CO_2 production and O_2 consumption of the nuisance macroalgae Sargassum on the beach and in nearshore waters

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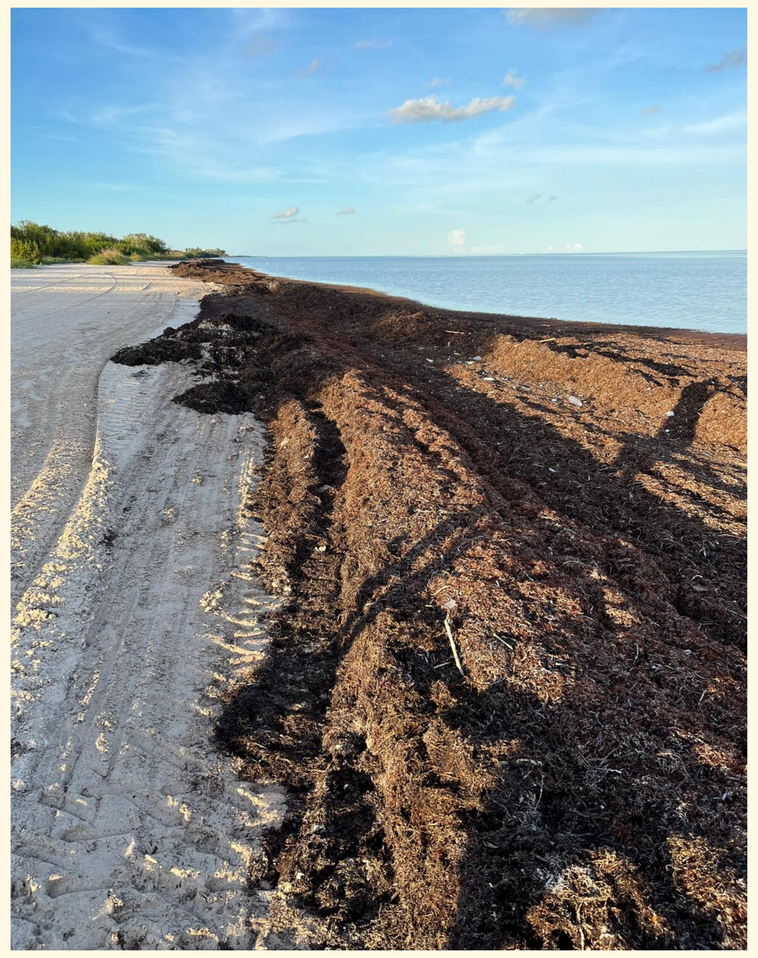

Figure 1. Sargassum in the Florida Keys June 2022

Figure 2. Sargassum in the water June 2022

ABSTRACT

The macroalgae *Sargassum sp.* threatens Florida and Caribbean sandy beaches where it accumulates in large piles, polluting beach and water and deterring tourists. This research aims to quantify the rate at which sargassum degrades through gas dynamics in moisture-saturated air (as on the beach surface) and air-saturated seawater (as in the nearshore waters). The working hypothesis was that the degradation rates in air and seawater are low but similar. To test this hypothesis, two laboratory experiments used air- and water filled gas-tight reaction jars, with known volume, respectively, were conducted to determine the degradation rates through changes in the oxygen consumption rates and carbon dioxide production rates. The results reveal relatively high degradation rates, with rates in moist air exceeding that in air-saturated seawater. Coastal managers can use these rates for planning clean up procedures suitable to best protect the environment and coastal economies.

Background

Sargassum macroalgae grow floating in warm seawater and benefit from ocean nutrient enrichment and warming. When large floats of these algae are washed onto the shore, the algae die and start decomposing in the shallow nearshore waters and on the beaches. The resulting oxygen consumption and sulfide production is harmful for aquatic and beach organisms, and the putrid smells deter tourists. This problem emerged about a decade ago and now these algal blooms became a regular summer event and are continuously becoming worse. Coastal managers need quantitative information for deciding whether or not to remove the algae at high costs or to allow the natural degradation process take care of the issue. Therefore, a research project was designed that quantifies the rate at which sargassum degrades when exposed to air at the beach surface and when degrading in nearshore waters. Two laboratory experiments used air- and water filled gas-tight reaction jars, with known volume, respectively, to determine the degradation rates through changes in the oxygen consumption rates and carbon dioxide production rates.

