MAMMALS IN A CO_2-ENRICHED AND WARMER WORLD

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We begin this brief analysis of the effects of global warming and atmospheric CO_2 enrichment on Earth's mammals with a review of the study of Norment *et al.* (1999)[1], who summarized and compared the results of many surveys of mammal populations observed along the Thelon River and its tributaries in the Canadian Northwest Territories from the 1920s through much of the 1990s. This endeavor revealed that over the time period investigated, red squirrel, moose, porcupine, river otter and beaver were found to have established themselves in the studied area in recent years, significantly increasing its biodiversity; and Norment *et al*. then suggest that the primarily northward range expansions that produced these results may be explained by "a recent warming trend at the northern treeline during the 1970s and 1980s." Alternatively, they note that the influx of new species may also be due to "increasing populations in more southerly areas." In either case, we have a situation where many mammals appear to be faring quite well - in fact *thriving* - in the face of increasing temperatures in this forest-tundra landscape.

At the other end of the world, Pockely (2001)[2] reported the results of a survey of the plants and animals on Australia's Heard Island, a little piece of real estate located some 4,000 kilometers southwest of Perth. Over the prior fifty years this sub-Antarctic island had experienced a local warming of approximately 1°C that resulted in a modest retreat of its glaciers; after which, for the first time in a decade, scientists were documenting what this warming and melting had done to the ecology of the island.

Pockley began by reporting on the "rapid increases in flora and fauna" that had accompanied the warming, quoting Dana Bergstrom - an ecologist at the University of Queensland in Brisbane - as saying that areas that previously had been poorly vegetated were by that time "lush with large expanses of plants." And to this information he added that populations of fur seals had also expanded rapidly. In fact, he cited Eric Woehler of Australia's environment department as informing him that fur seals had emerged from "near extinction" to a population of 28,000 adults and 1,000 pups.

Interestingly, and contrary to the conclusions of earlier more simplistic studies that had predicted dramatic global warming-induced reductions in the numbers of mammals in this region, Lawlor concluded that "virtually no extinctions can be expected from a projected 3°C rise in temperature."

[1] http://www.co2science.org/articles/V3/N3/C5.php
[2] http://www.co2science.org/articles/V4/N16/BEDIT.php

In between these far-flung chilly regions (where warming would be *expected* to enhance the abilities of land mammals to survive and reproduce), Lawler (1998)[3] examined biogeographic relationships of mammals that are typically found on mountaintops in the Great Basin of western North America, which effort was undertaken with the objective of determining their future well-being in the face of predicted climate-driven changes in their environment. Interestingly, and contrary to the conclusions of earlier more simplistic studies that had predicted dramatic global warming-induced reductions in the numbers of mammals in this region, Lawlor concluded that "virtually no extinctions can be expected from a projected 3°C rise in temperature."

The results of this study, as well as those of Grayson (2000) and Grayson and Madson (2000) stand in stark contrast to the doom-and-gloom predictions of climate alarmists, who incessantly claim that global warming will lead to a mass extinction of species nearly everywhere on Earth *because*, as they say, plants and animals will not be able to migrate rapidly enough to keep up with the shifting climatic zones to which they are currently accustomed, or that they will literally "run out of places to run," as in the case of mountain-top dwellers. As logical as that hypothesis might sound, however, more complex studies, such as the one reviewed here, indicate that it is *wrong*, simply because Earth's plants and animals are not the simpletons climate alarmists make them out to be, possessing a wide array of strategies for coping with environmental change and re-colonizing former territories after having once been forced out of them.

Somewhat similar relationships to those that have been observed in colder locations on land have also been identified in colder marine environments. Heide-Jorgensen and Laidre (2004)[4], for example, examined changes in the fraction of open-water found within various pack-ice microhabitats of Canada's Foxe Basin, Hudson Bay, Hudson Strait, Baffin Bay-Davis Strait, northern Baffin Bay and Lancaster Sound over a 23-year interval (1979-2001), using remotely-sensed microwave measurements of sea-ice extent, after which they related the trends they discovered to the winter success and survival of various marine animals, including the *cetaceans* (water mammals, such as whales, porpoises and dolphins).

