Swamped by Climate Change?

Ancient wetlands defy modern rules of survival

By RICHARD MONASTERSKY

Something is growing in the recesses of the Smithsonian Museum of Natural History, behind the dinosaur displays and the mounted African bush elephant, beyond the mobs of schoolchildren whose chatter fills the main hall. In a quiet side wing of the museum, an idea is taking shape. Two researchers who study the fossilized remains of ancient swamps are developing a new picture of how life survives in the face of change.

Paleontologists William A. DiMichele and Scott L. Wing gaze back through time to two long-ago eras when wetlands covered vast regions. DiMichele turns his clock back 315 million years to a period long before dinosaurs walked the land. Wing sets his timepiece at about 55 million years ago, 10,000 millenia after the gargantuan reptiles had bellowed their last song.

Sifting through swampland fossils from those disparate periods, both researchers have drawn the same startling conclusion: The distant past may have followed evolutionary rules far different from those that shaped today's environment.

Ecologists view the modern world as an arena of continual change, especially within the last 2 million years as a series of ice ages has sent huge glacial sheets sweeping periodically back and forth over much of North America, Europe and Asia. In such times of unstable climate, communities of organisms apparently lack stability. The situation resembles a neighborhood where families come and go so quickly that they never have time to form lasting friendships with their neighbors. Ecologists conclude that animals and plants live together in a particular community for only a few thousand years before the community disintegrates. Within this topsy-turvy environment, it seems, neighbors don't coexist long enough to influence each other's evolution.

But in the swamps of yesteryear, Wing and DiMichele see a different mode of life — one where various types of trees live side by side for millions of years in a seemingly stable community, even as the climate goes through major changes. This, they say, suggests that the instability of the modern world may not offer a true portrait of the rest of Earth's history.

"If that's true, that would be fantastic because it would imply there are two different styles of evolution," says paleontologist David Jablonski of the University of Chicago.

But the swampland findings could also have chilling implications for how forests and other ecosystems might react to a future global warming.

DiMichele gleans his evidence of stability from fossils found within coal seams throughout the central United States, western Europe and parts of the Soviet Union. Around 315 million years ago, during the Pennsylvanian period of Earth's history, these regions formed the tropical belt of a huge supercontinent that straddled the equator. By studying tens of thousands of plant fossils from the coal seams, DiMichele and Tom L. Phillips of the University of Illinois in Urbana-Champaign have reconstructed the Pennsylvanian wetland forest.

A time traveler from today's world would have a hard time recognizing the trees in this forest, especially the strange lycopods that ruled the ancient swamps. Lycopods exist today, but only as small, grass-like plants. During the Pennsylvanian, they towered as high as 130 feet.

And unlike modern trees, which rely on their wood for structural support, the lycopods were more bark than anything else. They spent most of their existence without branches, sprouting a small crown of limbs only near the end of their lives as they prepared to reproduce.

Dominated by limbless lycopods, the Pennsylvanian swamp would have looked like "a forest of telephone poles," DiMichele says. Insects, huge millipedes, primitive amphibians and walking fish made their lives among these trees.

Lycopods dominated the wetlands because they could endure the nutrient-poor, harsh environment better than most other plants. Like conquerors splitting up a vanquished land, various lycopod species divided the swampland among themselves. Some grew in the water, some took root in drier regions, and others sprang up in places recently cleared by fire.

As DiMichele and Phillips tracked the kinds of trees that grew in the ancient swamps, they found that the same general types of lycopods controlled the swamplands for 9 million years — an incredibly long period compared with the fleeting existence of modern ecosystems. Individual lycopod species didn't survive through the entire time span, but as one species died out, a very similar one would arise to take its place. DiMichele calls this "replacement on a theme."

