# Fungi living in cattail roots could improve our picture of ancient ecoystems

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Lead author Az Klymiuk in waders collecting cattail roots. Credit: Az Klymiuk, Field Museum

Paleobotanist Az Klymiuk didn't set out to upend science's understanding of the fossil record of plant-fungal associations. She just wanted to figure out the environment that some fossil plants lived in. That question led her to look at modern cattail roots and the fungi that live inside of them. She found that fungi have a harder time growing in cattail roots that are underwater. And that discovery, which is being published in the journal *Mycologia*, could change how we interpret some parts of the fossil record, including an important community of early land plants.

"I was studying fossil plants that are 48 million years old. In these fossils, we can see the plant cells and everything in them, including fungi. In describing these fossil fungi, I realized we actually don't know much about fungi that are living in wetland plants today," says Klymiuk, the Field Museum's collections manager of paleobotany and lead author of the *Mycologia* study. "There's been very little work done, next to nothing in terms of their ecology and distribution."

Fungi, which include mushrooms, molds, and yeasts, aren't plants—they're their own separate kind of organism, more closely related to animals than anything green. But almost all land plants have tiny fungi living inside their roots. These microscopic fungi grow tendrils that snake out into the soil, where they can break down dirt and absorb the element phosphorus that's present in the soil and rocks. The plant host then uses that phosphorus to create energy (bonus points if you remember from high school biology that the energy comes in the form of a molecule called adenosinine triphosphate—ATP). Without the fungi, the plants have a much harder time pulling phosphorus from the soil. All this is to say, plants need the fungi living in their roots so that they can create the energy they need to survive. In addition to these "helpful" fungi, plants also host an enigmatic group of fungi called dark septate endophytes—the verdict is still out on whether these fungi are weak parasites, latent pathogens, or helpful partners. What we do know is that most plants host them, including the fossil plants Klymiuk worked with.

Klymiuk was curious about the possible ecological roles of these fungi, but was also intrigued by why some fossil plants had lots of root fungi and others had very few. Since these fossil plants were from areas that had been swampy wetlands millions of years ago when the plants were alive, she decided to look for clues in modern wetland plants, which have a lot in common with the ancient ones: cattails.

Fungi from cattail roots in Petri dishes. Credit: Az Klymiuk, Field Museum

To do this, she collected cattail roots from several wetlands, sampling plants from the shoreline all the way to the deepest point at which they grew. "I was out there in hip waders with my undergraduate assistants, and we were digging up cattails. You get in there with a shovel, and you just yank up this giant plant that's as tall as you," says Klymiuk, who began work on the project at the University of Kansas with co-author Benjamin Sikes. "Memorably, in one reservoir, I had literally just told Abby [my undergraduate] to watch out because there was a sharp drop-off, and what'd I do? Ker-splash, right over. It was our last site that day, so thankfully we were close to the lab, which meant I could at least do a fast wardrobe change before we did sample prep."

Back in the lab, she examined the roots under a microscope and compared the fungi in cattail roots that had been growing at different depths underwater. She found that, at least in these cattails, the fungi don't do well with inundation at all. It didn't matter if they were growing in two inches of water, or four feet—cattails growing in water had very little fungi in their roots. Up on dry land, however, cattails had plenty of fungi living in their roots, comparable to grass roots Klymiuk collected alongside the cattails. "It turns out that any degree of flooding whatsoever massively suppresses the amount of fungi in plant roots," says Klymiuk.

Since the number of fungi living in plant roots appears to indicate whether the plants are growing fully in water or up on the shoreline, scientists looking at fungi in fossil plant roots can make a better guess about what environment those plants lived in. "This gives us a new way to understand what we're seeing in the fossils," says Klymiuk. "I have some roots where fungi are completely absent. I can look and look and look and there's nothing there. I have other roots that are just loaded, packed. To me, that indicates that we're dealing with different levels of inundation. I feel pretty confident saying that when we find a lot of fungus in a plant root, that root was probably not inundated during its life."

As well as giving scientists a new tool for figuring out what some prehistoric ecosystems were like, this study also suggests that some of our understanding of the fossil record of plant-fungal interactions might need recalibrating. "There's been this pervasive narrative, all across biology," Klymiuk says. "The basic idea is that plants needed fungi to get out of water, to get onto land. The oldest preserved community of land plants, the 407 million-year-old Rhynie Chert, is often cited as fossil evidence for this. This community of land plants has mostly been interpreted as a wetland assemblage associated with hot spring overflow or outwash, and many of these early land plants hosted mutualistic fungi, just like most living plants do today. What my research suggests, is that these plants were probably victims of intermittent flooding, as opposed to living right in the water."

