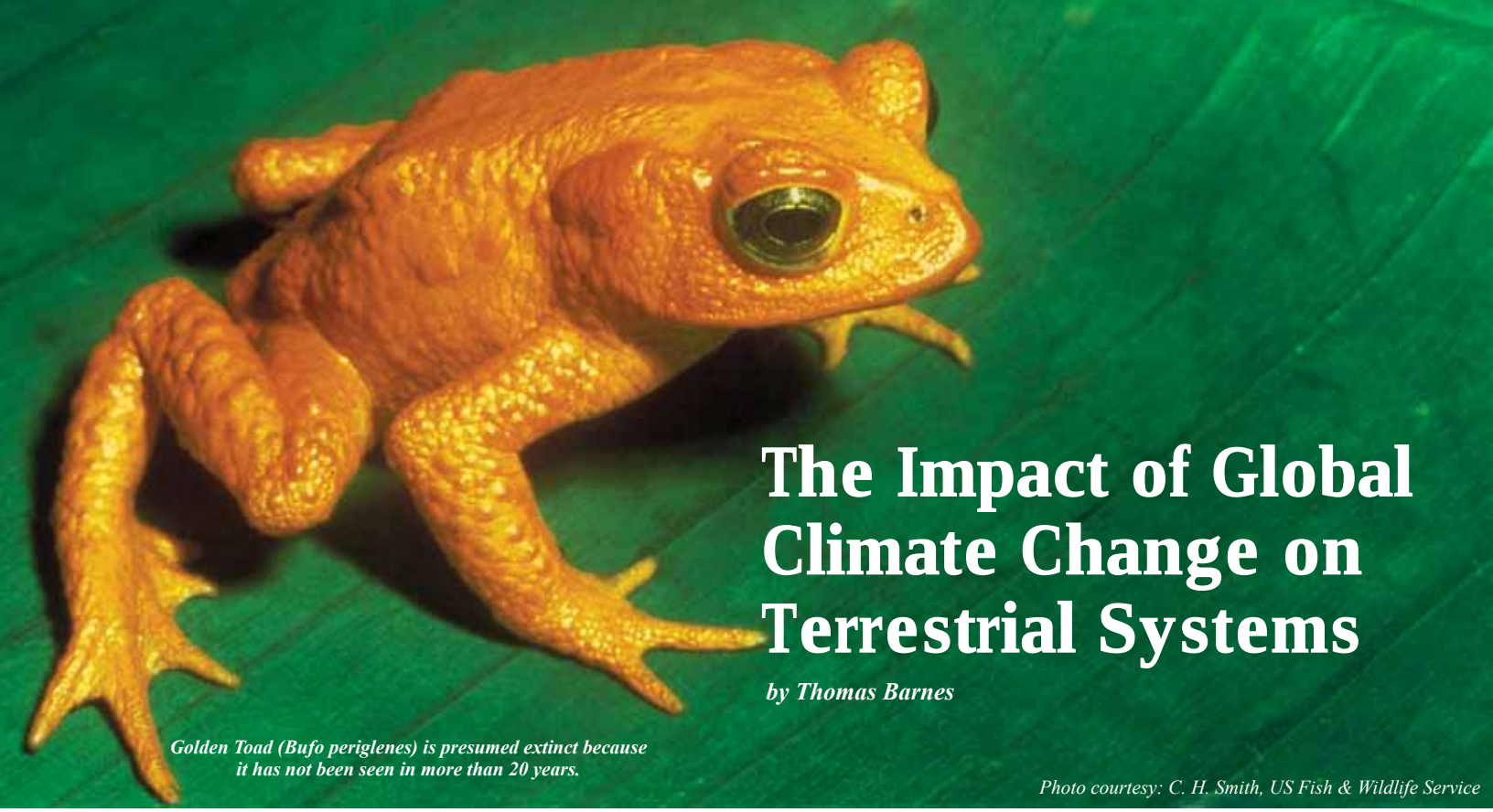


The Impact of Global Climate Change on Terrestrial Systems

by Thomas Barnes

Golden Toad (Bufo periglenes) is presumed extinct because it has not been seen in more than 20 years.

