# Unexpected effect of climate change: Stream ecosystem responses to the 2007 spring freeze

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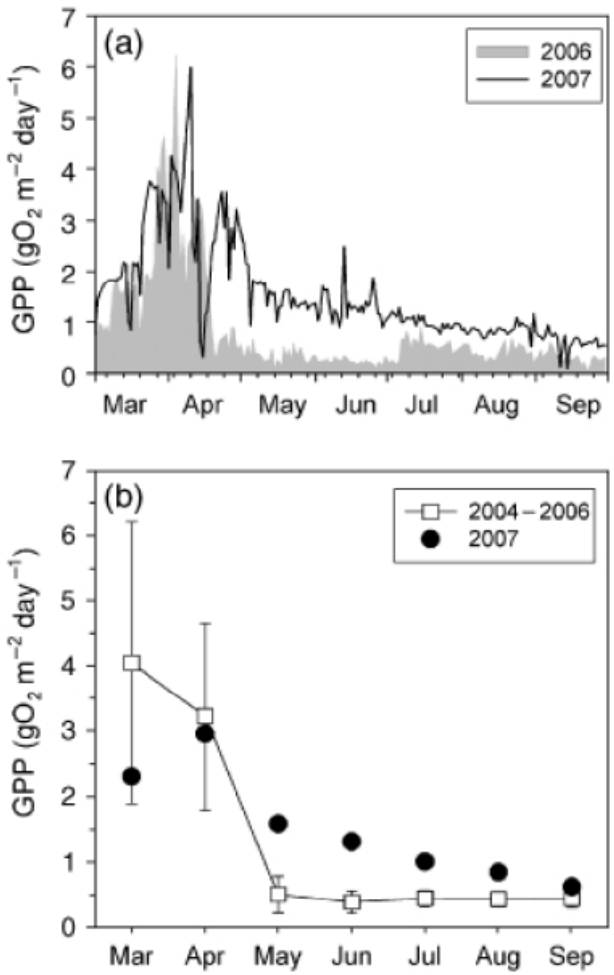
DOE/Office of Science/Biological & Environmental Research

- Climate records indicate warmer late winter periods in recent decades, but the date of last hard freeze remains highly variable with no long-term trend.
- In 2007, throughout much of the eastern United States, March was extremely warm, leaf emergence was early, and leaves of many trees were killed by a hard freeze in early April.
- Canopy foliar display never recovered to normal levels from freeze damage leading to sustained elevated light levels reaching forest streams on the Oak Ridge Reservation.
- Increased light levels produced a cascade of ecological effects in the stream including: higher gross primary production, nutrient uptake, and growth rates of the dominant stream herbivore (a snail).
- Our results suggest that a common effect of climate change may be a reduction in length and size of the late winter-early spring productivity pulse experienced by stream biological communities due to early leaf emergence. Such sustained responses could reduce nutrient uptake and food availability in stream ecosystems.



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Some expected changes in climate resulting from human greenhouse gas emissions are clear and well documented, but others may be harder to predict because they involve extreme weather events or heretofore unusual combinations of weather patterns. One recent example of unusual weather that may become more frequent with climate change occurred in early spring 2007 when a large Arctic air mass moved into the eastern United States following a very warm late winter. In this paper, we document effects of this freeze event on Walker Branch, a well-studied stream ecosystem in eastern Tennessee. The 2007 spring freeze killed newly grown leaf tissues in the forest canopy, dramatically increasing the amount of light reaching the stream. Light levels at the stream surface were sustained at levels considerably above those normal for the late spring and summer months due to the incomplete recovery of canopy leaf area. Increased light levels caused a cascade of ecological effects in the stream beginning with considerably higher (2-3 times) rates of gross primary production (GPP) during the late spring and summer months when normally low light levels severely limit stream GPP. Higher rates of stream GPP in turn resulted in higher rates of nitrate (NO3-) uptake by the autotrophic community and lower NO3- concentrations in stream water. Higher rates of stream GPP in summer also resulted in higher growth rates of a dominant herbivore, the snail *Elimia clavaeformis*. Typically, during summer months net NO3- uptake and snail growth rates are zero to negative; however, in 2007 uptake and growth were maintained at moderate levels. These results show how changes in forest vegetation phenology can have dramatic effects on stream productivity at multiple trophic levels and on nutrient cycling as a result of tight coupling of forest and stream ecosystems. Thus, climate change-induced changes in canopy structure and phenology may lead to large effects on stream ecosystems in the future.

**Mulholland, P. J., B. J. Roberts, W. R. Hill, and J. G. Smith. 2009. Stream ecosystem responses to the 2007 spring freeze in the Southeastern United States: Unexpected effects of climate change. *Global Change Biology 15: 1767-1776,* doi: 10.1111/j.1365-2486.2009.01864.x**.