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Latitudinal Variation in Carbon Storage Can Help Predict Changes in Swamps Affected by Global Warming

Baldcypress Swamps and Global Climate Change

Plants may offer our best hope of removing greenhouse gases (gases that contribute to global warming) emitted to the atmosphere from the burning of fossil fuels. At the same time, global warming could change environments so that natural plant communities will either need to shift into cooler climate zones, or become extirpated (Prasad and Iverson, 1999; Crumpacker and others, 2001; Davis and Shaw, 2001). It is impossible to know the future, but studies combining field observation of production and modeling can help us make predictions about what may happen to these wetland communities in the future.

Widespread wetland types such as baldcypress (*Taxodium distichum*) swamps in the southeastern portion of the United States could be especially good at carbon sequestration (amount of CO_2 stored by forests) from the atmosphere. They have high levels of production and sometimes store undecomposed dead plant material in wet conditions with low oxygen, thus keeping gases stored that would otherwise be released into the atmosphere (fig. 1).

To study the ability of baldcypress swamps to store carbon, our project has taken two approaches. The first analysis looked at published data to develop an idea (hypothesis) of how production levels change across a temperature gradient in the baldcypress region (published data study). The second study tested this idea by comparing production levels across a latitudinal range by using swamps in similar field conditions (ongoing carbon storage study). These studies will help us make predictions about the future ability of baldcypress swamps to store carbon in soil and plant biomass, as well as the ability of these forests to shift northward with global warming.

Figure 1. Oldgrowth baldcypress trees and knees at Cat Island Swamp (St. Francisville, La.). Although the actual function of knees is debated (Kramer and others, 1952), the height of knees is positively related to flooding (Kernell and Levy, 1990). Knees may anchor trees in storms and aerate stored photosynthates. To further complicate the debate on carbon sequestration (amount of CO_2 stored by forests from the atmosphere), knees emit methane, a major contributor of greenhouse gases, which contribute to global warming (Pulliam, 1992). The very tall knees pictured here likely are related to the water depths in Cat Island Swamp, which typically exceed 15 feet (4.6 m) during flood peaks. The pristine swamps used in the carbon storage study have natural hydrologies similar to Cat Island Swamp in that they experience water pulses from rivers during flood periods (winter and spring) but are either dry or with shallow water (drawdown; summer and fall). Baldcypress in the study swamps typically are hundreds of years old, and those at Cat Island Swamp are among the largest trees east of the Sierra Madre Mountains (Virginia Rettig, U.S. Fish and Wildlife Service, oral commun.). Benjamin Handley, Johnson Controls Inc., is pictured for scale (photo by Beth Middleton, USGS).

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Findings of the Published Data Study

Baldcypress swamps of the southern United States are ideal for the study of global climate change since they already occur in a large geographical region that spans many different temperature environments and latitudes. Accordingly, swamps in the South are already exposed to the environments that swamps in the North may be subjected to in the future with climate warming, as many researchers of climate change predict (Prasad and Iverson, 1999; Crumpacker and others, 2001).

Also, baldcypress swamps are dominated by only one or two species, making it possible to look at the climate effects on particular species in these communities. Individual species are expected to respond differently to climate change because they have individual ways of responding to temperature. If future temperatures become warmer, climates farther north may become similar to those presently in the south, providing us with an easy way to look at the effects of increased temperatures on species ranges and carbon storage ability. A study of the current rates of production across a latitudinal gradient can give insight into potential future changes as based on the inherent capability of species to respond to climate change (Middleton and McKee, 2004).

Our analysis of published data shows that litter production (amount of leaf, twig, and seed material produced) patterns are highest in the mid-range and lowest at the northern and southern extremes of the baldypress swamps region, a pattern that describes a curvilinear model (fig 2). By using litter production information along with ongoing studies of organic soil content, decomposition rates and standing crop biomass, future carbon sequestration patterns across these latitudes can be inferred from those of baldcypress swamps already experiencing a variety of climatic environments along this latitudinal gradient (fig. 3). To make predictions of the potential of species to shift northward, detailed information should be entered into models including dispersal limitations (Middleton, 2000, 2003), and physiological (inherent ability) and ecotypic (local variation) responses (fig. 2).

