

# SWS Research Brief

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## Elevated Carbon Dioxide: A Silver Lining for Coastal Wetlands?

Greenhouse gases such as CO<sub>2</sub> (Fig. 1) contribute to global warming, which leads to climate change. The increases in air and sea temperatures also cause melting of ice fields and expansion of ocean volume (warm water expands). As the volume of the ocean increases, sea-level rises and causes increased flooding and salinity in coastal wetlands.

Greater flooding or salinity causes some wetland plants to become stressed and they do not grow as well or may eventually die-off completely. In addition, sea-level rise can eventually submerge coastal wetlands, converting them permanently to open water. The risk of coastal wetland loss due to sea-level rise is especially high for wetlands in areas that are sinking, like those in the Mississippi River Delta.

Although CO<sub>2</sub> contributes to sea-level rise through global warming, it may have an unexpectedly positive effect on coastal wetlands. The reason is that CO<sub>2</sub> in the atmosphere acts like a fertilizer to plants.

All higher plants, including wetland species, use CO<sub>2</sub> during photosynthesis to produce food and build tissues. As CO<sub>2</sub> increases, some wetland plants may increase their growth and production of organic matter. Why is increased production important for countering sea-level rise? By growing more, plants vertically build up the soil by adding more roots belowground (Fig. 2) and by contributing more shoots or leaves (after they die) to the soil surface. By building vertically, wetlands have the capacity to offset increases in flooding and salinity caused by sea-level rise.

Thus, CO<sub>2</sub> may positively affect plant responses important for vertical soil building and may help prevent wetlands from being overtopped by rising seas.

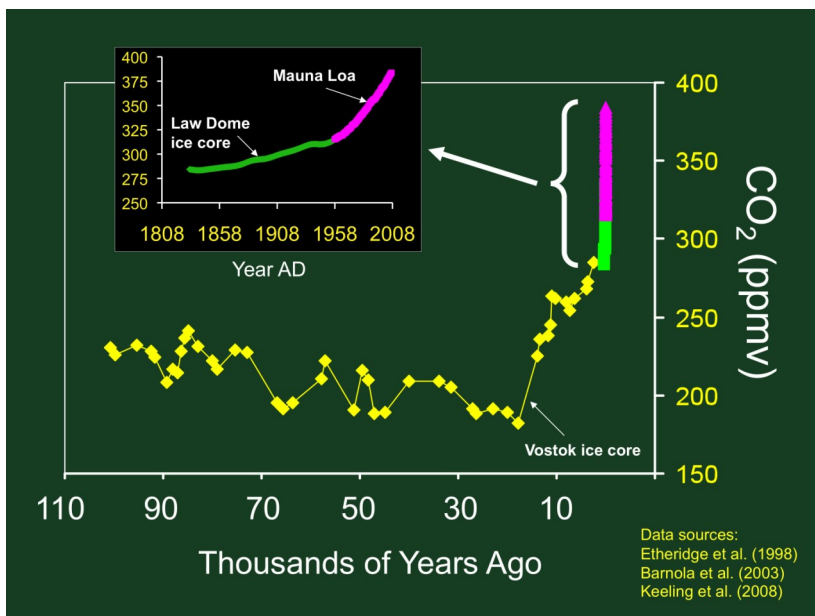


**Figure 2.** Root growth can be substantial and contribute to vertical soil building.

### Are all plants the same?

Not all plant species respond similarly to increases in CO<sub>2</sub> in the air. Through an adaptation to hot, dry or salty conditions, some plants, called C-4 plants, have the ability to remain productive when CO<sub>2</sub> levels are relatively low. An increase in CO<sub>2</sub> typically does not stimulate C-4 growth because they are already very efficient at using CO<sub>2</sub>. Other plants, called C-3 plants, do not use CO<sub>2</sub> as efficiently, and elevated CO<sub>2</sub> often stimulates their growth. In addition, not all plants respond similarly to changes in water level and salinity.

