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The effect of coarse particulate organic matter on the rate of sediment organic matter processing in man–made ponds.

Abstract

The number of man–made ponds have been increasing over the past few centuries as part of the overall influence of human land use changes. In many regions, man–made ponds represent an abundant but novel aquatic habitat that can alter patterns of biodiversity and biogeochemistry. Ponds are sites of organic matter accumulation but also active sites of decomposition, so they may represent a critical component in the carbon cycle. The factors that regulate the accumulation and decomposition of organic matter in man–made ponds are virtually unstudied and likely differ from those factors identified from natural systems. The proposed research project will focus on quantifying one aspect of organic matter accumulation and decomposition dynamics in man–made ponds. The organic matter in ponds can be divided into a coarse and a fine fraction. The coarse fraction is mainly the leaf litter of vascular plants and the fine fraction derives from the decomposition of the coarse fraction, as well as from algal production and sediment transport. Previous work in my lab has shown that there is a correlation between the coarse and fine fractions but it is unknown how the presence of coarse organic matter affects the overall decomposition of sediment organic matter. The proposed project will evaluate the relationship between coarse and fine organic matter using sediment incubation experiments that measure sediment oxygen demand. These data will advance our understanding of how man–made ponds affect carbon cycling and climate change.

Project Narrative

Background

Human activities have had substantial impacts on the Earth's ecosystem processes. Human land use has altered the distribution of ecological habitat, increased the dispersal of species, and disrupted the cycling of biologically important materials (Zalasiewicz et al. 2008). Examples of the most striking changes are the alterations to global climate that are occurring as a result of human forest clearing and fossil fuel burning (IPCC Synthesis Report) and the loss of biodiversity as a result of human habitat modification and the facilitation of species dispersal (Naeem et al. 2009). Such dramatic global changes through the activity of a single species is unparalleled in the Earth's history (Naeem et al 2009).

One striking example of a human activity that has profound impacts on ecosystem biogeochemistry and biodiversity is the construction of ponds and reservoirs. The number of man-made ponds has increased exponentially since the 18th century (Downing et al. 2006) and in many regions that lack natural lakes, such as the southeast United States, man-made ponds represent a novel but now dominant freshwater habitat. Furthermore, ponds are highly active sites of biogeochemical processing and can integrate processes occurring in their entire watersheds (Tranvick et al. 2009). A clear understanding of the way that man-made ponds affect biodiversity and biogeochemical processes is essential for understanding the ways that human land use are altering the Earth's ecosystem processes.

Rationale

Ponds accumulate organic matter that is produced within the pond and that is transported to the pond from the watershed (Brainard and Fairchild 2012). The decomposition of this accumulated organic matter is a critical step in the carbon cycle. Sediment organic matter represents the net imbalance between photosynthetic (i.e., organic matter producing) and decomposition (i.e., organic matter consuming) processes and is therefore both the bank of energy and materials for heterotrophic metabolism and also a pool of sequestered atmospheric carbon (Schelsinger 1998). Thus the factors that affect the decomposition of sediment organic matter represent the key drivers of the rate of energy and material use by the ecosystem but also regulate the capacity of the system to buffer increases in atmospheric carbon dioxide.

The particulate organic matter that accumulates in aquatic systems is operationally divided into a coarse fraction (coarse particulate organic matter – CPOM) that is retained by a 1 mm sieve, and a fine fraction (fine particulate organic matter – FPOM) that passes through a 1 mm sieve (Wetzel 2001). The CPOM is largely derived from the senescent leaves of plants in the watershed and growing along the pond margin (Wetzel 2001).

The decomposition of CPOM results in the production of FPOM and this process has been shown to be regulated by the activity of sediment dwelling invertebrates and fungi (Webster and Benfield 1986). However these processes are largely unstudied in man-made ponds. My PRISM project from 2013 collected data on the summer standing stock of CPOM in man-made ponds in Farmville and found that CPOM is a common component of the total organic matter pool and the amount of CPOM is correlated with the FPOM in the sediments (figure 1). Furthermore, we found that the invertebrate groups most commonly associated with CPOM decomposition were absent from the lakes we studied. My lab is quantifying the effect of invertebrates on the rate of CPOM decomposition using experiments being conducted during the Fall of 2013.

The decomposition of FPOM is mainly regulated by microbial processes. The results of our 2013 PRISM research show that the amount of CPOM in the pond sediments is correlated with the amount of FPOM but we do not have information on the mechanistic relationship between these two organic matter pools. The correlation between CPOM and FPOM could result from the conversion of CPOM to FPOM, from the suppression of FPOM decomposition by the presence of CPOM, or from a correlation between CPOM and FPOM accumulation dynamics in the pond. The proposed project would conduct experiments to quantify the relationship between CPOM and the rate of total sediment organic matter decomposition.