Photo courtesy: C. H. Smith, US Fish & Wildlife Service

The world is changing right before our eyes. Many woodland owners are not aware of how their woodlands are changing, because the change is happening so slowly that we fail to stop and observe nature on her time scale. We humans seem to lack a certain level of patience when it comes to these activities. Nature is infinitely complex and while we can put men into outer space for weeks and months at a time, we are still largely ignorant of how natural systems function and change over time. And our natural systems are changing as a result of a warming climate. For those interested in gaining a further understanding of the mechanisms of global climate change, or what I like to call global climate weirdness because of the widely erratic changes that are happening, the following web resources provide an excellent summary of the scientific evidence for climate change based on peer-reviewed scientific literature: www.ucsusa.org/global_warming/ and www.pewclimate.org/. The purpose of this article is to provide a brief overview of what is currently happening to terrestrial ecosystems as a result of a warming world.

The future impacts of climate change are difficult to predict because of many variables that impact complex natural systems, including climate, soil processes, movement and migration patterns, dispersal mechanism, and the ways individuals and species compete with one another. However, we do know that we are experiencing some of the "predicted" effects today. This is evident from the greater and more variable weather extremes that have given rise to increasing droughts; intensive, heavy precipitation events; and more days with extreme temperatures—all of which global climate change models predict. It would be fantastic to show the impacts of these changes on Kentucky's natural resources, but Kentucky lags far behind other states with respect to conducting research on the present and future implications of climate change. However, significant peer-reviewed scientific information from around the U.S. and the globe is important to Kentucky, and weighty observational information is available from here in the Commonwealth.

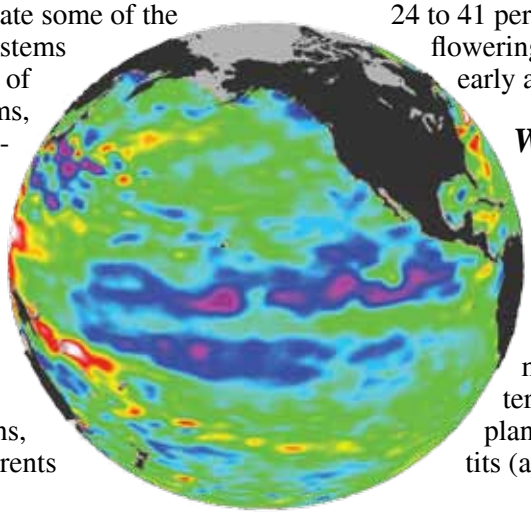
First and foremost, the world will not end if we do nothing to slow or stop the effects of global climate change. It most certainly will be a different world, and there will be winners and losers. For example, research shows that red fox (a generalist) numbers are increasing and arctic fox (a specialist) numbers are dwindling as the bigger and more aggressive red foxes move into tundra areas that have warmed. If we continue on the current trend we can anticipate a general loss of between 15 and 37 percent of known plants and animals by the year 2050; most studies predict species loss in the 20 to 30 percent range. Not only will individual species become extinct, entire ecosystems such as mangrove swamps and salt marshes will be lost. Even if we were to curtail greenhouse gas emissions today, models all indicate that the impacts of climate change will proceed for several decades because of the time scale and the delayed effects of climate change.

Since climate change is happening as you read this article, just what are the

Salt water marshes like the one above could be lost due to global climate change.

