Researchers study carbon capture in Upper Newport Bay salt marshes

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USC researchers are studying the tidal salt marshes of the Upper Newport Bay Ecological Reserve. Credit: David Bañuelas

Despite covering just 2% of the ocean, coastal wetlands—such as tidal salt marshes, mangrove forests and seagrass beds—are responsible for storing nearly half of all carbon found in ocean sediment. These "blue carbon" ecosystems naturally absorb vast amounts of carbon dioxide (CO_2) from the atmosphere and bury it deep within their soil.

But rising sea levels—projected to increase by up to a meter by 2100—threaten to disrupt the water's chemistry and the delicate balance of microorganisms essential for carbon cycling. Rising tides could also transform marshes into mudflats, releasing stored carbon back into the atmosphere and exacerbating climate change.

With support from the USC Wrigley Institute for Environment and Sustainability's new Carbon and Climate Initiative, USC researchers are studying this threat through a two-part project in the tidal salt marshes of Upper Newport Bay Ecological Reserve, an estuary along Orange County's 42-mile-long coastline in Southern California.

Spanning more than 600 acres of wetlands, this area supports populations of shorebirds, waterfowl, native plants and several rare and endangered species.

The research team is examining how sea level rise may affect the marsh's microbial communities, which ultimately influence carbon capture and storage, through a combination of field observations, laboratory experiments and advanced modeling techniques. Doing so will give the team a clearer picture of the marsh's potential vulnerability to climate change.

"Salt marshes, like those at Upper Newport Bay, can actually store as much carbon as the Amazon rainforest or any other forest in the world, making them powerful allies in the fight against climate change," said David Bañuelas, a USC Presidential Sustainability Solutions Fellow and the project's lead researcher.

"Our goal is to develop methods to predict and mitigate carbon loss, quantify the amount of carbon at risk, and identify restoration techniques to ensure continued carbon capture and storage well into the next century."

Blue carbon capture: Why microorganisms rule the world

Microorganisms play a critical role in the carbon cycle within coastal wetlands. These small but mighty organisms absorb CO_2, convert it into organic matter, and, depending on the species, either sequester this carbon or release it back into the atmosphere.

"Microorganisms control all the carbon cycling on planet Earth," said Cameron Thrash, associate professor of biological sciences at the USC Dornsife College of Letters, Arts and Sciences and co-investigator on the project.

"As much as humans are putting CO_2 into the atmosphere, microbes control what the ultimate fate of that CO_2 is—whether it's getting turned into fixed organic carbon, sequestering that carbon in our oceans or soils, or converting it back into CO_2."

One of the primary ways coastal wetlands store carbon is through the breakdown of dead organic matter by microorganisms. Bacteria and fungi in these ecosystems convert organic matter into a form that can be used by other organisms, like phytoplankton and zooplankton. These smaller organisms are then consumed by larger animals higher up on the food chain.

However, as sea levels rise, saltwater intrusion can change which microorganisms are present in a system, potentially altering the way organic matter is processed and transferred through the food chain. These disruptions can have cascading effects on the entire ecosystem, particularly affecting the nutrient availability for saltmarsh vegetation, which helps sequester carbon in the marsh's soil.

Vegetation in these areas captures carbon dioxide from the atmosphere, and microorganisms play a role in breaking down organic matter to both store it in the sediments and release some into CO_2. Over time, sequestered carbon accumulates in layers of peat, soil and sediments, forming long-term carbon reservoirs. These carbon-rich deposits can remain intact for hundreds or even thousands of years.

"We know that in 50 to 100 years, much of the salt marsh will turn into mudflats, which are actually sources of carbon emissions. Without vegetation, a lot of the carbon that would otherwise be stored is going to be released back into the atmosphere," said Bañuelas.

Blue carbon: From sea to lab

In aquatic ecosystems, microorganisms are incredibly diverse, with between 100,000 and 10 million cells in every drop of water. These microbes are highly sensitive to environmental changes, such as rising sea levels and saltwater intrusion. Understanding how these changes affect microbial communities is crucial for predicting the future of carbon capture and storage in coastal wetlands, Thrash said.

Partnering with the California Department of Fish and Wildlife, the Newport Bay Conservancy and the Irvine Ranch Water District, the researchers are closely tracking the most common microbial groups in the marshes of Upper Newport Bay, including one key group of bacteria called SAR11, the most abundant type of plankton in our oceans, and which play a major role in the aquatic carbon cycle.

Traveling out to the marsh by kayak or boat, the research team routinely collects water samples to identify and quantify the different microbes present on the marsh. The researchers then process the samples in Thrash's lab by extracting DNA to study the microbial genetic code and the water's chemistry. Using computational biology techniques, the team then decodes the genomic data from these microbes to gain insights into their carbon-processing abilities.

"Our goal is to accurately predict where different microbes will be found based on salinity forecasts over large areas and time frames," Bañuelas said. "This breakthrough will help us anticipate and respond to climate change impacts, allowing us to better protect our vulnerable watersheds."

The future of blue carbon capture and storage

To protect and restore the tidal salt marshes of Upper Newport Bay, the researchers are also exploring engineering solutions that would lead to a net increase in carbon storage in the marsh.

To do this, they've teamed up with Felipe de Barros, an associate professor of civil and environmental engineering at the USC Viterbi School of Engineering, whose research focuses on developing models that can simulate large hydrogeological ecosystems.

Together, they are developing advanced computer models to predict how microbial communities and their carbon processing potential will respond to climate-induced changes in the salt marshes of Upper Newport Bay.

"With predictive models, we can quantify the carbon balance between the ocean and coastal wetlands, enabling us to make rational decisions to safeguard these vital ecosystems," de Barros said. "These models also allow us to predict how different hydrological conditions can affect the carbon balance."

The findings will extend beyond Upper Newport Bay and could be relevant for coastal marine and estuarine systems worldwide.

"By studying the interconnectedness of salinity, microbial communities and carbon cycling in Upper Newport Bay, we're developing a blueprint for understanding and predicting the impacts of environmental changes on coastal ecosystems worldwide," Thrash said.

His research group, the Thrash Lab at USC, is conducting similar studies in major estuaries, including those in the Gulf of Mexico around the Mississippi River and the Atchafalaya River deltas in Louisiana, to build a greater understanding of the microbial dynamics that will inform conservation efforts and sustainable management practices.

"The future of our planet depends on the health of our oceans and coastal ecosystems," Bañuelas said. "By preserving blue carbon habitats, we're taking an important step toward a more sustainable future."

Provided by University of Southern California

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