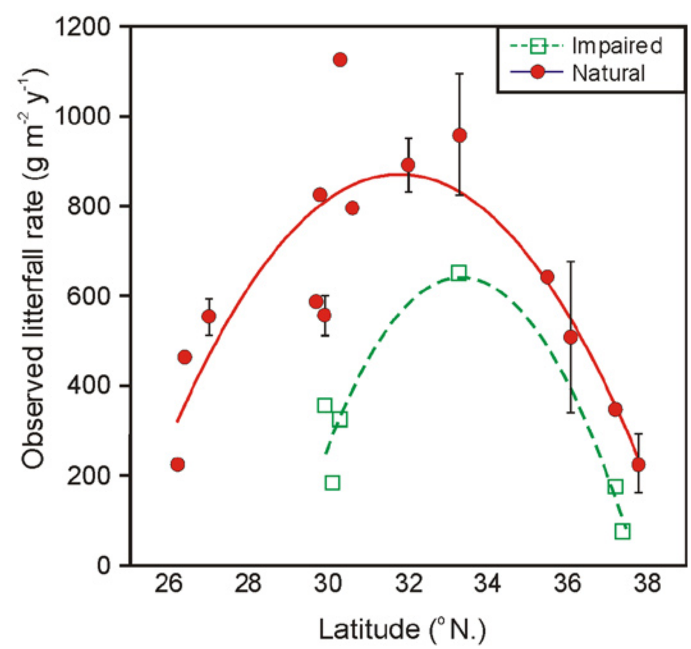

Figure 2. Analysis of published litterfall (leaves, wood and seeds) data of baldcypress swamps with natural vs. impaired hydrology (e.g. dam), which shows that litter production is higher in the middle part of the range (e.g., Arkansas) than either the northern or southern extremes of the range (Illinois vs. Louisiana; Middleton and McKee, 2004). Analyses of production levels across latitude compared with temperature can help us make predictions about future shifts in baldcypress distribution. Also, baldcypress swamps with impaired hydrology have lower production than swamps with natural hydrology, and the production is relatively more impaired in the South (latitude x latitude x type interaction: F = 4.38; p = 0.05) (Middleton and McKee, 2004; copyright with permission of *Global Ecology and Biogeography*).

Study Sites for the Latitudinal Test of the Curvilinear Model

To estimate production in similar field conditions across a temperature gradient, an ongoing study of litterfall and other factors related to carbon storage is being conducted in 30 baldcypress swamps within the North American Baldcypress Swamp Network (table 1 and fig. 4). Litterfall is collected in swamps by using floating litter collectors (fig. 5). This process was replicated at five different swamps in each of the six latitudes (fig. 4).

The seasonally flooded swamps are similar hydrologically; each is flooded in the spring/winter and drawn down in summer/fall. Swamps in the ongoing study have minimal hydrologic modification and fully developed canopies. Vegetation is a mix of baldcypress, water tupelo (*Nyssa aquatica*), and overcup oak (*Quercus lyrata*), but baldcypress is dominant. Many cooperators throughout the southeastern United States are involved in the North American Baldcypress Swamp Network