Photo courtesy:Billy Humphries, Forest Resource Consultants, Inc., Bugwood.org

impacts of climate change that we are experiencing at this point in time? The remainder of this article will discuss the current effects of climate change on plants, forests, birds, and amphibians, which demonstrate some of the strongest impacts in terrestrial systems from climate change. The effects of climate change on oceanic systems, particularly coral reefs and fisheries, are even more dramatic as ocean acidity has increased by as much as 38 percent from the 1700s, having serious implications for all oceanic life. In addition, climate change is affecting ocean temperatures, the supply of nutrients from the land, ocean chemistry, food chains, shifts in wind systems, ocean currents and extreme events such as cyclones, which in turn affect the distribution, abundance, breeding cycles and migrations of marine plants and animals, which millions of people rely on for food and income. The effect of climate change also impacts el Niño and la Nina events, which affect terrestrial short-term weather patterns in North America.



The effect of climate change impacts El Niño and La Nina events, which affect terrestrial short-term weather patterns in North America. This image shows a La Nina, the blue area in the center of the image along the equator, which persisted for more than a year in 2007-2008.

Photo courtesy:NASA Jet Propulsion Laboratory

What would the famous naturalist, Henry David Thoreau have to say about what is happening with the wildflowers in Concord, Massachusetts, his hometown? They are flowering earlier just like plants are doing in many places around the world. Research has shown that wildflowers are blooming an average of seven days earlier than when Thoreau wandered around the woods and forests. Even in Kentucky, naturalists have observed wildflowers blooming earlier, often by as much as several weeks. Twenty five years ago the peak of the spring wildflower season was generally the last week in April, today it is early to mid-April and in western Kentucky; the peak of the spring flowering season is done by mid- to late-April. Other empirical data indicate that increasing temperatures are affecting the timing of plant growth, development and flowering, even in unlikely places such as the American southwestern deserts, where spring blooming shrubs are flowering 20 to 41 days earlier, lilacs flowering 7.5 days earlier, honeysuckles 10 days earlier; 15 percent of all wildflowers are blooming earlier. In New York, 6 of 15 wildflowers studied bloomed an average of 20 days earlier than in the past 50 years and no species was found flowering later. Ten species of Wisconsin woodland flowers bloomed earlier, and 15 species trended toward flowering earlier. In the northern Great Plains region, 24 to 41 percent of hundreds of native species shifted flowering times; most of them flowered unusually early as a result of warming temperatures.

One sign that the climate is changing is that wildflowers are blooming earlier. In Kentucky, naturalists have observed wildflowers flowering up to several weeks earlier.

Photo courtesy: Thomas Barnes

Why should we worry if plants flower earlier?

On the surface it appears that plants adapting to warming temperatures is positive. But that casual observation is made without the understanding that species adapted to using that particular plant may not be able to adapt, particularly in terms of pollination, seed dispersal or other plant-animal interactions. One study of great tits (a bird common to the Netherlands) shows that warmer springs result in a mismatch of peak food availability and hatchling requirements. The peak availability of the insects the birds eat is occurring nine days earlier, and the result has been a decline in the number of offspring surviving, which has led to population declines. Some evidence indicates that this population may be adapting to a warming planet, but the bird's long-term survival will depend on whether enough of the population can remain productive for the population to recover.

Mis-timing of food resources and reproductive success has also been documented for the Pied flycatcher. These are among the most studied songbirds in the world. During the past two decades, some populations have declined by 90 percent as a result of the birds arriving from the wintering grounds, nesting and beginning to raise young only to find that the caterpillars are no longer available to feed the young.

How else is climate change affecting birds in North America?

Generally speaking, the range of migratory birds is moving north, and a recent Audubon study found that nearly 60 percent of 305 species have shifted their ranges north by an average of 35 miles. In addition, studies from around the globe have documented that climate change is altering migration timing; some species have abandoned migration altogether, and reproductive failures have been shown to be related to changes in insects and habitat availability. In addition, birds such as the American tree swallow; snow and Canada geese and Mexican jays are nesting earlier. So why care if the nesting dates change, or range or habitats change? The birds will adapt, won't they? Perhaps, but perhaps not, because ecological systems are complicated.