The two scientists report that Foxe Basin, Hudson Bay and Hudson Strait showed small increasing trends in the fraction of open-water, with upward trends at all microhabitats studied ranging from 0.2 to 0.7% per decade. In Baffin Bay-Davis Straight and northern Baffin Bay, on the other hand, the open-water trend was downward, and at a mean rate for all open-water microhabitats studied of fully 1% per decade, while the trend in all Lancaster Sound open-water microhabitats was also *downward*, in this case at a mean rate of 0.6% per decade. In addition, Heide-Jorgensen and Laidre report that "increasing trends in sea ice coverage in Baffin Bay and Davis Strait (resulting in declining open-water) were as high as 7.5% per decade between 1979-1999 (Parkinson *et al*., 1999; Deser *et al*., 2000; Parkinson, 2000a,b; Parkinson and Cavalieri, 2002) and comparable significant increases have been detected back to 1953 (Stern and Heide-Jorgensen, 2003)." They also note that similar trends in sea ice have been detected locally along the West Greenland coast, with slightly lower increases of 2.8% per decade (Stern and Heide-Jorgensen, 2003).

[3] http://www.co2science.org/articles/V5/N18/C2.php
[4] http://www.co2science.org/articles/V8/N18/B1.php

With respect to these observations, the two scientists note that "two types of vulnerability have been identified relative to increasing sea ice: i) the direct physical impact of sea ice as a barrier for air-breathing foraging animals; and ii) the cascading effects of changes in marine productivity."

The first of these problems most affects the cetaceans, including over 50,000 narwhal, 20,000 beluga and many bowhead whales; and Heide-Jorgensen and Laidre say "there is sufficient evidence to detect a clear decline in the amount of open-water in several narwhal wintering microhabitats, including the Northern Wintering Ground, Southern Wintering Ground, Disko Bay, Store Hellefiske Bank, North Water and Cumberland Sound and adjacent offshore areas," several of which locations also serve as wintering grounds for beluga and bowhead whales. A crisis of huge proportions appears to be building, as the sea ice of these regions continues to increase in response to regional cooling. Also, increasing sea ice coverage *in combination with environmental variability*, as they describe it, "leads to an increased frequency of periodic complete freeze-over," and according to the two scientists from the Greenland Institute of Natural Resources, who are experts in the field, this phenomenon "can result in catastrophic mortalities that can affect population trajectories." In the case of Disko Bay, for example, they report that "less than 5% open-water was observed on 89% of the days in March between 1992-1995, and during this period 15% of these days had complete freeze-over." Already, in fact, hundreds of narwhals had died during episodes of rapid sea ice formation caused by sudden cold periods (Siegastad and Heide-Jorgensen, 1994; Heide-Jorgensen *et al*., 2002).

Clearly, the decades-long cooling of these regions is becoming very dangerous for the marine mammals that inhabit them. As described by Laidre and Heide-Jorgensen (2005)[5], "cetacean occurrence is generally negatively correlated with dense or complete ice cover due to the need to breathe at the surface," and that "lacking the ability to break holes in the ice," narwhals are vulnerable to reductions in open water availability, as has been demonstrated by ice entrapment events "where hundreds of narwhals died during rapid sea ice formation caused by sudden cold periods," which events are becoming ever more likely as local temperatures continue to decline and sea ice cover *and variability* increase, which latter two trends were found by them to be "highly significant at or above the 95% confidence level." Hence, they concluded that "with the evidence of changes in sea ice conditions that could impact foraging, prey availability, and of utmost importance, access to the surface to breathe, it is unclear how narwhal sub-populations will fare in light of [cooling-driven] changes in the high Arctic."