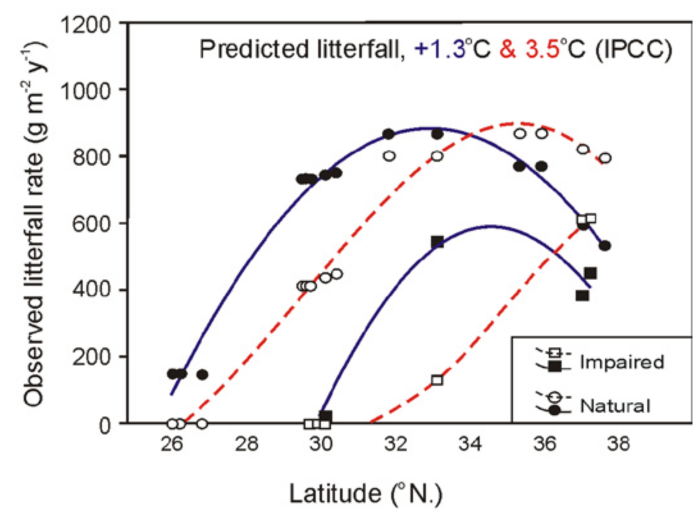

Figure 3. Predicted shift of baldcypress swamp distribution and production with a 1.3EC and 3.5EC increase in daily mean temperature (potential climate change as estimated by the Intergovernmental Panel on Climate Change). Note the southern end of the range is lost with increased warming, particularly in sites with impaired hydrology. Baldcypress swamps may not be able to migrate northward to keep pace with climate warming because of dispersal limitations (Middleton, 1999; Middleton, 2000), which is why the curves cut off in the northern latitudes (Middleton and McKee, 2004; copyright with permission of *Global Ecology and Biogeography*).

Table 1. Site names and managers in the North American Baldcypress Swamp Network for the ongoing study of carbon storage and test of the curvilinear model in the baldcypress swamp region.

State	Manager <email>	Site
Illinois	Kelly Neal <KNEAL@dnrmail.state.il.us> Jim Waycuilis <JWAYCUILIS@dnrmail.state.il.us> Bill Reynolds <BREYNOLDS2@dnrmail.state.il.us>	Heron Pond, Little Black Slough, Section 8 woods, Highway 37 bridge tract, Deer Pond State Natural Area
Tennessee	Randy Cook <randy_cook@fws.gov>	Reelfoot National Wildlife Refuge (NWR) (Lake Isom, Grassy Lake, Long Point (north, east, west))
Arkansas	Richard Hines <richard_hines@fws.gov>	White River NWR (Swan Lake/Sandy Bayou, Goose Lake, Turner Lake, Essex Bayou, Burnt Lake)
Mississippi	Travis Carpenter <travis_carpenter@fws.gov> Chris Woodson <chris_woodson@fws.gov> David Linden <david_linden@fws.gov> Tim Wilkins <tim_wilkins@fws.gov>	Hillside NWR (Black Creek, Upper Bear Lake, Bear Lake, Tipton Bayou, Morgan Brake)
Louisiana (north)	Jerome Ford <jerome_ford@fws.gov> Stanley Howarter <stanley_howarter@fws.gov>	Tensas River NWR
Louisiana (south)	Virginia Rettig <virginia_rettig@fws.gov> Jim Baker <jim_baker@fws.gov>	Cat Island NWR (checkstation, Blackfork trail, lateral canal, Blackfork Lake)
Texas	Mike Lange <mike_lange@fws.gov>	Brazoria NWR, Fort Bend County
Delaware/ Maryland	Bill McAvoy <william.mcavoy@state.de.us> Doug Samson <dougsamson@tnc.org> Dwight Williams <dwilliams@dnr.state.md.us>	Murderkill and St. Jones Rivers (Del.); Pokomoke Cypress Swamp and Nassawango Creek and Battle Creek Cypress Swamp (Md.)
Florida	Jim Birch <jim_birch@nps.gov> Julio Cruz <julio_Cruz@nps.gov>	Big Cypress (N.P.D) and Corkscrew Swamp (NAS)

