

# From roots to resilience: Investigating the vital role of microbes in coastal plant health

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Georgia Tech researchers surveying field sites in the salt marshes of Sapelo Island, Georgia. Credit: Georgia Institute of Technology

Georgia's saltwater marshes—living where the land meets the ocean—stretch along the state's entire 100-mile coastline. These rich ecosystems are largely dominated by just one plant: grass.

Known as cordgrass, the plant is an ecosystem engineer, providing

habitats for wildlife, naturally cleaning water as it moves from inland to the sea, and holding the shoreline together so it doesn't collapse. Cordgrass even protects human communities from tidal surges.

Understanding how these plants stay healthy is of crucial ecological importance. For example, one known plant stressor prevalent in marsh soils is the dissolved sulfur compound, sulfide, which is produced and consumed by bacteria. But while the Georgia coastline boasts a rich tradition of ecological research, understanding the nuanced ways bacteria interact with plants in these ecosystems has been elusive. Thanks to recent advances in [genomic technology](#), Georgia Tech biologists have begun to reveal never-before-seen ecological processes.

The team's work was [published](#) in *Nature Communications*.

Joel Kostka, the Tom and Marie Patton Distinguished Professor and associate chair for Research in the School of Biological Sciences, and Jose Luis Rolando, a postdoctoral fellow, set out to investigate the relationship between the cordgrass *Spartina alterniflora* and the [microbial communities](#) that inhabit their roots, identifying the bacteria and their roles.

"Just like humans have [gut microbes](#) that keep us healthy, plants depend on microbes in their tissues for health, immunity, metabolism, and nutrient uptake," Kostka said. "While we've known about the reactions that drive nutrient and carbon cycling in the marsh for a long time, there's not as much data on the role of microbes in ecosystem functioning."



Georgia Tech postdoctoral fellow Jose Rolando (right) and graduate student Gabrielle Krueger prepare samples for chemical analysis in the field at Sapelo Island, Georgia. Credit: Georgia Institute of Technology

## Out in the marsh

A major way that plants get their nutrients is through [nitrogen fixation](#), a process in which bacteria convert nitrogen into a form that plants can use. In marshes, this role has mostly been attributed to heterotrophs, or bacteria that grow and get their energy from organic carbon. Bacteria that consume the plant toxin sulfide are chemoautotrophs, using energy from sulfide oxidation to fuel the uptake of carbon dioxide to make their

own organic carbon for growth.

"Through previous work, we knew that *Spartina alterniflora* has sulfur bacteria in its roots and that there are two types: sulfur-oxidizing bacteria, which use sulfide as an energy source, and sulfate reducers, which respire sulfate and produce sulfide, a known toxin for plants," Rolando said. "We wanted to know more about the role these different sulfur bacteria play in the [nitrogen cycle](#)."

Kostka and Rolando headed to Sapelo Island, Georgia, where they have regularly conducted fieldwork in the salt marshes. Wading into the marsh, shovels and buckets in hand, the researchers and their students collected cordgrass along with the muddy sediment samples that cling to their roots. Back at the field lab, the team gathered around a basin filled with creek water and carefully washed the grass, gently separating the plant roots.

Next, they used a special technique involving heavier versions of chemical elements that occur in nature as tracers to track the microbial processes. They also analyzed the DNA and RNA of the microbes living in different compartments of the plants.



Joel Kostka, the Tom and Marie Patton Distinguished Professor and associate chair for Research in the School of Biological Sciences. Credit: Georgia Institute of Technology

Using a sequencing technology known as shotgun metagenomics, they were able to retrieve the DNA from the whole microbial community and reconstruct genomes from newly discovered organisms. Similarly, untargeted RNA sequencing of the microbial community allowed them to assess which microbial species and specific functions were active in close association with plant roots.

Using this combination of techniques, they found that chemoautotrophic

sulfur-oxidizing bacteria were also involved in nitrogen fixation. Not only did these bacteria help plants by detoxifying the root zone, but they also played a crucial role in providing nitrogen to the plants. This dual role of the bacteria in sulfur cycling and nitrogen fixation highlights their importance in coastal ecosystems and their contribution to plant health and growth.

"Plants growing in areas with high levels of sulfide accumulation tend to be smaller and less healthy," said Rolando. "However, we found that the microbial communities within *Spartina* roots help to detoxify the sulfide, enhancing plant health and resilience."

## **Local to global significance**

Cordgrasses aren't just the main player in Georgia marshes; they also dominate marsh landscapes across the entire Southeast, including the Carolinas and the Gulf Coast. Moreover, the researchers found that the same bacteria are associated with cordgrass, mangrove, and seagrass roots in coastal ecosystems across the planet.



Researchers washing cordgrass roots for microbial analysis. Credit: Georgia Institute of Technology

"Much of the shoreline in tropical and temperate climates is covered by coastal wetlands," Rolando said. "These areas likely harbor similar microbial symbioses, which means that these interactions impact ecosystem functioning on a global scale."

Looking ahead, the researchers plan to further explore the details of how marsh plants and microbes exchange nitrogen and carbon, using state-of-the-art microscopy techniques coupled with ultra-high-resolution mass spectrometry to confirm their findings at the single-cell level.

"Science follows technology, and we were excited to use the latest genomic methods to see which types of bacteria were there and active," Kostka said. "There's still much to learn about the intricate relationships between plants and microbes in coastal ecosystems, and we are beginning to uncover the extent of the microbial complexity that keeps marshes healthy."

**More information:** J. L. Rolando et al, Sulfur oxidation and reduction are coupled to nitrogen fixation in the roots of the salt marsh foundation plant *Spartina alterniflora*, *Nature Communications* (2024). [DOI: 10.1038/s41467-024-47646-1](https://doi.org/10.1038/s41467-024-47646-1)

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