Returning to land mammals, we encounter the reports of two studies that broach somewhat different aspects of the CO_2-climate-mammal connection. In the first, which is discussed in our Editorial of 7 Aug 2002[6], we note that New Zealand scientists have demonstrated that *condensed tannins*, which are found in many pasture plants, can reduce methane emissions from grazing mammals such as sheep and cattle, and thereby reduce the global warming potential provided by this powerful greenhouse gas. So what are condensed tannins, and what do they have to do with atmospheric CO_2?

[5] http://www.co2science.org/articles/V7/N43/C1.php
[6] http://www.co2science.org/articles/V5/N32/EDIT.php

Condensed tannins are naturally-occurring compounds found in a number of different plants that sometimes act to deter herbivorous insects. In New Zealand, the "legume lotus" is one of the primary sources of these substances; and scientists have determined that sheep and cattle feeding on it reduce their methane emissions by as much as 16%. So thrilled were they by this finding, they began talking, not only of using more tannin-producing species as animal forage, but of genetically introducing tannins into other pasture species as well.

The role of the ongoing rise in the air's CO_2 content in this scenario may be deduced from a 1999 study of its effects on condensed tannin production in four genotypes of *Lotus corniculatus*, specimens of which were collected half a world away in meadows south of Paris, France. In that study, Goverde *et al*. (1999) determined that a 350-ppm increase in the atmosphere's CO_2 concentration increased tannin production in one lotus genotype by 17%, in a second genotype by 33%, in a third by 61%, and in a fourth by 140%. It is interesting to note, in this regard, that whereas the world's scientists are just now discovering this significant means of combating one of the atmosphere's most powerful greenhouse gases, i.e., methane, nature has been employing the technique since the dawn of the Industrial Revolution, steadily boosting tannin production in plants that are eaten by ruminants as the air's CO_2 content has gradually risen.

These findings are truly welcome, yet they are only part of the good news reported by the New Zealand scientists, who note that tannins "have a variety of other animal related benefits, such as improved milk yields, increased live weight gain, decreased internal parasite burden and reduced occurrence of bloat, dags and fly strike." And, again, all of these tannin-induced benefits would be expected to be significantly enhanced by the increases in the air's CO_2 content that increase forage tannin concentrations. In addition, it is important to note that there are a great number of grazing mammals in addition to sheep and cattle, including antelope, bison, buffalo, camel, deer, giraffe, goat, llama, etc., and that these mammals eat a number of other types of plants, which may also experience increases in leaf tannin production as the air's CO_2 content rises, as has in fact been found to be true for a number of different plant species, including both deciduous and evergreen trees (Lindroth *et al*., 1993, 1995; Traw *et al*., 1996; Hattenschwiler and Schafellner, 1999) and grasses (Goverde *et al*., 2002).

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In light of these several observations, it can be appreciated that many mammals, both wild and domesticated the world over, may be participating in this important natural "program" for reducing methane emissions to the atmosphere. Could it be they are partially responsible for the reduction in the rate-of-rise of the atmosphere's methane concentration that has been observed over the past few decades (see Methane (Atmospheric Concentrations)[7] in our Subject Index)? If so, we can expect to see more of the same as the air's

[7] http://www.co2science.org/subject/m/methaneatmos.php

CO_2 content continues to climb; for the biosphere, it would seem, takes care of its own, as demonstrated by this unique negative feedback phenomenon that tempers greenhouse gas-induced global warming.

We come next to the study of Mattson *et al*. (2004)[8], who grew one-year-old seedlings of silver birch trees in closed-top chambers for one summer and autumn in pots containing an unfertilized commercial peat maintained at three different soil nitrogen levels and two temperature regimes in air of either 362 or 700 ppm CO_2, after which feeding trials with caged Eurasian hares were carried out and a number of chemical analyses made of the tops of the seedlings and the basal parts of their stems. In a second experiment, they grew paper birch trees from seed for two 140-day growing seasons in well-watered and fertilized pots placed within FACE rings maintained at atmospheric CO_2 concentrations of either 362 or 562 ppm, after which (in an unplanned aspect of the study) North American eastern cottontail rabbits fed *ad libitum*, consuming bark tissue down to and scoring the wood, on the basal third of the seedlings, which tissues were also tested for the presence of various herbivore-deterring chemical constituents.

