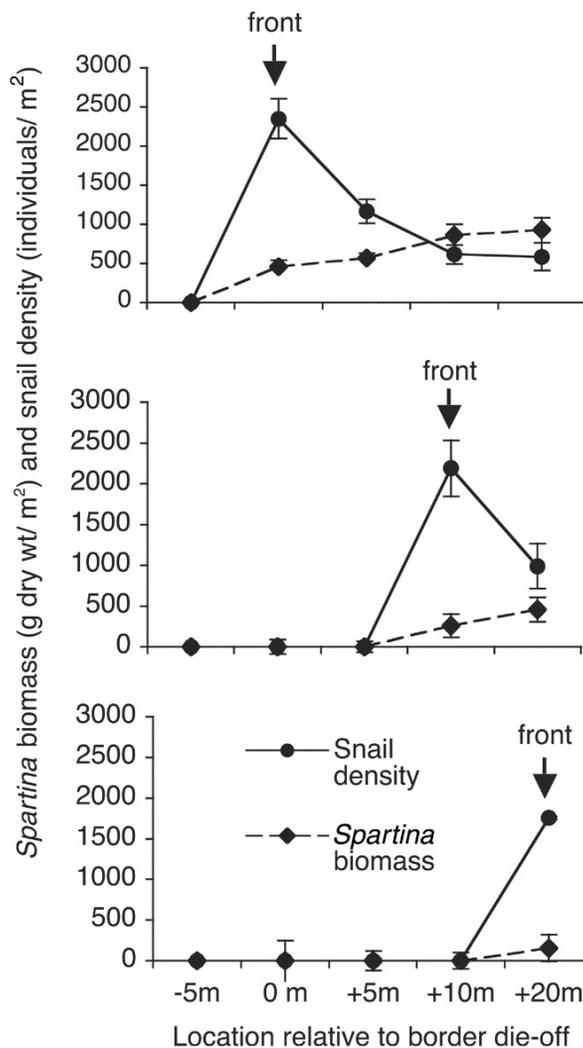




HOW TO USE THIS RESOURCE

Show the following figure and caption to your students. The accompanying “Student Handout” provides space below the caption for “Observations, Notes, and Questions” and space next to the “Background Information” for “Big Ideas, Notes, and Questions.” The “Interpreting the Figure” and “Discussion Questions” sections of the “Educator Materials” provide additional information and suggested questions that you can use to prompt student thinking, increase engagement, or guide a class discussion about the characteristics of the figure and what it shows.

Additional information related to pedagogy and implementation can be found on [this resource’s webpage](#), including suggested audience, estimated time, and curriculum connections.



Caption: The density of periwinkle snails (*Littoraria sp.*) and biomass of cordgrass (*Spartina sp.*) in a Georgia salt marsh at three time points: the beginning of the study (top), after 6 months (middle), and after 12 months (bottom). Zero meters (0 m) on the x-axis marks the original boundary (at the beginning of the study) between a vegetated salt marsh and a barren mudflat. Negative distances indicate locations toward the interior of the

mudflat. Positive distances indicate locations toward the vegetated salt marsh. Error bars represent ± 1 standard error of the mean (SEM) over five replications.

BACKGROUND INFORMATION

Coastal salt marshes carry out important ecological functions, many of which enhance the economies of local communities. Salt marshes are incredible fish factories and support world-renowned shrimp, oyster, and finfish industries. Marshes also act as natural sea walls, dampening incoming waves as well as reducing storm surge. Finally, they are pollution sponges; they soak up carbon from the atmosphere as well as land-derived nutrients that would otherwise cause harmful algal blooms. In the last 100 years, the U.S. has lost ~25% of its coastal salt marshes due to changes in food webs, land use, and climate.