A good example of how climate change is altering bird species ecology is the grey jay. The grey jay is a common resident of the boreal forest in North America. It hoards food to get through long, cold winters. The grey jay is now in serious trouble because warmer winters are causing their

food stashes to rot; the birds are also experiencing food poisoning from eating rotten food. This situation has tremendous ecological implications for the long-term survival of this species and demonstrates how the disruption of one single component in the bird's life history has a ripple effect. Because these birds come into the reproductive period in less than prime condition, and because they typically mate for life, there are fewer permanent mating pairs. Now 50 percent of them re-mate, which means reproductive problems for the entire system as younger, more inexperienced birds mate, creating nest failures, which leads to more re-mating, which leads to more nest failures, which results in breeding chaos. The results of the 25 year study indicate that birds in the southern range, including southern Canada, Maine, Vermont, and the Rocky Mountains, may become extinct.

Photo courtesy: Terry L. Spivey, Terry Spivey Photography, Bugwood.org

The grey jay is in trouble because warmer winters are causing their food stashes to rot and the birds are also experiencing food poisoning from eating rotten food.

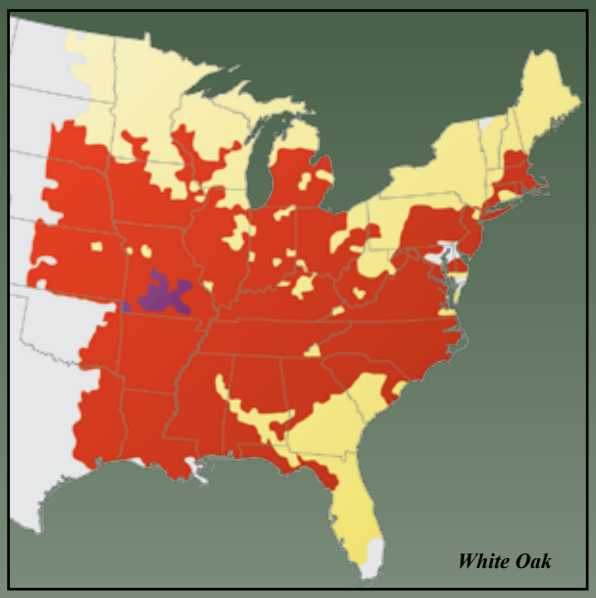
How is climate change affecting forests?

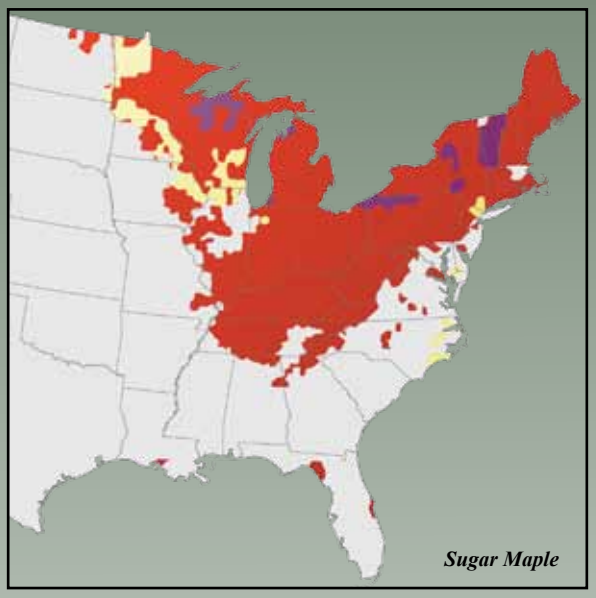
There is no doubt that changing temperatures and precipitation patterns will alter forests. On the positive side, climate change in the short term is increasing forest productivity by 10 to 20 percent and increasing carbon sequestration, but the long-term effects tell another story. Other factors such as pollution (acid rain); forest management trends in harvesting, fire control, insects, and other pathogens, and land use changes will interact with climate change, and specifically interpreting the actual impacts of climate change will be challenging. We do know that changing precipitation and temperatures will likely cause geographic shifts in tree species and the composition, productivity, and location of various forest types will change as some will migrate or shift their distributions northward or to higher elevations or will decline. For example, the tree line in the Sierra Nevada Mountains has moved more than 100 feet in elevation during the past 100 years, and the white spruce in the arctic is rapidly declining because warm summer temperatures exceed the threshold for that species. Climate-induced tree mortality is well documented on this continent and throughout the world. Studies have documented more than 20 million ha of forests from Canada to Mexico that have succumbed. Specific examples include more than 1 million ha of spruce in Alaska, more than 10 million ha of lodgepole pine and 1 million ha quaking aspen in Canada and more than 1 million ha of pinyon pine in the southwestern United States. In the eastern United States and Canada, red oak mortality and decline has been documented from Missouri to South Carolina, and a die off of maples in Quebec has also been linked to the effects of climate change.