So what did the scientists learn? "As expected," in their words, "elevated CO_2 substantially increased the above-ground woody biomass growth of both paper birch (63%) and silver birch (21%)." In addition - noting that "numerous studies have shown that elevated atmospheric CO_2 often, but not always, elicits increases in carbon partitioning to carbon-based secondary plant compounds," which tend to act as deterrents to herbivory - they say their findings "confirm this general pattern in silver and paper birch." Last of all, they report that high CO_2 *reduced hare feeding* on silver birch shoots by as much as 48%, and that it *reduced rabbit feeding* on paper birch stems by about 51%, while neither temperature nor severe early-season defoliation (another experimental treatment) affected tree resistance against these mammalian herbivores.

Calling the anti-herbivory effect of elevated CO_2 "remarkably strong," and noting that rabbits "overwhelmingly preferred ambient CO_2 plants," Mattson *et al*. said their data "clearly suggest that the defensive biochemistry of paper birch twigs as well as the main stem were [positively] altered as the result of elevated CO_2." Hence, we can expect that as the air's CO_2 content continues to rise, at least these two species of birch trees will have a significantly easier time getting established and growing to maturity, in that they likely will not be harmed nearly as much by rabbits and hares munching away at their trunks and branches

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[8] http://www.co2science.org/articles/V7/N40/B3.php

while in their early growth years. And, of course, this phenomenon should leave much more foliage for other ruminant mammals to feed upon.

In light of these several findings, we see that where warming-induced extinctions of mammals have often been predicted to occur, they are highly unlikely to be realized in nature, and that where warming may be expected to open up new territories for mammal range expansions, such does indeed take place. We also see that warming may benefit many marine mammals that currently are threatened by extensive seasonal ice cover, and that rising atmospheric CO_2 concentrations may lead to reductions in methane emissions from land mammals, while they simultaneously produce changes in the palatability of the trunk and branch tissues of certain trees that may protect them from being killed by voracious hares and rabbits. Yet even more new and important facts continue to be discovered.

Jumping ahead a few years, for example, we encounter a review paper (Schipper *et al*., 2008[9]) that was authored by 130 scientists who employed data compiled by over 1700 acknowledged experts in the field, which they described as "the most comprehensive assessment to date of the conservation status and distribution of the world's mammals, covering all 5,487 wild species recognized as extant since 1500." And what did they find?

First of all, they determined that 25% of all mammals for which adequate data are available are threatened with extinction, with the percentage for marine mammals rising to 36%. These figures included 188 critically endangered species that face what they call "a very high probability of extinction," as well as 29 species for which they said "it may already be too late."

So what are the primary causes of the possible near-term mammal extinctions? The international team of experts stated that "worldwide, habitat loss and degradation (affecting 40% of species assessed) and harvesting (hunting or gathering for food, medicine, fuel and materials, which affect 17%) are by far the main threats to [land] mammals." With respect to *marine* mammals, however, they say "the dominant threat is accidental mortality (which affects 78% of species), particularly through fisheries by-catch and vessel strike," while "pollution (60% of species) is the second most prevalent threat."

Looked at from the *opposite* perspective, one may ask what factor is the most important for *maintaining* mammal species richness and *preventing* wholesale extinctions? As stated in the table of contents tag line to the article of Schipper *et al*., the comprehensive assessment of the 130 researchers "shows that primary productivity drives species richness on land and sea," while in the article itself the authors write that "as with land species, marine richness seems to be associated with primary productivity," noting that "whereas land species' richness peaks toward the equator, marine richness peaks at around 40°N and S, corresponding to belts of high oceanic productivity."