Researchers have studied how physical disturbances to salt marsh ecosystems can alter soil characteristics, such as drought and nutrient availability, which can cause die-offs of cordgrass. But less is known about how cordgrass grazers like the periwinkle snail influence salt marsh ecosystems that are stressed by drought. Under normal conditions, the periwinkle snail indirectly regulates cordgrass growth by facilitating fungal infection from scraping the plant's leaves, creating a wound for fungus to grow; essentially farming the fungus that it later eats. During times of drought, snail grazing on drought-stressed plants intensifies and grass dies in localized areas, forming bare patches called mudflats. Once the grass dies in this area, snails always move across the mudflat toward healthier grasses and slow down once they find live grass. As a result, periwinkle densities pile up and over time increase along the edges of the mudflats, forming a "snail front." In this study, researchers tracked changes in cordgrass and snail densities after a lengthy period of drought in order to determine whether periwinkle snail fronts expand mudflats and contribute to salt marsh die-offs.

INTERPRETING THE FIGURE

At the beginning of the study, the top graph shows that the mudflat (distance of -5 m) contains no vegetation or snails. In contrast, the boundary between the mudflat and healthy salt marsh (0 m) supports the highest density of snails and the lowest cordgrass biomass in areas where it still grows. Additionally, cordgrass biomass appears to increase the farther it is from the edge of the mudflat. This suggests that the high density of periwinkle snails may be reducing cordgrass biomass at the boundary between salt marsh and mudflat (marked "front" in the figure).

After 6 months (middle graph), the snail front has moved 10 meters away from the starting location. Meanwhile, the zone between zero and 10 meters, which once supported both cordgrass and snails, became a barren mudflat. This suggests that the mudflat has expanded, and it provides evidence that the snails might be driving cordgrass loss farther into the previously intact salt marsh. At 12 months, the snail front has moved 20 meters away from the starting location, and cordgrass has once again completely disappeared from the area where the snail front passed.

From the graphs alone, it's not possible to determine cause and effect: did a decrease in cordgrass cause snail populations to move? Or did snail activity kill off the cordgrass, causing the snails to migrate in search of healthy cordgrass? Based on additional experiments conducted in the original study, we know that the snails killed off the cordgrass after it was already compromised by drought stress. As their food source disappeared, the snail front moved toward new grass, further perpetuating and expanding the die-off.

Teacher Tip: Prompt your students to explain the parts of the graph as applicable:

- Graph Type: Line graph

- **X-Axis:** Distance (in meters) relative to the original position of the boundary between mudflat and salt marsh at the beginning of the study
- **Y-Axis:** Cordgrass biomass (in grams of dry weight per square meter) and snail density (number of snails per square meter)
- **Error bars:** Represent ± 1 standard error of the mean (SEM), which is used to express the precision of an estimate of the mean, for each distance at each site ($n = 5$). Note that some of the error bars are small and may be difficult to see without magnifying or enlarging the image.

DISCUSSION QUESTIONS

- What happened to the “snail fronts” as time progressed?
- What happened to cordgrass biomass as time progressed?
- Describe the relationship between the trends in snail density and cordgrass biomass over time.
- What is the range in the density of snails in the front over time? Propose an explanation for why snail front density may have an upper limit.
- Write a claim describing the effect of the snail front on the salt marsh. Include at least one piece of evidence from the graph and explain your reasoning.
- Is it possible to determine cause and effect from the figures? In other words, is snail activity causing changes in cordgrass biomass, or are changes in cordgrass biomass causing changes in snail density?
- Explain how drought impacted the ecosystem and how it was able to trigger the “snail front.”
- Do you think that the trends shown in the figures would have occurred in the absence of a drought? Why or why not?
- Define top-down versus bottom-up factors that control ecosystems. Give examples of each from this experimental system. How do the different factors interact to produce the observed changes?
- Is there any sign of marsh recovery in areas that became mudflats? Cite evidence from the graphs.
- Propose a solution that would mitigate the effect of the snail front on the salt marsh. How would you test the effectiveness of this solution experimentally?
- Climate change is increasing the frequency and duration of intense droughts. In addition, blue crabs, which prey on snails, are declining. Considering these two factors, what do you predict for the future of salt marshes?

SOURCE

Figure 3 from:

Silliman, Brian R., Johan van de Koppel, Mark D. Bertness, Lee E. Stanton, and Irving A. Mendelsohn. “Drought, snails, and large-scale die-off of southern U.S. salt marshes.” *Science* 310, 5755 (2005): 1803–1806.

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CREDITS

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