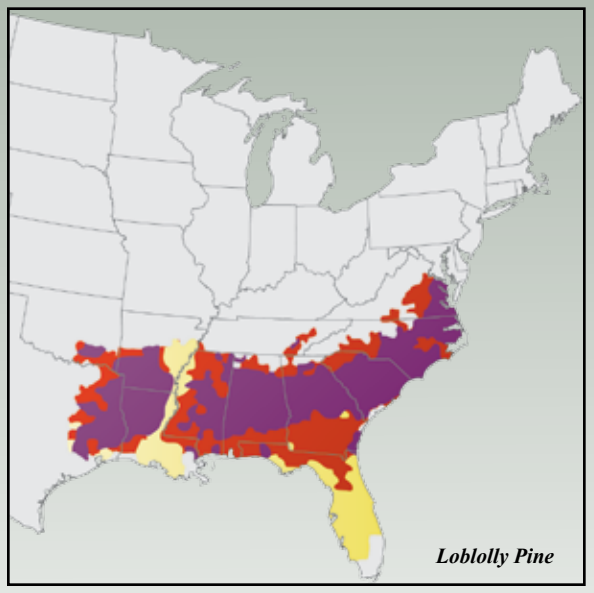
The U.S. Forest Service has made detailed models of three scenarios of increasing carbon emissions and has found that more pine (such as loblolly) and oak will shift their ranges northward. Furthermore, population declines of 10 to 50 percent are predicted for balsam fir, red and black spruce, black, sugar, and mountain maples, paper and yellow birch, and big tooth and quaking aspen. Finally, it is well documented that climate change is increasing the fire risk and insect pathogens in our forests today.