Flooding and high salt concentrations are stressful to many plants, but some are better able to tolerate flooding while others are better able to tolerate salinity. Many coastal wetlands contain a mixture of both C-3 and C-4 species, as well as a mixture of salt-tolerant and flood-tolerant species. Thus, the response of plant communities to elevated CO<sub>2</sub> and sea-level rise may depend on the types of species present in the wetland.



**Figure 1.** Change in atmospheric carbon dioxide (CO<sub>2</sub>) concentrations over the past 110,000 years. Yellow and green lines are reconstructed from gas extracted from ice cores; pink line shows CO<sub>2</sub> measured at the Mauna Loa Observatory.

**“THE CHALLENGE IS TO EXAMINE HOW PLANTS REACT TO MULTIPLE INTERACTING FACTORS AT ONCE”**



Hurricane Katrina, August 29, 2005 (NOAA)

### Hurricanes & Wetlands

*Coastal wetlands protect us from the damaging effects of hurricanes by absorbing wave energy and retaining flood waters. However, these storms may also affect the capacity of coastal wetlands to counterbalance sea-level rise. Hurricanes can scour and erode wetland soils, or cause flooding or saltwater intrusion that is stressful to plant communities. Under these circumstances, hurricanes may negatively affect vertical soil building by reducing or removing plants and sediment. Conversely, hurricanes can introduce nutrients and sediments to coastal wetlands in the storm surge. This input of nutrients and sediment may enhance vertical soil building by stimulating plant growth and directly adding sediment to the soil surface (see below). Whether positive or negative effects prevail depends, in part, on the strength and path of the storm. As climate changes, the strength of these hurricanes may also change, which could have significant effects on our coastal wetlands and their ability to protect us from severe storms.*



**Hurricanes can deposit sediment that vertically expands soil surfaces, as observed in some wetlands after *Katrina*.**

### The complexity of it all

Changes in CO<sub>2</sub> levels may affect plants directly or alter other factors that influence plant responses. Because plants can respond in various ways to these different factors, it can be difficult to tell which of the possible responses to environmental change will prevail in coastal wetlands.

This uncertainty raises some interesting research questions and propels science forward. For instance, it is important to explore (1) how elevated CO<sub>2</sub> and sea-level rise will affect wetland plant communities, (2) if C-3 species respond to these changes differently than C-4 species, and (3) whether or not plant responses will improve vertical soil building and the capacity of coastal wetlands to keep pace with sea-level rise. Answers to these types of questions will help us understand how wetlands respond to different environmental conditions, and may help us protect coastal wetlands in the future.

### Getting started

Nature is complex and ever-changing, with multiple environmental changes occurring at once. Wetland plants are not given the opportunity to respond to one thing at a



**Figure 3. Collection of plant and soil plugs from a brackish marsh.**

time. Instead, they must multi-task, dealing with changes in factors like CO<sub>2</sub>, water, and salinity, all at the same time. When researching wetland plant responses to climate change, the challenge is to examine how plants react to multiple interacting factors at once.

While there are several ways to examine wetland plant responses to elevated CO<sub>2</sub> and sea-level rise, one approach is to conduct experiments in greenhouses equipped with a system to deliver elevated levels of CO<sub>2</sub> to the plants. This approach requires taking the plants out of their natural environment, but it allows researchers to manipulate multiple factors at once in a controlled setting. This approach has been used successfully in several experiments with various wetland communities.

In one such study, my collaborators and I collected plugs of soil and plants (Fig. 3) and transferred them to greenhouses in the Wetland Elevated CO<sub>2</sub> Experimental Facility in Lafayette, Louisiana, USA (Fig. 4). We collected plugs from a brackish wetland located in Big Branch Marsh National Wildlife Refuge near Lacombe, Louisiana. Two species dominated the wetland plant community. The first was three-square bulrush, a C-3 plant that is relatively flood-tolerant, but less salt-tolerant. The second was saltmeadow cordgrass, a C-4 species that is relatively salt-tolerant, but less flood-tolerant. Based on what is known about the two dominant species, we were able to make some predictions of how these plants would respond to different levels of CO<sub>2</sub>, flooding, and salinity.