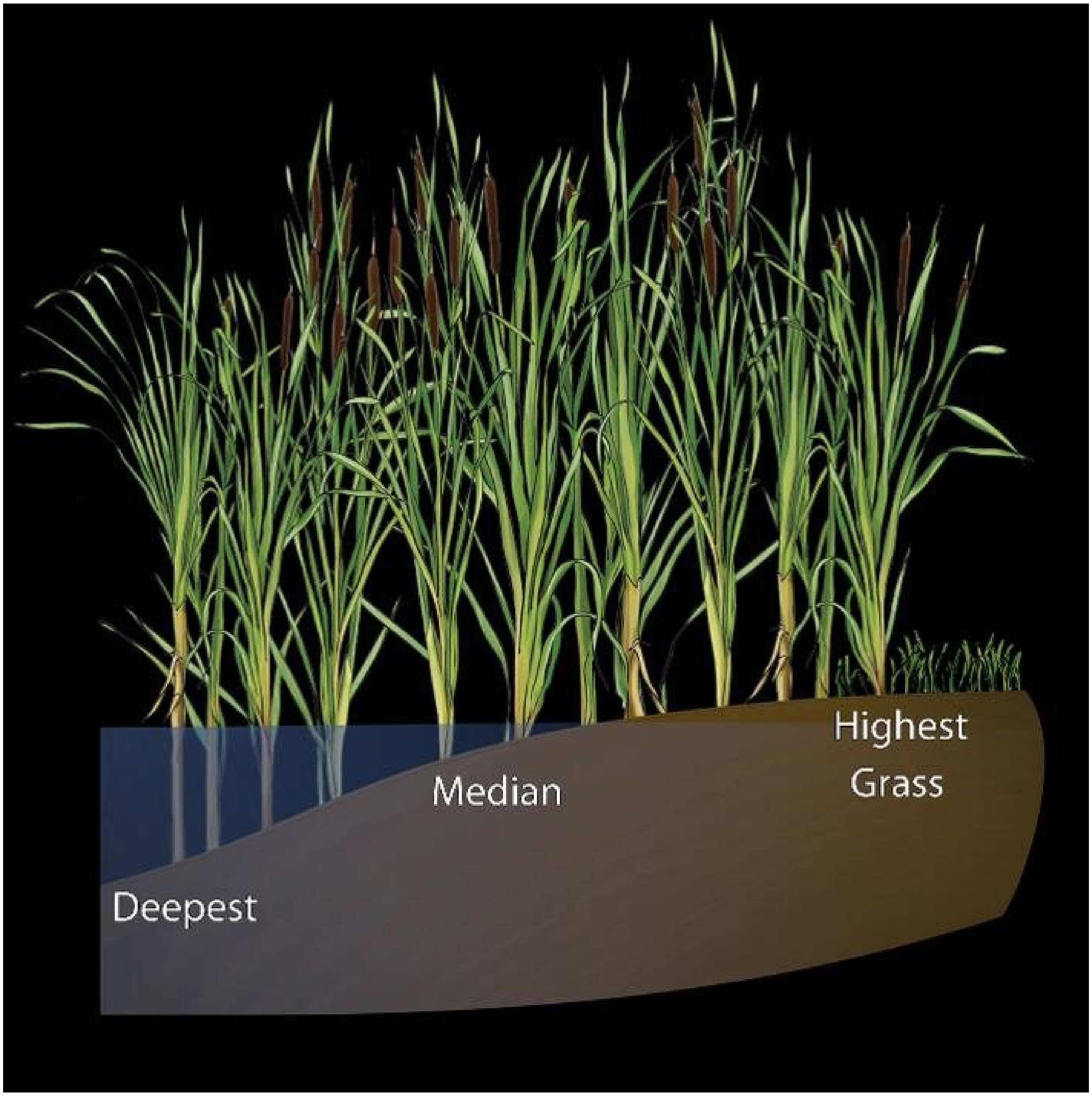


Illustration showing cattails growing at different inundation levels. Credit: Az Klymiuk, Field Museum

So did plants need fungal helpers to get onto land? "I don't disagree that they found fungal partnerships extremely useful once they were on land, but I don't think proto-plants would have needed to bother with them if they were in water, because phosphorous is readily bioavailable in water," says Klymiuk. "My personal feeling is that the earliest land plants were probably never in water to begin with. There are lots of groups of green algae that are fully terrestrial. I think it's very possible that land plants evolved from fully terrestrial green algae, and that water was a secondarily-invaded habitat. Stay tuned, there's a lot of really cool research emerging on this question."

Klymiuk's work doesn't just speak to the past, but also sheds light on future life on Earth. "It's important for us to understand these relationships because so many of our crops and forests are under stress due to climate change," says Klymiuk. "Not only are we dealing with more flooding, and of longer duration (and more droughts, and more everything), but it's very probable that the way in which plant-fungal interactions work will change as we continue to move into a higher CO2 world—we know that some groups of fungi are 'better roommates' under low CO2 than high; they pay their rent on time. Increase the CO2 and suddenly some of them are falling behind on phosphorus-as-rent, or ordering pizza on their host's credit card (using excess photosynthates at cost to the host plant). I can draw this analogy out in twelve different ways, and it will always end with 'we don't know enough about how these systems function in order to generalize or predict anything with confidence yet.' It's still seriously understudied."

Beyond the potential applications of this work, Klymiuk says she's excited about the project for the sake of discovery. "There's this mysterious, microscopic world that we don't usually think about. I'm genuinely fascinated by plants and their evolution, because so much of paleobotany is detective work. I just get excited by putting these puzzles back together and chipping away at some fundamental mysteries."

Provided by Field Museum