Shipper *et al*. thus conclude their review by stating that their results "paint a bleak picture of the global status of mammals worldwide." And so they do. However, we *can reduce* the loss and degradation of habitat and animal harvesting on land, as well as accidents and pollution at sea,

[9] http://www.co2science.org/articles/V11/N46/EDIT.php

but only if we truly dedicate ourselves to doing so. On the other hand, attempting to prevent catastrophic mammal extinctions by trying to change the world's *climate*, as Al Gore, James Hansen and others claim we must do by restricting CO_2 emissions, is even worse than wishful thinking, for it simply cannot be done. What is more, fully half of all the archived content of our website is a testament to the *fact* that atmospheric CO_2 enrichment significantly increases primary productivity, both on land and at sea; and this phenomenon is the greatest known force for *maintaining* Earth's mammal species richness.

Four years later, Hof *et al*. (2012)[10] also addressed the topic of sub-Arctic mammals, noting that "it is supposed that the large expected climate change at high northern latitudes … makes species in (sub)arctic regions particularly susceptible" - citing the studies of Virkkala *et al*. (2008), Sala *et al*. (2000) and Jetz *et al*. (2007) - "especially the European part of the (sub)arctic, since this region is the most geographically complex with the most infrastructure and great cultural, social, and political heterogeneity (Nilsson *et al*., 2010)." However, they think *differently*; and they go on to tell us *why*.

As Hof *et al*. describe it, they "assessed potential changes in the geographic distribution of all terrestrial mammal species currently present in (sub)arctic Europe," along with additional species that might possibly colonize the region from the south. This they did using "species distribution modeling, incorporating projections of future climate and vegetation, in order to provide a better insight into the magnitude of the risk mammal species are facing, and the potential community level changes they have to endure due to climate change." And "contrary to expectation," as they write, the three Swedish researchers report that their modeling of species distributions suggests that (1) "predicted climate change up to 2080 will favor most mammals presently inhabiting (sub)arctic Europe," and that (2) "no species is predicted to go extinct."

Hof *et al*. thus conclude their discussion of the subject by stating that "for most (sub)arctic mammals it is not climate change per se that will threaten them, but possible constraints on their dispersal ability and changes in community composition." And, therefore, with a little help from the region's human population, most (sub)arctic mammals should be able to survive any future warming that may be experienced there.

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Also publishing a pertinent paper in the same year were Canale *et al*. (2012)[11], who introduced their study of this intriguing subject by writing that "understanding whether, and to what extent, females can flexibly adjust their energetic investment to reproduction according to unpredicted food shortages is essential to predict whether organisms could compensate climate changes

[10] http://www.co2science.org/articles/V16/N23/B2.php
[11] http://www.co2science.org/articles/V16/N36/B3.php

by plastic phenotype adjustments," citing Bronson (2009), Moreno and Moller (2011) and Wingfield *et al*. (2011). And, therefore, in the words of the three researchers, they say they "experimentally tested the consequences of chronic-moderate and short-acute food shortages on the reproductive output of a small seasonally breeding primate, the grey mouse lemur (*Microcebus murinus*) under thermo-neutral conditions," where "two food treatments were respectively designed to simulate the energetic constraints imposed by a lean year (40% caloric restriction over eight months) or by a sudden, severe climatic event occurring shortly before reproduction (80% caloric restriction over a month)," during which time they "assessed the resilience of the early stages of reproduction (mating success, fertility, and gestation to these contrasted food treatments, and on the later stages (lactation and offspring growth) in response to the chronic food shortage only."

This study revealed, in their words, that "food deprived mouse lemurs managed to maintain constant most reproductive parameters, including oestrus timing, estrogenization level at oestrus, mating success, litter size, and litter mass as well as their overall number of surviving offspring at weaning," although they note that "offspring growth was delayed in food restricted mothers." And in light of these several findings, the three researchers say their results suggest that "heterothermic, fattening-prone mammals display important reproductive resilience to energetic bottlenecks," and that "more generally, species living in variable and unpredictable habitats may have evolved a flexible reproductive physiology that helps buffer environmental fluctuations."