REFERENCE

Huettel, M., Cook, P., Janssen, F., Lavik, G., & Middelburg, J. J. (2007). Transport and degradation of a dinoflagellate bloom in permeable sublittoral sediment. Marine Ecology Progress Series, 340, 139-153.

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Figure 3. Calibration of Pyroscience Oxygen Optode, LiCor LI-850A CO_2 Sensor, and custom-made CO_2 sensor.

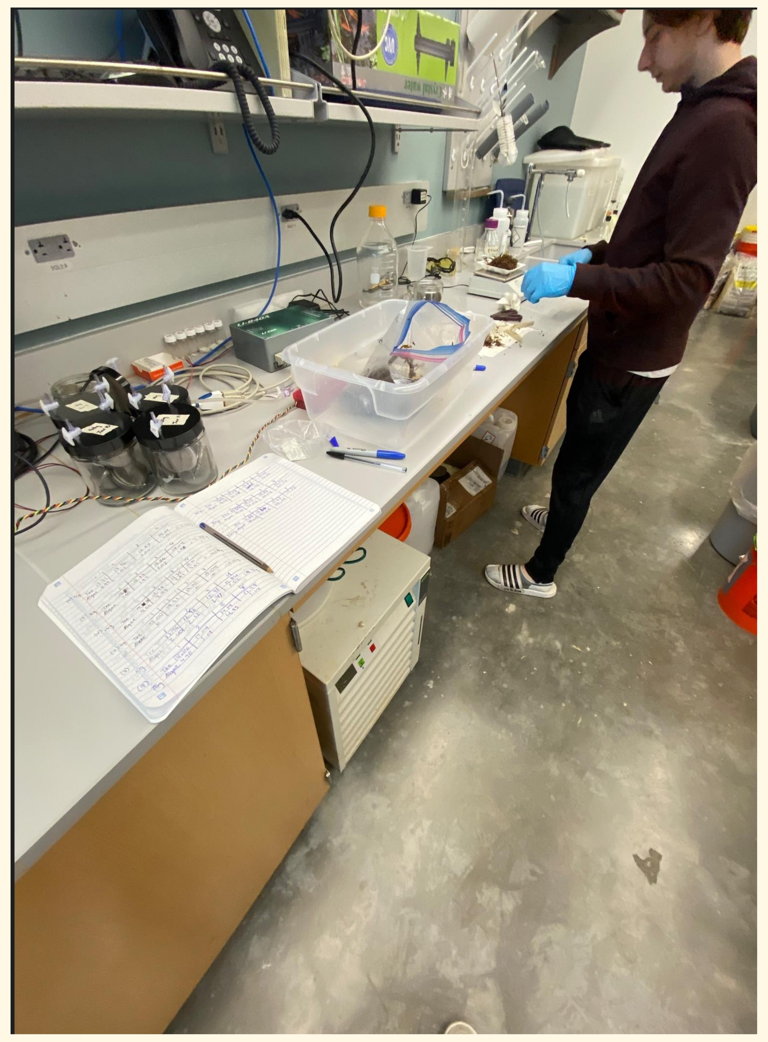

Figure 4. Preparation of Airjars

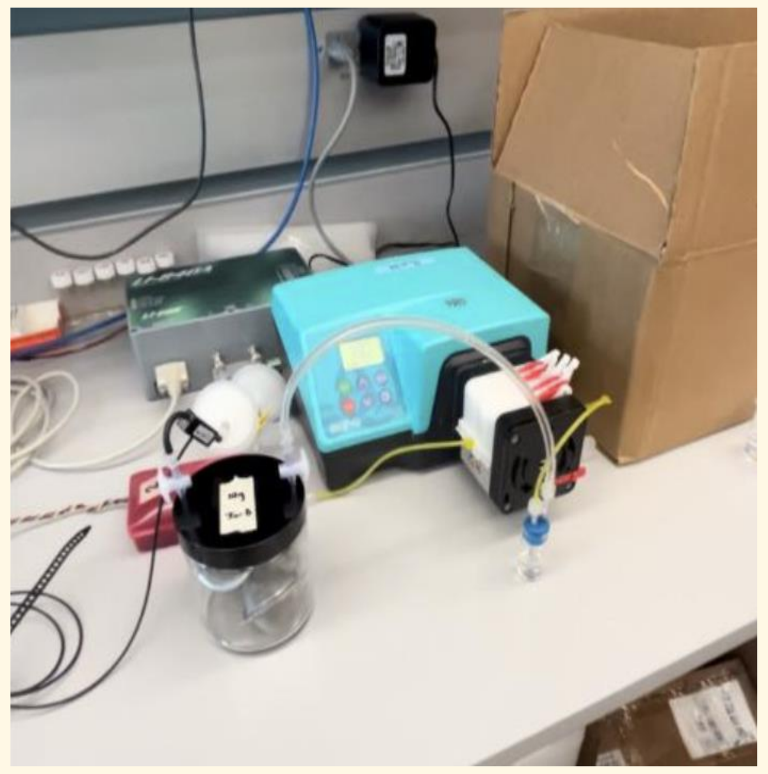

Figure 5. Collection of O_2 and CO_2 Concentration

METHODS

Air jar experiment

Fresh but dead Sargassum algae, enclosed equally in stainless steel mesh balls (3.8 cm inner diameter, 1.5 mm mesh openings), were added to 12 air-filled jars with 0, 1, 2, 4, 8, 0, 10, 16, 20, 40, 80 and 160 g algae in jars 1 to 12, respectively. The jars were made of glass (460 ml) and closed by plastic lids with two stop cocks allowing connection of tubes to pump air through the jars.

The experiment started by closing all jars airtight, and the aerobic microbial degradation of the algae consumed only oxygen contained in the jars. Likewise, all carbon dioxide produced by the algae remained enclosed in the jars. Incubation times ranged from 1 h to 18 h. After completion of the incubation time, the air contained in the jars was pumped with a peristaltic pump through a closed circuit containing an O_2 and a CO_2 sensor measuring the respective gas concentrations in the air of the jar attached to the recirculation circuit.

