Effects of Ocean Acidification on a Turtle Grass Meadow

With increasing atmospheric CO₂ concentrations, the oceans are expected to increase in acidity during the next century. Increasing ocean acidity has been shown to negatively affect many marine ecosystems, particularly calcifying organisms. We investigated acidification effects on the turtle grass communities of Little Cayman Island, British West Indies (BWI). We hypothesized that acidified seawater would decrease turtle grass growth, the presence of calcifying epiphytic algae, and the metabolism of snail grazers. We placed turtle grass and snails in tanks with acidified or natural seawater for four days. We found that turtle grass growth decreased, leaf senescence increased, and epiphytic algal cover was strongly reduced in acidified seawater. We also found that snail activity was negatively affected by acidic seawater. Our results suggest that continuing ocean acidification could be detrimental to the productivity and health of turtle grass meadows.

Introduction

Oceans act as important carbon sinks for anthropogenic emissions, reducing atmospheric concentrations of CO₂ by up to one-third (1). As oceans become saturated with CO₂, the pH of seawater is predicted to drop from 8.1 to 7.7-7.8 by the end of this century (2,3). This increased acidity may have dramatic effects on marine organisms, in part because it reduces the concentration of carbonate ions and the solubility of aragonite, a form of calcium carbonate used to create biological structures (1,3).

Turtle grass (Thalassia testudinum), the most common marine plant in the Caribbean, supports an ecosystem with a variety of organisms, including epiphytic algae and snails, which will likely be impacted by ocean acidification (4). Hendriks et al. found that, in acidic environments, gastropod survival and growth rates decreased by 93 percent and 63 percent, respectively (5). Some invertebrates depress their metabolic rates to maintain an internal acid-base balance in response to increased acidity (13). While metabolic rates of other marine heterotrophs decrease with acidification, the metabolic response of gastropods has not yet been studied (5).

Additionally, growth and recruitment of several species of unattached crustose coralline algae decrease at lowered pH levels (6,7). However, few studies have investigated the effects of acidification on epiphytic calcifying red algae, although the algae are important to the function of coastal seagrass meadows. The epiphytic algae that grow on turtle grass leaves provide protection from desiccation and herbivory (8).

Here we investigate the effects of ocean acidification on growth and metabolism of turtle grass and presence of epiphytic crustose coralline algae (Hydrolithon farinosum). We also examined how the metabolic rates and grazing behavior of snails (Littorina sp.) were impacted by lowered pH. We hypothesized that lowering the pH of seawater would stress turtle grass, thereby reducing its growth and metabolic rate. We predicted that the percent cover of calcifying algae on turtle grass would decrease in a lower pH environment because calcium carbonate structures necessary for algal growth would degrade. We predicted that acidified treatments with snails added would have the least amount of algal cover, which would further reduce turtle grass growth rates. Finally, we hypothesized that snail metabolic rates and activity would decrease with increased acidity because snails would be under greater stress.

Methods

We conducted an experiment simulating the effects of ocean acidification on turtle grass communities at Little Cayman Research Center, BWI, from March 6 to 9 2011.

We created an acidic environment by filling 12 clear, square tanks of 7.5 L capacity with 5 L of seawater and 100 mL of 5 percent white vinegar. Acid was added daily to maintain the tanks at pH 7, measured with pH strips. We created 12 control tanks filled with 5 L of seawater (pH 8). Tanks maintained a constant temperature of 26°C, which is similar to the average afternoon temperature of 29.5°C that we measured at the turtle grass collection site.

Turtle grass mats including belowground biomass were collected using a shovel from the seagrass meadow in front of the Little Cayman Research Center, Little Cayman, BWI. Because Corlett and Jones found that the coralline red algae Hydrolithon farinosum was the most abundant epiphyte on turtle grass growing near Grand Cayman, BWI, we assumed that this was the same epiphytic calcifying algae we found in our experiment (9). Snails were collected from the seagrass meadow at South Hole Sound, Little Cayman Island, BWI.

We massed turtle grass samples and placed mats of similar biomass in 12 tanks of acidified seawater and 12 tanks of natural seawater. We added 20 snails to six of the acidified tanks and six of the control tanks.

We analyzed the cover of calcifying algae on 10 haphazardly sampled turtle grass leaves from each tank daily. We measured total length of the leaf and the length of the leaf that was white due to coverage by epiphytic algae. Because algal cover was not uniform on the white area of the leaf, we approximated percent cover on this portion to the nearest 25 percent. We also noted leaf senescence daily as evidenced by browning of leaves.

We estimated growth on turtle grass blades by poking holes with a toothpick at the base of individual leaves at the beginning of the experiment. We measured growth of 10 haphazardly chosen blades in each tank at the end of four days by recording the distance (mm) from the base of the leaves to the growth scar.
Snail metabolic rate was estimated once daily by measuring changes in dissolved oxygen after snails were added. We removed all snails from the tanks and placed them together in 125 mL Nalgene® bottles filled completely with seawater. Dissolved oxygen (percent and mg/L) was measured before and 30 min after adding snails using a YSI Inc. Pro Optical Dissolved Oxygen™ meter.

