Frequency of Bioturbation in Sediments Impact Greenhouse Gas Ebullitions

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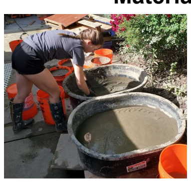
Introduction

Greenhouse gas (GHG) emissions from freshwater systems are an important contributor to global carbon emissions, but the factors controlling the rates and forms of carbon released are an active area of research. One potential factor is bioturbation, the disturbance of sediment by organisms as they move, feed, or reproduce. Previous studies have shown that bioturbation by benthic feeding fish can lead to increases in GHG ebullitions, the bubbling of gas out of sediments, but they are inconsistent in which gas (CO_2 or CH_4) dominates output. A lab experiment found that high frequency of disturbance in aerobic sediments may prevent CH_4 bubbles from building up, therefore reducing its release into the environment and increasing CO_2 emissions (Oliveira et al. 2019). In the field, particularly shallow, anaerobic rice patties, fish presence and more infrequent bioturbation increased CH_4 emissions (Frei et al. 2007). It is important to note the differences between ebullitive and diffusive emissions. CO_2 more readily dissolves in water; therefore the main form of CO_2 emissions is through diffusion (Oliveira et al. 2019). CH_4 is much less soluble in water, so its main form of emissions is through ebullitions (Oliveira et al. 2019). My project's aim is to analyze ebullitive-only emissions of both GHGs, particularly to the total ebullitions between tank treatments and the relative ratios of CH_4:CO_2.There are still many uncertainties regarding the mechanisms behind the production and release of both gases. Our project wanted to investigate further the effect of the frequency of the disturbance on ebullitive gases in a controlled lab setting.

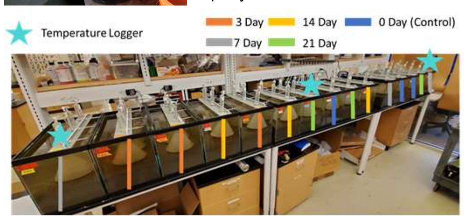
- **Question:** What frequency of bioturbation in sediments will result in the largest releases of greenhouse gases and highest ratio of CH_4:CO_2? How do the amounts of ebullition due to disturbance change over time?
- **Hypothesis:** An intermediate disturbance rate of either 7 or 14 days will result in the largest ebullitions and CH_4:CO_2 ratio.

Materials and Methods



Sediment:

- Sediment was taken from Acton Lake, a shallow reservoir in Southwest Ohio. Organic material was sieved out, and the sediment was homogenized (pictured right) before being divided and transferred equally into the 15 tanks.



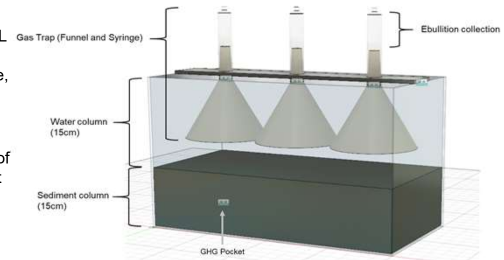
Tanks:

- Fifteen 38 L tanks (pictured above) were randomly assigned frequencies of either no disturbance (0 days), 3 days, 7 days, 14 days, or 21 days (pictured below). Tanks 1, 7, and 15 contained continuous temperature loggers.

Materials and Methods (Continued)

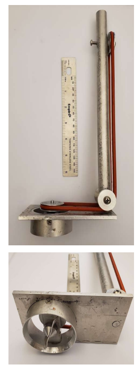
Tanks (Continued):

- Each tank setup (pictured right) consisted of three inverted funnels connected to 50mL syringes to act as gas traps. Water was pulled up into the traps above the water line, so that gas ebullitions from sediment below the funnels was captured in the trap until sampling.
- A three-way stopcock was placed on top of each syringe to allow sampling and prevent gas leakage and contamination.



Disturbances:

- Our disturbances were created with the use of an engineered mechanical bioturbator (pictured right). By pulling the rubber band near the handle, the propeller turns (pictured below right) and stirs up the first 2.5 cm of sediment beneath it. This action imitates feeding behavior of benthic fish typically found in lakes, rivers, and reservoirs.
- For a given treatment day, 48% of the surface area of the sediment in each tank was disturbed. The areas disturbed were randomized each treatment day.



Data Collection:

- Ebullition rates were measured for 60 days prior to initiation of the 90-day experimental treatments.
- On treatment days, volumes of gas were recorded before and after disturbing each tank to record the amount of ebullition caused directly by bioturbating.
- To determine ratios and amounts of ebullitive CO_2 and CH_4, gas was collected from ebullition traps using syringes when sufficient volume was available for analysis (typically weekly) and stored in 5 mL evacuated exetainers until analysis on a Bruker gas chromatograph with FID, TCD, and ECD detectors.
- Weekly water quality measurements were taken in addition to the continuous temperature loggers using a YSI multiparameter water quality meter. We recorded temperature, FNU, and dissolved oxygen levels (both percent saturation and mg/L) to monitor abiotic conditions across all fifteen tanks.