Degradation rates were determined from the carbon dioxide production over time, which was related to the biomass contained in the jars.

Water jar experiment

In the 12 water-filled jars, corresponding algal weights contained in the mesh balls were 0, 0, 1, 1, 2, 2, 4, 4, 8, 8, 16 and 16 g. The jars were made of glass (960 ml) and closed by plastic lids with two stop cocks allowing connection of tubes to pump water through the jars. Incubation times ranged from 0.1 to 1 h after which jar water was pumped in a closed loop through an O_2 and a CO_2 sensor, similar to the air jar experiment.

The degradation rates were calculated from the carbon dioxide concentration in crease in the water, which was related to the biomass contained in the jars.

RESULTS

Air jar experiment

- Carbon dioxide production rate in the air jars ranged from 10 to 5 µmol CO_2 g^{-1} Sargassum h^{-1}
- The carbon dioxide production in the air jars decreased over time at a rate of -0.11 µmol h^{-1} g^{-1} per day.
- Oxygen consumption rate in the air jars was 29 to 8 µmol O_2 g^{-1} Sargassum h^{-1}, twice as much as carbon dioxide was produced
- Oxygen consumption decreased over time as well at a rate of -0.28 µmol h^{-1} g^{-1} per day, which was more than twice as fast as the drop in CO_2 production rate over time.