**Figure 4. Greenhouses used in elevated CO<sub>2</sub> studies.**



*“Under certain circumstances, elevated CO<sub>2</sub> can help coastal wetlands by stimulating plant production and vertical soil building.”*

We anticipated that the three-square bulrush would grow more under elevated CO<sub>2</sub>, and do better under higher flooding and lower salinity conditions. We also predicted that the three-square bulrush would tolerate the flooding or salt stress better under elevated CO<sub>2</sub>. On the other hand, we expected that the saltmeadow cordgrass would grow about the same under ambient (similar to current atmospheric levels) and elevated CO<sub>2</sub>, but would grow more under lower flooding and higher salinity. To test these hypotheses, we conducted an experiment in which plants were exposed to different combinations and levels of CO<sub>2</sub>, flooding and salinity that approximated a variety of climate change scenarios.

Once transported back to the greenhouse, the plugs of wetland plants and soil were placed in containers called mesocosms (Fig. 5) and exposed to either ambient CO<sub>2</sub> levels or elevated CO<sub>2</sub> levels (twice as high as current levels). They were also randomly assigned to a range of salinity levels (fresh to higher than normal), and water levels (drained, intermittently flooded, and constantly flooded). We then measured plant growth and rates of soil building (Figs. 6, 7) for the different combinations of environmental conditions.



Figure 5. Mesocosms receiving elevated CO<sub>2</sub> in the greenhouse study.

This approach permitted examination of multiple factor interactions that would be difficult to manipulate in the field, and also allowed us to measure responses for a range of different conditions.

#### Does CO<sub>2</sub> make a difference?

Under certain circumstances, elevated CO<sub>2</sub> can help coastal wetlands by stimulating plant production and vertical soil building. In the case of coastal brackish wetlands, CO<sub>2</sub> helped the three-square bulrush grow more, especially under flooded conditions, and it helped reduce the negative effects of high salinity. The same was not true for the saltmeadow cordgrass, which did not respond as much to elevated CO<sub>2</sub>, and did best under lower flooding and higher salinity conditions. As a result, mesocosms exposed to elevated CO<sub>2</sub> tolerated the stresses of sea-level rise better and expanded vertically more than those under ambient conditions.

The range of vertical soil building observed in the greenhouse experiment was similar to that observed in two Louisiana brackish marshes. In addition, a field experiment testing effects of CO<sub>2</sub> and nutrient additions on a Chesapeake Bay brackish marsh found that CO<sub>2</sub> enhanced plant production and stimulated soil building.



Figure 6. Measuring vertical soil building in a mesocosm.

Positive responses by plants to elevated CO<sub>2</sub> that result in enhanced vertical soil building have been observed in different community types as well. Other experiments conducted at the Wetland Elevated CO<sub>2</sub> Experimental Facility revealed that soil building can be enhanced under elevated CO<sub>2</sub> in both freshwater wetlands and mangrove wetlands. In all of these greenhouse studies, plant production of biomass growing belowground was especially important for vertical soil building, and suggests plant responses are critical for countering sea-level rise.

#### Concluding thoughts

Experiments designed to investigate the effects of CO<sub>2</sub> on coastal wetlands have the potential to contribute a great deal to our understanding of wetland responses to climate change. Results of studies to date reveal that CO<sub>2</sub> can stimulate plant production and vertical soil building, but the extent of this response will vary depending on the types of plants and the other environmental conditions in the wetland. Because multiple factors interact to influence plant responses in nature, there is still a lot to learn about the effects of elevated CO<sub>2</sub> on coastal wetlands and their capacity to keep pace with sea-level rise.



Figure 7. Collection of plant data from mesocosms in the greenhouse study.

## Additional Information

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