One year later, noting that Southern elephant seals (*Mirounga leonina*) are apex predators of Antarctic marine food webs and that knowledge of the status of elephant seal populations "provides insights into the environmental status of Antarctica," Gil-Delgado *et al*. (2013)[12] derived estimates of southern elephant seal subpopulation sizes on two beach areas of Byers Peninsula (Southern Beaches and President Beaches), which are believed to be the main distribution areas of the animals on Livingston Island (of Antarctica's South Shetland Islands), according to Aguayo and Torres (1967), who first monitored elephant seal populations there in the 1960s. This Gil-Delago *et al*. did via seal counts they conducted along numerous transects at a distance of 50 m from the shoreline (some in excess of 11 km in length), which they traversed on foot "using binoculars and approaching to large groups when spotted," between 22 December 2008 and 1 January 2009. And they report that the number of pups they thus counted was used to estimate the *total* elephant seal population by multiplying their numbers by a conversion factor of 3.5, which they say "has often been used in inventories of southern elephant seal populations," citing the studies of Laws (1994) and Lewis (1996). And what did they thereby find?

The eight Spanish researchers report that the final numbers they derived represent an increase of 150% since the sub-population they studied was first counted some 30 years ago. And they say that their finding of an increased subpopulation on Byers Peninsula suggests that "the entire South Georgia stock may also be increasing instead of being stable as currently assumed." In addition, they note that "the occurrence of southern elephant seals breeding in recent times and in areas located at higher latitudes, such as Anvers island (ASPA 113, 2009), suggests that the breeding range of this species is expanding." And they thus conclude that "habitat availability for

[12] http://www.co2science.org/articles/V16/N35/B1.php

southern elephant seals in Antarctica could increase as a result of climate change, thus providing additional suitable breeding habitats," as suggested at the turn of the century by the observations of McMahon and Campbell (2000).

Also publishing during the same time frame as Gil-Delgado *et al*. were Li *et al*. (2013)[13], who note in providing some background for their study that bamboo (*Fargesia rufa* Yi) -- which grows in the understory of subalpine coniferous forests in China -- is one of the main foods of the giant pandas that live there. Thus, it was only natural for them to wonder how the ongoing rise in the atmosphere's CO_2 concentration might impact the small bamboo plants and, thereby, the pandas source of food. More specifically, they were curious about the phenomenon of *photosynthetic acclimation* (or down-regulation, which is a decrease in originally-stimulated photosynthetic rates) that is sometimes observed in CO_2-enriched air, where the initial CO_2-induced stimulation of photosynthesis gradually erodes away over time.

Seeds of the dwarf bamboo plants were thus collected and sown in seedbeds where the resultant seedlings were allowed to grow for four years, after which healthy seedlings of a uniform size were transplanted into 120 20-L pots filled with surface soil taken from the natural forest floor. Then, starting in May of 2010, the planted pots were placed within eight enclosed-top growth chambers constructed from materials having a transparency of 85% (walls) and 82% (tops), where they grew until the end of the study in September 2010 in air of either ambient or double-ambient CO_2 and either ambient or ambient +2.2°C temperature, while numerous measurements were made on the young trees over the course of the 150-day experiment.

This work revealed, in the words of the six scientists, that "the light-saturated net photosynthetic rates of the dwarf bamboo increased by 57.6% under elevated CO_2," while in the case of both elevated CO_2 and elevated temperature together, the increase in net photosynthesis was 36.9%. They also report that they "found no evidence of photosynthetic down-regulation in the dwarf bamboo." In addition, they say there were also "no significant reductions in the nitrogen concentration based on mass in the dwarf bamboo," and that "there were even increases in the N concentration based on [leaf] area when exposed to elevated CO_2." And they speculate that "the lack of observed photosynthetic down-regulation may be related to this result."