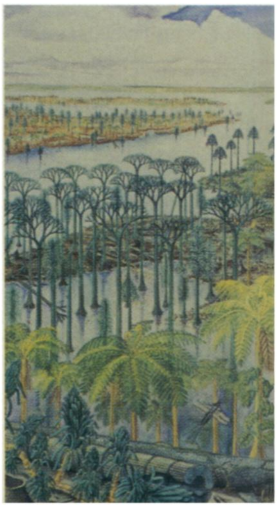
The geologic record shows that the environment changed throughout this period. As sea levels slowly bobbed up and down, the lowland swamps alternately flooded and drained. At times, the climate of the tropics dried out and the swamplands shrank.

But even during such periods of stress, the same basic wetland community persisted throughout the tropics. It was as if some sort of fabric connected the different lycopods, keeping the community together even during times of upheaval, DiMichele says. To put it another way, the swamp's stability may have resembled that of an exclusive country club: Although individual members leave town or die, the nature of the club remains the same because its membership requirements do not change.

About 306 million years ago, however, the fabric of the swamp disintegrated. "All hell broke loose," DiMichele says. The climate dried severely, most swamps disappeared, and a wave of extinctions wiped out virtually all lycopods within the tropical belt.

Then, as the climate grew wetter again and swamps reemerged, weedy plants called tree ferns crowned themselves the new monarchs of the wetland world.

Some 245 million years later, during the Paleocene epoch, the face of the planet looked radically different.



Swamp life during the Pennsylvanian time: The lycopod trees in the background dominated the swamp for 9 million years. Tree ferns, seen in front with their drooping branches, succeeded the lycopods.

The continents no longer huddled together along the tropics, and a growing ocean separated North America from Europe.

Large wetlands again covered portions of the North American interior, but they bore no resemblance to the telephone-pole forests of the Pennsylvanian period. Instead, the conifers that filled the Paleocene swamps looked much like the bald cypresses that now inhabit the wetlands of the southeastern United States. Alders, birches and other flowering trees also lived in the swamps, but the conifers ruled. On the animal side, early forms of many modern mammals had evolved, including hippopotamus-like herbivores, dog-sized horses, lemur-like primates and toothless anteater look-alikes. The fossilized remains of these plants and animals appear in the shale rocks of Wyoming and nearby states.

Although the Paleocene swamps studied by Wing contrasted markedly with the Pennsylvanian swamps studied by DiMichele and Phillips, Wing finds they behaved similarly.

"For a period of at least 5 million years and probably longer, the composition of the swamp community changed very little," he says. By analyzing fossilized pollen within the rocks, Wing says he has traced the swamp history over extremely brief geologic intervals of a few hundred to a few thousand years. And even during these short periods, he sees very little change.

Like their Pennsylvanian counterparts, the Paleocene swamps had to endure periods of dryness and periods of flooding. But each time the swamps resurged, they held the same general community of plants, dominated by the conifers. When one type of tree died out, a similar version would replace it – variations on a theme, once again.

About 55 million years ago, the theme changed completely. The climate turned extremely dry, and the swamps disappeared for 2 million years. On their return they brought a very different forest, ruled not by conifers but by a diverse group of flowering trees. The old order had fallen.

Wing and DiMichele describe this sort of ecological pattern as a threshold effect. When the climate undergoes drastic changes, the fabric of the community unravels completely, allowing the establishment of a new community order. But if climate changes stay below a certain threshold level, they propose, the fabric remains strong enough to sustain the community's basic theme. Newcomers must fit into the "holes" of the fabric.

While the two researchers have been drafting these ideas about stability and thresholds for several years, they publicly presented their cases for the first time in July at the Fourth International Congress on Systematics and Evolutionary Biology, where they organized a special symposium on biological stability. Other scientists at the symposium reported additional evidence of communities that remained stable for millions of years, based on studies of Pennsylvanian marine animals.

Such findings could have broad implications for theories about evolution, says Wing. In a community that lasts only 10,000 years or so, species seemingly don't coexist long enough to influence their neighbors' evolution, whereas a community that persists for millions of years would give its members time to evolve with each other and adapt to each other's presence.