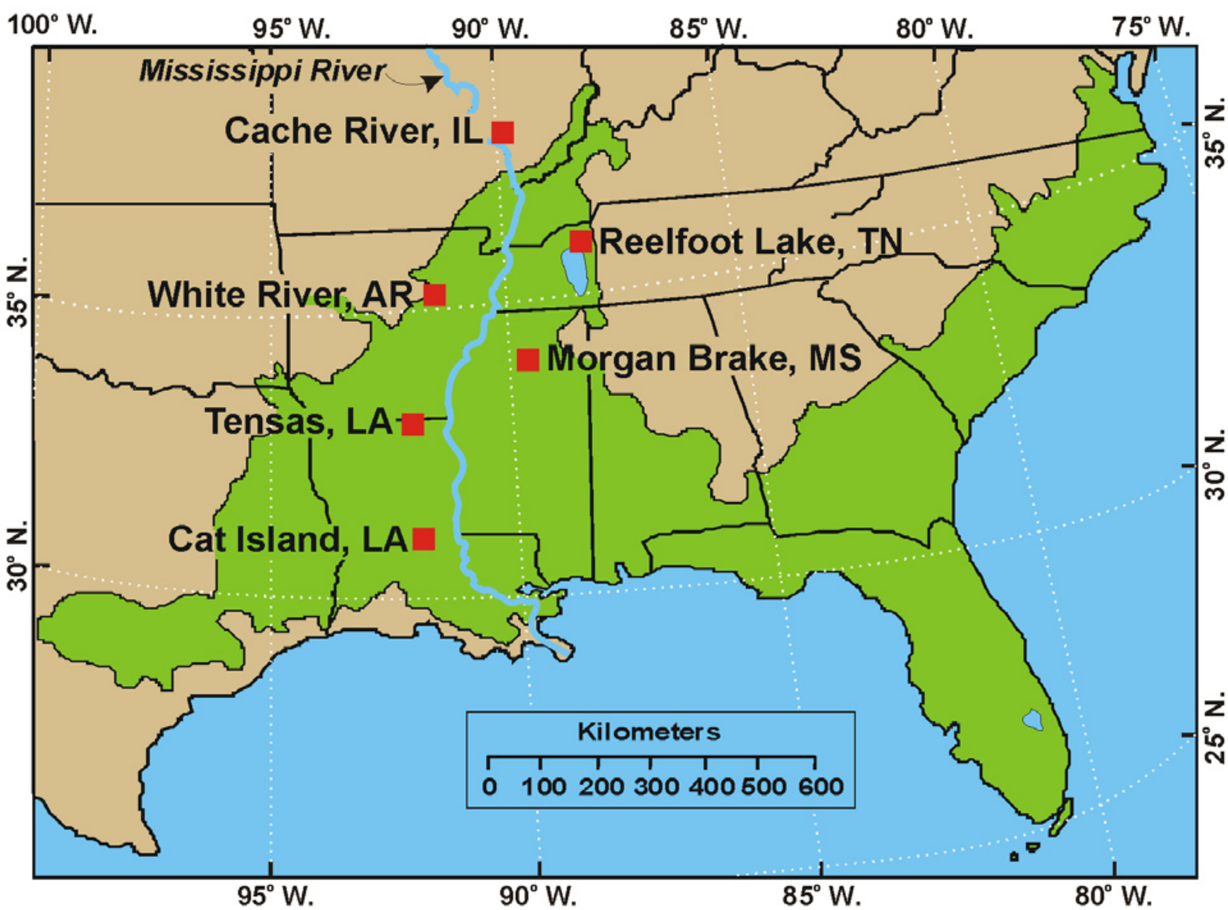

Figure 4. Locations of the study sites for the ongoing study of leaf litter production and carbon storage in the North American Baldcypress Swamp Network of the Gulf Coastal Plain. We replicated this study at the landscape level by conducting these experiments at five different swamps in each of the six latitudes. This study is designed to test the curvilinear model from the published data study, by collecting data in standardized field conditions.This ongoing study has important implications for distribution and carbon storage patterns across the range of widespread ecosystem types. Environmental conditions in each swamp are as similar as possible: forests are dominated by baldcypress, and hydrology is natural (flooded in spring/winter, drawdown in summer/fall). The study will be expanded to include sites in Texas, Delaware, and Florida.

Figure 5. Litterfall collector for the production study (latitudinal test of the curvilinear model). The collectors float on the water. The foil inside of the trap is covered with Tanglefoot© (flypaper glue) so that leaves, twigs, and seeds that fall on the trap are captured (Middleton, 1995).

(table 1); the sites are on U.S. Fish and Wildlife Service lands, except for those in Illinois (fig. 4). The study will eventually be expanded to include the far extremes of the range in Texas, Delaware/Maryland, and Florida. Other carbon storage information is being collected including root production, above ground storage (trunks, knees, roots), decomposition rates, soil percent carbon, and soil carbon accumulation.

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