In concluding their paper, Li *et al*. write that the dwarf bamboo plants could readily adjust their "physiology and morphology to enable the capture of more light, to increase water use efficiency and improve nutritional conditions." However, they also indicate that elevated *temperature* had just the *opposite* effects on the water use efficiency and nutritional traits of leaves. But *in the end*, they report that "the combination of elevated CO_2 and elevated temperature showed no significant interaction effect on the nutritional traits of leaves." And, therefore, their *ultimate* conclusion was that if and when "the dwarf bamboo confronts warmer climate for a long term, elevated CO_2 will be beneficial," as it will lead to the production of *more* equally-nutritious dwarf bamboo tissue.

[13] http://www.co2science.org/articles/V16/N37/B2.php

Also publishing a pertinent contemporary paper were Tveraa *et al*. (2013)[14], who wrote that "for caribou in Greenland earlier springs have been suggested to result in a lower reproductive success," based on the assumption that "*Rangifer* (caribou/reindeer) might be unable to adjust their timing of reproduction to the earlier surge of high quality food," which potential failure could "cause a mismatch between optimal forage conditions and the timing of reproduction." And, therefore, they stated that "concerns have been raised regarding the future viability of *Rangifer* in Arctic and sub-Arctic tundra ecosystems."

In a study designed to further explore this unsettled situation, Tveraa *et al*. analyzed a 10-year dataset of satellite-derived measures of vegetation green-up, population densities, calf body masses and female reproductive success in 19 reindeer (*Rangifer tarandus*) populations in Northern Norway. This work revealed, as they describe it, that "an early onset of spring and high peak plant productivity had positive effects on calf autumn body masses and female reproductive success," and that "the quantity of food available, as determined by the onset of vegetation green-up and plant productivity over the summer, were the main drivers of body mass growth and reproductive success." And as a result of finding *no evidence* for a negative effect of the speed of spring green-up, nor a negative mismatch between early springs and subsequent recruitment, the four Norwegian researchers simply concluded that the "effects of global warming on plant productivity and onset of spring are likely to positively affect sub-Arctic reindeer."

Most recently, and in light of continuing concerns about potential negative effects of predicted increases in global temperature on various plants and animals, Shi *et al*. (2014)[15] wrote that "microhabitats can partially decouple from regional climatic conditions, and species can persist *in situ* as regional climates become less suitable," citing the studies of Bennie *et al*. (2008), Ashcroft (2010) and Keppel and Wardell-Johnson (2012), while making special note of the microhabitats of tree hollows, roost cavities, tropical boulder fields and various microhabitats within primary rainforests, citing the additional studies of Isaac *et al*. (2008), Sedgeley (2001), Shoo *et al*. (2010) and Scheffers *et al*. (2014).

Focusing their attention on Australia's alpine boulder fields -- because they provide den and nest sites for a range of endemic small mammals -- the four researchers collected hourly temperature data from 70 sites located within nine boulder field clusters in an area of approximately 60 km x 30 km in New South Wales over a period of slightly more than two years duration. And what did they thereby find?

Shi *et al*. report that the boulder fields "buffered the surface temperature maxima by 2.91°C at a depth of 50 cm and 4.39°C at a depth of 100 cm, while they buffered the surface temperature minima by 0.54°C at the depth of 50 cm and 1.36°C at the depth of 100 cm." And these effects could well mean the difference between a species surviving or going extinct in a gradually warming world, especially if it is unable to migrate either poleward in latitude or upward in altitude.

[14] http://www.co2science.org/articles/V16/N41/B1.php
[15] http://www.co2science.org/articles/V18/apr/a11.php

In concluding this summary of the possible fates of many of Earth's mammals in a future CO_2-enriched and potentially warmer world, it is becoming ever more clear -- from a large number of scientific studies -- that the many positive *proven* responses of a great diversity of species greatly outweigh the negative *imagined* responses that have long been predicted by the world's climate alarmists.

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