Some ecologists and conservationists point to birds as the "canary

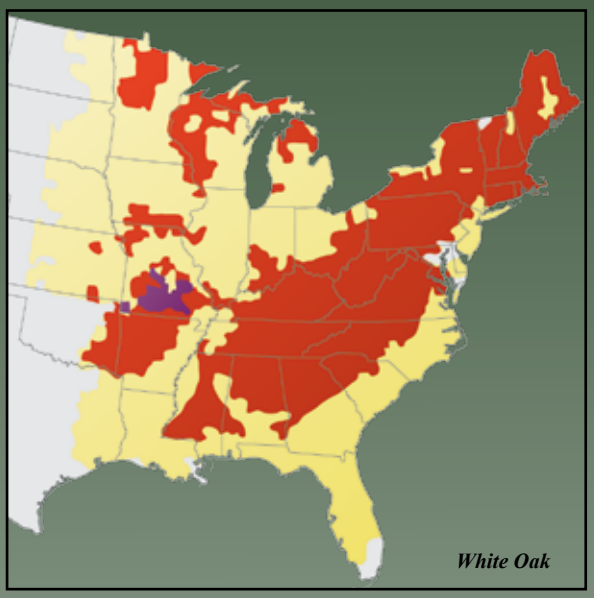
Current Ranges

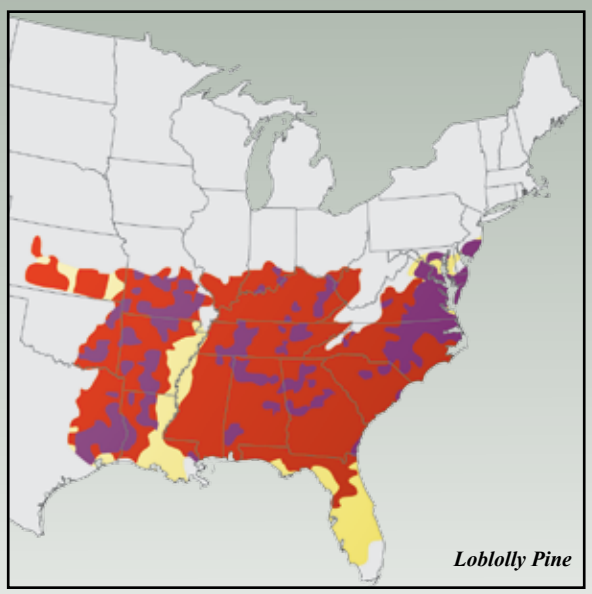






Projected Ranges





in the coal mine" with respect to how climate change will alter ecological systems today and in the future, but the real canaries are amphibians and reptiles. The harlequin frog and golden toad were once common in mountains of Costa Rica and about 20 years ago, they became extinct. In addition, 67 percent of the 110 species of Atelopus frogs endemic to the American tropics met the same fate. The disappearance remained a mystery until scientists discovered that changing climate and increasing temperatures have created the ideal environment for a pathogenic fungus that was the primary culprit. Climate change also affects other ecological factors. An increase in UV-B radiation can destroy or deform amphibian eggs and lead to significant population declines, as is the case with the Cascades frog and western toad in the western United States. Changes in soil temperature affect painted turtle eggs; warmer soil temperatures favor females over males, giving rise to a skewed sex ratio and localized extinctions of this once common and abundant turtle. Butterflies, fungi, mammals, fisheries, and oceanic systems such as coral reefs are all changing along with the climate.

Perhaps we can end on the terrestrial system side where we began, Thoreau's woods. As climate change stresses terrestrial systems and as disturbance regimes are altered, the potential for increased impact by invasive organisms grows larger because invasive plants are well suited to thriving in novel environments and beating out their competitors for resources. It stands to reason that the more we disrupt terrestrial systems, the better environment we create for invasive plants. At Walden Pond, Thoreaus's home in Massachusetts, invasive plants are winning the battle because they are better able to adjust their annual activities such as flowering and fruiting. In fact, 27 percent of the native species are already extinct, and 36 percent are so sparse that extinction is imminent.

About the Author:

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These three sets of range maps to the left show where white oak, sugar maple, and loblolly pine currently exist and where they are projected to be in the future. Based on these projections: white oak should be a Kentucky resident in the future; sugar maple will only be found in more northeastern parts of the U.S. and the tallest mountains in West Virginia; and loblolly pine will not only naturally be found in Kentucky but it will become much more important.

The maps show the importance value in the current ranges of the three selected tree species and the maps on the right show the importance value in the projected ranges of the species in the future. Importance value is an index value based on the number of stems and basal area of both the understory and the overstory—it is another way of looking at the particular dominance of a species within its range. The darker the color the more dominant that species is in that area. The projected range maps were generated by summarizing five different global circulation model scenarios and represent a best guess as to how these species ranges may change in the future. To explore other species and to learn more please visit the reference below.

Reference: Prasad, A. M. and L. R. Iverson. 1999-ongoing. A Climate Change Atlas for 80 Forest Tree Species of the Eastern United States [database]. www.fs.fed.us/ne/delaware/atlas/index.html, Northeastern Research Station, USDA Forest Service, Delaware, Ohio.