The evidence for stability, however, conflicts with current ecological theories. "Long periods of stability just don't square with what we have been taught for years about how ecosystems work; it just isn't supposed to be that way," says Wing.

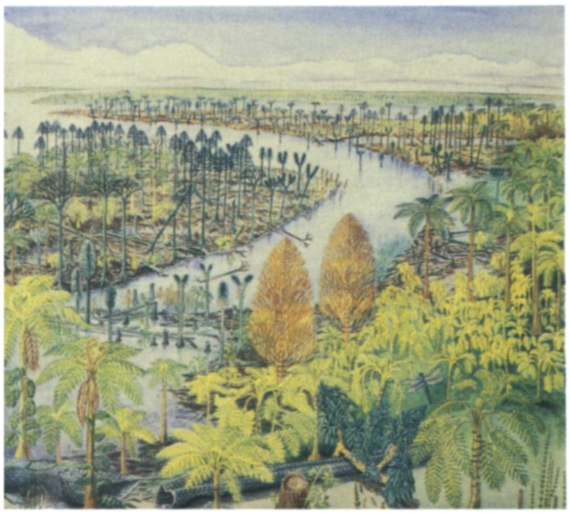
Ecologists draw most of their stability rules from studies of the present or the recent past, largely because these are the easiest times to investigate in detail. The prevailing belief that communities are fleeting rests in part on pollen retrieved from lakes and bogs. By comparing pollen from successive sediment layers, paleobotanists have traced changes in North American forests over the last tens of thousands of years.

Thompson Webb III, an ecologist at Brown University in Providence, R.I., says these records show that different plants do not form long-lasting associations with one another. For example, he notes, the boreal forests of northern Canada currently contain a particular mix of tree types – mostly spruce, along with firs, pines and birches. But pollen studies indicate the modern boreal forest represents a relatively new community that developed only 8,000 years ago although similar mixes of trees may have coexisted during previous interglacial periods.

Webb maintains that species react to climate change individually rather than as members of a group held together by ecological glue. The "every species for itself" rule manifested itself clearly in the northern midlatitudes at the end of the last ice age, when climate warming forced a grand reorganization in the plant world. Instead of forests migrating northward *en masse* to escape rising temperatures, tree species dispersed in different directions and many once-successful organisms grew rare, Webb says. Some species moved west to find more moisture, others traveled east for the cooler summers, and still others went north for the cooler winters. With each shift in locale, the plants found themselves entering into new associations with other species, as if taking part in a square dance where the partners constantly change.

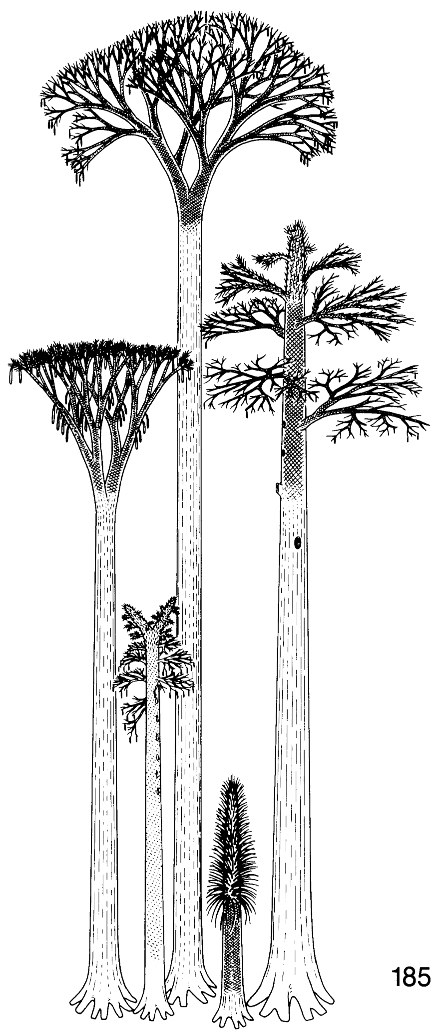
This type of reorganization goes on all the time in response to the constantly shifting climate, Webb says, as even minor climate changes spur alterations in the community.