Results

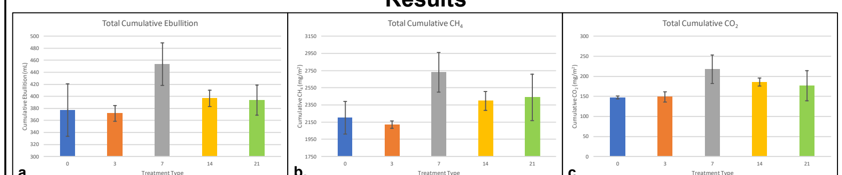


Figure 1. Cumulative ebullition volume and total GHG ebullitive emissions from experimental treatments, measured at the end of the 90-day experiment. The 7-day treatment had the a) greatest total ebullition volume, b) highest magnitude CH_4 ebullition, and c) highest magnitude CO_2 ebullition.

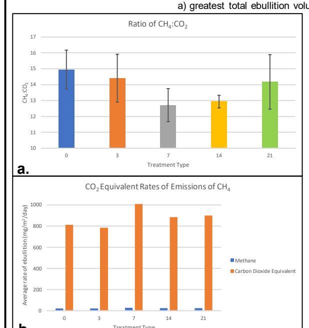


Figure 2. a) The 7-day treatments had the lowest ratio of CH_4:CO_2. b) Average rate of CH_4 ebullitions found by dividing the cumulative CH_4 by 92 treatment days. Average rates of CH_4 ebullitions were multiplied by 34 to determine CO_2 equivalents, based off the CH_4 global warming potential on a 100-year time horizon (Oliveira et al. 2019).

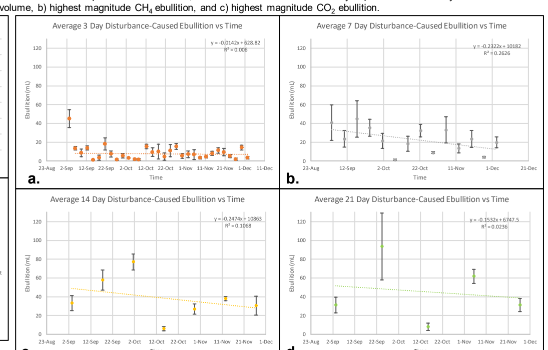


Figure 3. Changes in disturbance-caused ebullition volume over time. a) The 3-day treatment ebullition volume had no relationship to time but was low compared to other treatments. The initial ebullition value was considered an outlier and not included in the trend line fit. b) The 7-Day treatment volumes decreased over time. c) The 14-Day treatment had the greatest negative slope, but more variation. d) The 21-Day treatment had a negative slope.

Conclusions

The 7-day treatment tanks had the most overall ebullition, in both CO_2 and CH_4. However, the 7-day treatments also had the lowest ratio of CH_4:CO_2. In other words, while more GHG emissions came out of sediment in the 7-day tanks, they had less CH_4 relative to CO_2 bubble out. The 7-day tanks also saw a decrease in disturbance-caused ebullitions over time, with a slope of -0.2322 mL/day. The 14-day tanks had a similar, but slightly greater, decrease in disturbance-caused ebullition over time with a slope of -0.2474 mL/day. This result indicates that disturbance may have less effect on ebullition over time if it happens at an intermediate frequency. Although the relative amount of ebullitive CO_2 is less important than its more dominant method of release into the atmosphere by diffusion, it is interesting that more CO_2 bubbled out of sediment for the 7-day treatment. This result indicates that the 7-day treatment saw changes in biological processes within the sediment compared to other treatments.

Future Directions

- Analyze the relationship between macroinvertebrates and amounts of gas production in sediments; fish bioturbation will remove macroinvertebrates in sediments through feeding where our experiment did not
- Test the effect of the magnitude of disturbances on the amounts and types of gas production in sediments
- Investigate seasonal or temporal changes in gas production; do certain water temperatures or times of the year indicate a change in gas ebullitions from sediments in response to bioturbation?
- Analyze the changes in diffusive rates of GHG production in response to different bioturbation treatments

References

- Frei, M., M.A. Razzak, M.M. Hossain, M. Oehme, S. Dewan, and K. Becker. 2007. Methane emissions and related physiochemical soil and water parameters in rice-fish systems in Bangladesh. Agriculture, Ecosystems and Environment 120:391-398.
- Oliviera Jr., E.S., R.J.M. Temmink, B.F. Buhler, R.M. Souza, N. Resende, T. Spanings, C.C. Muniz, L.P.M. Lamers, and S. Kosten. 2019. Benthivorous fish bioturbation reduces methane emissions, but increases total greenhouse gas emissions. Freshwater Biology 64:197-207.

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