community composition at a given time was not only the product of existing environmental conditions, but also the consequence of previous cumulative episodes of extirpation and recolonization," that (2) "many circumpolar woody plants were able to survive when environmental conditions became unfavorable," and

[17] http://www.co2science.org/articles/V15/N26/B2.php.

that (3) "these populations acted as sources when the climate became more favorable again," which behavior, in their words, "is in agreement with modeling results at the local scale, predicting the persistence of suitable habitats and species survival within large-grid cells in which they were predicted to disappear by coarse-scale models."

The findings of Feurdean *et al*. thus contribute to those of the growing number of studies that have demonstrated the shortcomings of climate-alarmist-approved "climate envelope" models of both vegetation and animal responses to rising temperatures, which models are used by climate alarmists to predict *massive species extinctions* as a result of the "unprecedented" $CO_2$-induced global warming predicted by equally deficient *climate* models. Clearly, these two "wrongs" do *not* make a "right."

Most recently, Dobrowski *et al*. (2013)[18] wrote that "anthropogenic climate change is considered a threat to ecosystem services and to global biodiversity because of its magnitude, the potential for novel climatic conditions (Williams *et al*., 2007), and the rate at which it is occurring (Parmesan and Yohe, 2003; Montoya and Rafaelli, 2010)," but they stated that "species have always been subject to changing climatic regimes and have responded through adaptation (Davis and Shaw, 2001; Hoffman and Sgro, 2011), changes in phenology (Cleland *et al*., 2007), range shifts (Davis and Shaw, 2001), and the use of climate refugia (Dobrowski, 2011; Hampe and Jump, 2011)." In addition, they indicated that "the fossil record suggests that widespread extinctions of plant species were rare during periods of rapid warming (~2-10°C/century) such as the Pleistocene-Holocene transition (Willis and MacDonald, 2011), noting that instead of species disappearing, "ecological turnover and range shifts were common responses to rapid climate changes of the past (Botkin *et al*., 2010; Hof *et al*., 2011; Willis and MacDonald, 2011)."

***Earth's plants have many ways of adjusting to changes in various climatic elements in addition to their ability to move from places of rising warmth to somewhat cooler habitats; and, therefore, they are likely to be around a whole lot longer than many climate-alarmist publications have predicted.***

Delving into the subject in more detail, the seven U.S. scientists assessed "climate velocity (both climate displacement rate and direction) for minimum temperature, actual evapotranspiration, and climatic water deficit over the contiguous U.S. during the 20th century (1916-2005)." And in doing so, they discovered "a complex picture of the climate in the contiguous U.S.," where "velocity vectors vary regionally, show variable and opposing directions among the variables considered, and shift direction through time."

[18] http://www.co2science.org/articles/V16/N19/EDIT.php.

As examples of these diverse findings, Dobrowski *et al*. reported that: (1) "Tmin vectors calculated over decadal and century scales demonstrate complex dynamics (e.g. northerly and southerly directions, direction reversal through time) that vary regionally," that (2) "climate displacement vectors for metrics of the water balance were predominantly oriented toward the west and south, showing regional variability," and that (3) "divergent climate vectors between temperature and water balance may help explain why roughly 10-30% of species assessed in previous climate change studies have not shifted their ranges whereas nearly 25% of species have shifted their ranges in a direction counter to expectations (Parmesan and Yohe, 2003; Chen *et al*., 2011; Crimmins *et al*., 2011)."

These results, in Dobrowski *et al*.'s estimation, "suggest that the expectation of poleward and upward shifts associated with all taxa, previously referred to as a 'globally coherent fingerprint' (Parmesan and Yohe, 2003), may be derived from an oversimplification of the climate dynamics that have been observed over the 20th century." In fact, they concluded that their findings implied that "a more full understanding of changes in multiple climatic factors, in addition to temperature, may help explain unexpected or conflicting observational evidence of climate-driven species range shifts." And in light of these developments, Dobrowski *et al*. additionally suggested that "moving away from viewing climate as simple monotonic changes in temperature is a necessary step in advancing our understanding of how species have and will respond to climate shifts," *and* one could add, how they have been able to largely avoid massive extinctions of the type that climate alarmists typically predict for them if the world continues to warm as their models say it will.

Clearly, it would appear from the findings discussed above that Earth's plants have many ways of adjusting to changes in various climatic elements in addition to their ability to move from places of rising warmth to somewhat cooler habitats; and, therefore, they are likely to be around a whole lot longer than many climate-alarmist publications have predicted.

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