Wing and DiMichele argue that modern times may be atypical and that life on Earth has not always followed today's rules. "We're trying to bring ancient systems into the debate about stability of ecosystems, because right now, they are not really



Phillips

Lycopods on display: The four tallest trees represent different species of lycopods all in the reproductive growth phase. Prior to that stage, most species looked like the branchless juvenile.

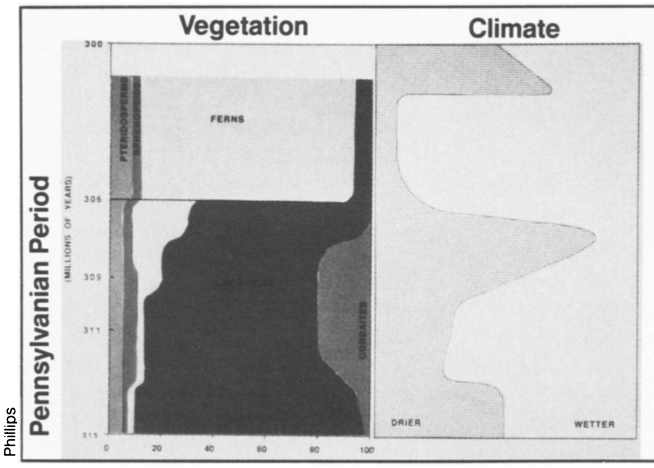


DiMichele

included as part of the picture for how ecosystems behave over a long period of time," DiMichele says.

Evidence from the ancient swamps will force scientists to take a more realistic look at evolution in the past, adds paleontologist Jablonski. "What it tells us is that there may be more than one way for communities to behave, and that's very important for understanding the broad outlines of evolution and how it works," he says.

To a certain extent, however, stability rests in the eye of the beholder, cautions ecologist James A. MacMahon of Utah State University in Logan. He suggests that communities may lack stability over short periods, such as those examined by most ecologists, while maintaining general stability over the longer spans studied by paleontologists. Moreover, he says, whether or not a scientist sees stability may depend on his or her definition of community. For instance, one researcher might view a vast territory as a single neighborhood while another focuses on a fraction of that space.



Phillips

Life at the threshold: Lycopods maintained their control over the Pennsylvanian swamps even as the climate went through changes. After a severe drying of the climate, however, tree ferns took over.

Such caveats aside, the woodlands of the past may have had good reason for behaving differently from those of today. "One has to recognize the peculiarities of the modern world, which has developed during a glacial period with a highly variable climate," notes ecologist Margaret B. Davis of the University of Minnesota in Minneapolis. DiMichele and Wing are suggesting, she says, "that maybe if the climate were not as highly variable, evolution would take place in a different manner."

The Smithsonian paleontologists think their tales from the swamps might hold an unsettling message regarding the threat of a global warming. If the planet warms in the future as many scientists predict, temperature and rainfall patterns could shift faster than ever before, placing unprecedented levels of stress on the environment. And if biological communities have a certain threshold for climate change, as DiMichele and Wing suggest, ecosystems such as the boreal forests might show no signs of weakness until stress crosses that threshold and the communities abruptly collapse.

"The idea of a threshold makes the world less predictable," warns DiMichele.

He and Wing acknowledge that they've ventured far into the realm of speculation in considering implications for the future. It's possible, they say, that the behavior of ancient swamps bears little relevance to what will happen in the next few centuries.

"None of us feel that the past is a crystal ball. It's a cracked and warped mirror, but it's the only mirror we've got," says Wing. "It's not perfect by a long shot, but it certainly leads you to be cautious." □