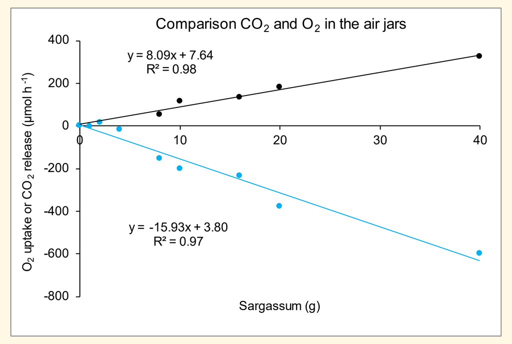

Figure 6. Sargassum degradation in air for the 12/1/22 sampling

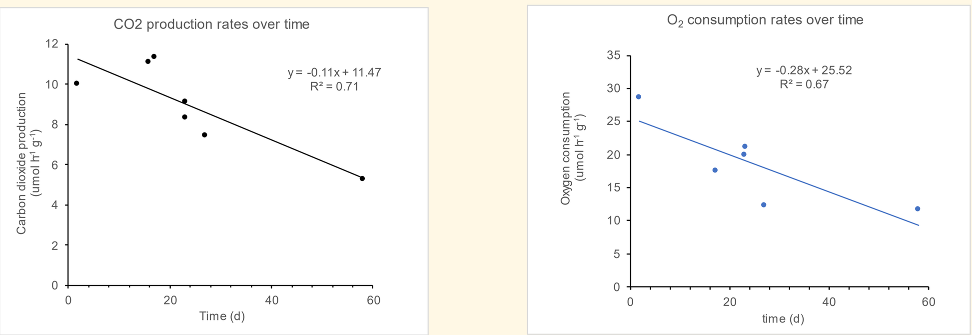

Figure 7. Decrease of the Sargassum degradation in air over time

Water jar experiment

- Carbon dioxide production rate in the water jars ranged from 9 to 1 µmol CO_2 g^{-1} Sargassum h^{-1}, and thus was similar to the degradation rates measured in the air jars.
- The carbon dioxide production in the water jars decreased over time at a rate of -1.36 µmol h^{-1} g^{-1} per day, about 14 time faster than in the corresponding air jars.
- Oxygen consumption in the water jars was 18 to 12 µmol O_2 g^{-1} Sargassum h^{-1}, twice as much as carbon dioxide was produced. However, O_2 consumption was less than in the air jars
- Oxygen consumption decreased over time initially as well at a rate of -1.48 µmol h^{-1} g^{-1} per day.
- At the highest Sargassum concentrations, the linear trends of carbon dioxide production and oxygen consumption changed to non-linear, revealing oxygen limitation and the onset of anaerobic degradation processes.

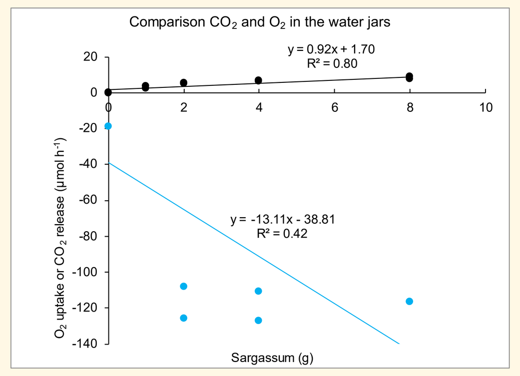

Figure 8. Sargassum degradation in water for the 12/1/22 sampling

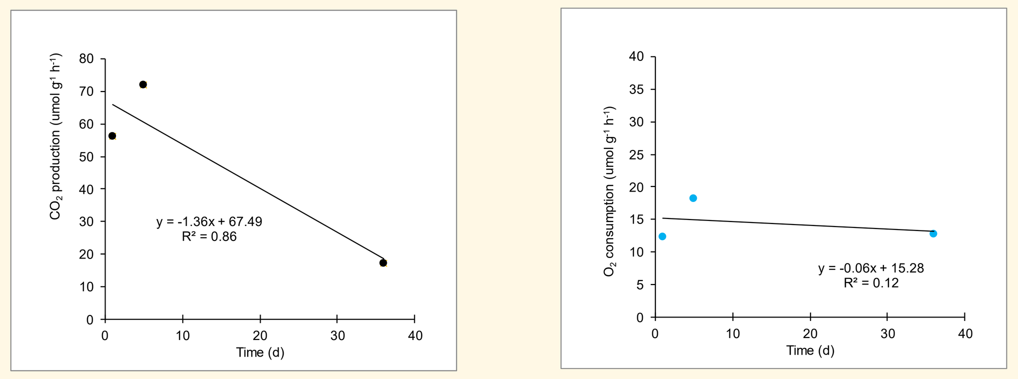

Figure 9. Decrease of the Sargassum degradation in water over time

Discussion and Conclusions

The experiments quantifying the degradation of fresh, dead Sargassum revealed that the macroalgae initially degrade relatively quickly at rates of up to 10 µmol CO_2 g^{-1} Sargassum h^{-1}. This converts to a rate of about 120 µg C per h and g Sargassum. 5.3% of the Sargassum is degraded per day in this initial phase. Under aerobic conditions, the degradation in air and water were similar, but the oxygen consumption decreased much less over time in the water jars. This can be explained with the dissolution of some of the Sargassum into dissolved organic matter that provided substrate for a large variety of microbes that cannot consume solid Sargassum. The quantitative rate estimates for Sargassum rotting on the beach or in the shallow water quantified in this study provide key information to coastal managers who need to know how long the decaying Sargassum macroalgae will persist on the beach and in the shallow nearshore waters.