Salt marsh grass on Georgia's coast gets nutrients for growth from helpful bacteria in its roots

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School of Biological Sciences researchers set up a study site near Dean Creek on Sapelo Island. Credit: Joel Kostka Lab

Salt marshes cover much of the state of Georgia's coast and perform key "ecosystem services" for people. They clean the water, protect coastlines against storm surges, and provide a habitat for fish and shellfish. A new study from a team of Georgia Tech School of Biological Sciences researchers finds that a species of grass that dominates those marshes has bacteria in its roots and surrounding soil that affects productivity by providing nutrients, highlighting the importance of soil microorganisms in the entire ecosystem.

The study, "The core root microbiome of Spartina alterniflora is predominated by sulfur-oxidizing and sulfate-reducing bacteria in Georgia saltmarshes, U.S." is published in *Microbiome*. The research team includes Georgia Tech Ph.D. students Jose Rolando (the study's lead author) and Tianze Song; Max Kolton, a former postdoctoral researcher, now senior lecturer and principal investigator with Ben-Gurion University of the Negev in Beer Sheva, Israel; and corresponding author Joel Kostka, professor and associate chair for Research in the School of Biological Sciences with a joint appointment in the School of Earth and Atmospheric Sciences, who is also a member of Georgia Tech's Center for Microbial Dynamics and Infection.

The study shows that diverse and abundant microbes associated with spartina cordgrass help mineralize sediment organic matter and release bioavailable nutrients to the plant, suggesting that the microbes help support plant productivity.

The work could assist efforts to restore salt marshes that will help to strengthen the coastline to be more resilient in the face of sea level rise and climate change.

Kostka says about 40% of salt marshes have disappeared in the U.S. over the past 100 years. "So coastal ecosystem restoration has become a huge field, with an important goal to manage or restore marshes so that they continue to provide critical ecosystem services to people," he explains.

Kostka adds that certain bacteria benefit plants not only by removing potentially toxic sulfide from the root zone, but also by giving the plant nutrients and potentially carbon. "In other words, this is an example of how we think the classic lines might be blurred by what we generally think of as autotrophs (plants that grow via photosynthesis) and heterotrophs (microbes) in ecosystems."

Dean Creek off of Lighthouse Road at low tide on Sapelo Island near Georgia's coast. Credit: Joel Kostka Lab

Sulfur in the roots

The study was conducted at salt marshes near Sapelo and Skidaway

Islands on the Georgia coast in 2018 and 2019. There, ocean water washes over the salt marsh grasses, and that water is rich in sulfate. "Sulfide is a phytotoxin or plant toxin," Kostka says. "A lot of sulfide will kill plants or at least stress them out, but when you add just a little bit (to Spartina alterniflora), it fuels microbial factories in the plant roots."

Kostka's team found that Spartina alterniflora has concentrated sulfur bacteria in its roots, and those bacteria are in two categories: sulfur oxidizers, which use sulfide as an energy source—"then you have sulfate reducers which breathe or respire sulfate from seawater, producing sulfide."

In this microbial cell factory, bacteria are using sulfide as an energy source to fix nitrogen—and possibly carbon—which then is passed to the grasses. Nitrogen fixation happens when a microbe takes nitrogen gas from air or water and makes usable ammonium out of it. In nature, soil microbes primarily perform this process—occasionally lightning in the atmosphere can also spark it.

The study's findings suggest that fixation is happening via chemoautotrophy (using chemical reactions for energy) by bacteria living inside the plant roots.

"The next chapter of this story is to learn how the plant and bacteria exchange nitrogen and the environmental controls of that exchange," Kostka says. "We also know these bacteria can fix carbon, and could potentially be passing carbon to the plant. The plant may have a cell factory that's making biomass from chemical energy rather than photosynthesis."

Spartina alterniflora, the dominant plant in salt marshes on the Atlantic and Gulf coasts of the U.S, in the Dean Creek marsh. Credit: Joel Kostka Lab

Finding climate clues in plants

The new study's research in salty wetlands is similar to climate-related work Kostka leads on peat mosses in freshwater bogs at the Spruce and Peatland Responses Under Changing Environments (SPRUCE) research facility in northern Minnesota. The facility is managed by the U.S. Department of Agriculture's Forest Service and the Oak Ridge National Laboratory.

A study Kostka and his team published in 2021 showed that warming peat bogs are releasing higher amounts of the greenhouse gas methane that is trapped inside them. Peatlands comprise just about 3% of the Earth's landmass, but they store around one-third of the planet's soil carbon. As they warm, bogs may also start releasing more carbon along with their methane into ecosystems, a harmful one-two punch for the environment.

The saltwater marshes that Kostka's team studies have also been termed "blue carbon" sinks because they act to mitigate climate change by sequestering large amounts of carbon from the atmosphere on a global scale. "Salt marshes or coastal marshes are not only critical as habitat for fish and shellfish that we like to eat—along with other vegetated coastal ecosystems—they store as much or more carbon as the remainder of the seafloor," Kostka says.

A triumph for omics, and what's next

Kostka credits 'omics', technologies which allow for the study of microbes in the environment without cultivation, for advances in uncovering microbiomes—all the microorganisms in a specific environment. Metagenomics and metatranscriptomics, the sequencing of all genes or expressed genes in the environment, allows scientists to chart the potential for microbes to carry out important ecosystem functions like nitrogen fixation. This is critical since very few microbes out of the large diversity that is out there can be grown in the lab, Kostka explains.

"The work is another example of how we are uncovering plant microbiomes—the microbes that live inside or on the tissues of environmentally relevant plants that help the plants to grow better," Kostka adds. "If we can add microbes to the roots when we plant them, and therefore increase the survival of those plants, we can improve restoration efforts."

More information: Jose L. Rolando et al, The core root microbiome

of Spartina alterniflora is predominated by sulfur-oxidizing and sulfate-reducing bacteria in Georgia salt marshes, USA, *Microbiome* (2022).
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