We also estimated respiration rate of the turtle grass each afternoon by measuring dissolved oxygen change. Dissolved oxygen was measured before and 30 min after the tanks were covered with airtight black plastic bags. Snail activity was estimated daily by recording the location of each snail in the tanks as on the tank wall, on the leaves, or on the sandy substrate. We classified snails on the leaves and wall, where they must exert effort to maintain suction with the surface, as displaying active behavior.

We multiplied the proportion of leaf length covered in algae by the percent cover of those algae to estimate overall leaf algal cover. Algal cover data were arcsine-square-root transformed and the 10 leaves observed per replicate were averaged across treatments. Plant respiration was weighted by initial plant mass.

We used ANOVA to examine differences in growth between treatments. We used a repeated-measures ANOVA to quantify the effect of treatment and time on algal cover. We used Student’s t-tests to determine the difference in senescence and plant oxygen consumption in acidified and control treatments. We also used Student’s t-tests to examine differences in snail activity and respiration between treatments.

**Results**

We found that turtle grass growth differed significantly among treatments, with control treatments experiencing twice the growth of acidified treatments (F3,20 = 22.9, p < 0.0001; Fig. 1). A Tukey-Kramer HSD test showed that both control treatments (those with and without snails) grew more than both acidified treatments. Respiration rates showed no difference between acidified and control treatments (t21.5 = -1.38, p = 0.18).

We found a significant treatment by time interaction on algal cover among treatments, with algal cover decreasing over time in acidified but not in control treatments (Wilks’ lambda value = 0.174, F9, 41.5 = 4.85, p = 0.0002; Fig. 2). Visual observations confirmed this finding, as algal cover was reduced in acidified treatments more quickly and to a greater degree than in control treatments (Fig. 3). We also found that leaf senescence was 28 percent higher in acidified treatments (t21.9 = -7.96, p < 0.0001, Fig. 4).

Snails were significantly more active in control treatments (t21.5 = 7.66, p < 0.0001; Fig. 5). There was no significant difference in snail respiration rates between acidified and control treatments (snail: t33.9 = 0.64, p = 0.52).

**Discussion**

We conclude that ocean acidification will negatively affect the health of turtle grass because we found a decrease in growth and an increase in leaf senescence of plants in acidified treatments. The acidic environment also appears to be detrimental to epiphytic calcifying algae, as algal cover on turtle grass leaves was reduced in the acidified tanks. The acid may have dissolved the algal calcium carbonate structures, as
acidified seawater in an ocean acidification experiment conducted at Little Cayman Island, BWI. Snails were placed in tanks of turtle grass for four days. Snails were determined to be active if they were attached to turtle grass leaves or the walls of the tank.

Acid washes have been known to be effective in reducing epiphyte loads on seagrasses (10). Additionally, the change in chemical composition of the seawater may have prevented the algae from producing new structures and growth.

The reduction in epiphyte cover on the turtle grass may have negatively affected the turtle grass through several mechanisms. The reduced cover of algae may have contributed to the increased leaf senescence in the acidified tanks because epiphytes can protect seagrass from desiccation and harmful ultraviolet radiation (8,11). Herbivores may also eat older leaves with greater cover of nutrient-rich epiphytic algae, which reduces consumption of younger, photosynthetic basal seagrass leaves (8).

We found that both acid and control tanks with snails had less algal cover than those without snails (Fig. 3); Frankovich and Zieman also found that snails reduce epiphyte cover (12). However, snail grazing, even by snails in natural seawater, may not reduce epiphyte cover enough to affect the turtle grass, as we found the growth of turtle grass was not lower in control and acid tanks with snails than in tanks without them (Fig. 1).

We conclude that increasing ocean acidity will be detrimental to snails because we found fewer active snails in the acidified tanks, and many died (Fig. 5). The decreased activity of the snails in acidic tanks may be due to the reduced ability of the snails to maintain acid-base regulation in their body tissue (13). Snail health may be further threatened by acidification as their shells degrade due to the difficulty of creating calcified structures (1,3).

While we did not see a change in plant or snail respiration rates between treatments, our methods for measuring respiration were limited, as we could not completely seal the tanks and prevent gas exchange. However, Bibby et al. found that rates of oxygen uptake decrease in snails under stress of both lowered pH and predation (14).

However, the addition of acetic acid alone may not accurately simulate the effects of ocean acidification due to increased CO₂ concentrations. For instance, while a higher concentration of CO₂ may decrease the pH of seawater, it may also increase photosynthetic rates of seagrass, causing higher reproductive outputs and biomass production (15, 16). We suggest that further studies examine the long-term combined effects of increased CO₂ concentrations and acidity in seawater.

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References