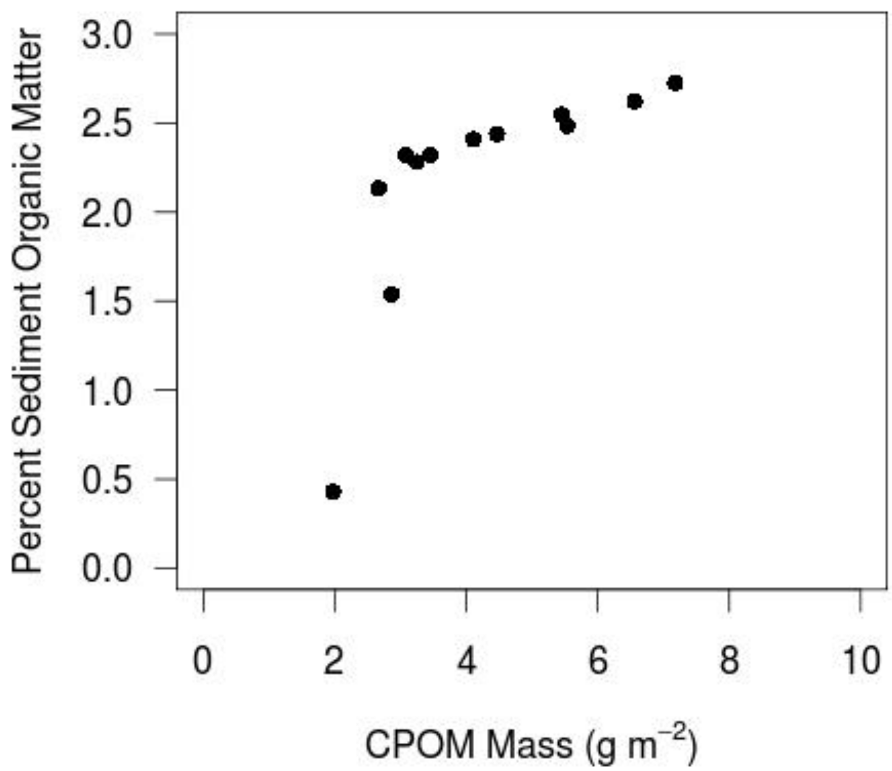

Figure 1. Relationship between CPOM mass and the percent organic matter in the sediments in Wilck's lake and Lancer Park pond during the spring of 2013. Each point represents an Ekman sample.

Goals

The goal of this project is to *Quantify the effect of CPOM on the rate of sediment organic matter processing in man–made ponds*.

This project will evaluate how the amount of CPOM affects the rate of sediment organic matter decomposition. We propose to conduct a series of laboratory incubation experiments where we will alter the quantity and characteristics of the CPOM and measure the effect on sediment oxygen demand (SOD). Since all of the heterotrophic decomposition pathways ultimately produce demand for oxygen, SOD is a measure of the total organic matter decomposition in the sediments.

Each of the experiments will use sediments from the same local ponds that are being used for the larger research project conducted by my lab. Sediments will be collected from the pond using an Ekman dredge and then passed through a 250 μm sieve to remove all CPOM and macroinvertebrates. The sieved sediment will then be distributed to 250 ml incubation jars and the remaining volume will be filled completely with pond water collected from the same depth as the sediments. Treatments will be created by adding varying amounts of senescent leaf material (i.e., CPOM) of different characteristics (e.g., different size fragments, tree species, etc…) to the jars. Sediment oxygen demand will calculated by measuring the change in the oxygen concentration of the overlying water during dark incubation with Winkler titration (Carpenter 1975).

Intellectual Merit

The results of these experiments will expand our understanding of the factors that affect the decomposition of sediment organic matter in man–made ponds, which are an abundant but critically understudied aquatic habitat. Given that man–made ponds accumulate organic matter at relatively high rates, there is some suggestion that these systems could serve to buffer changes in atmospheric carbon dioxide by sequestering organic carbon. However calculating the significance of this carbon sink requires that we understand the factors that control the decomposition of sediment organic matter in man–made ponds. It is clear from current research that we cannot apply our understanding of decomposition in natural ponds because man–made ponds lack many of the invertebrate groups that regulate CPOM decomposition in natural systems. Therefore, specific studies of organic matter dynamics in man–made ponds are needed.

Broader Impacts

Implementing this project at Longwood University will contribute to the strong program in environmental science that is being developed in the Department of Biological and Environmental Sciences. The department contains numerous faculty who specialize in aquatic systems, and thus there is a potential to create a strong center of aquatic biology and environmental science. Furthermore establishing research projects in local systems will provide a foundation for the continued development of aquatic environmental science research at Longwood and provide opportunities for collaboration within the department and with researchers at other universities.

Project Timeline

- Spring 2014 — literature review, project planning, and method development
- PRISM; Summer 2014 — data collection and analysis
    - Week 1 — experiment set–up
    - Weeks 2–6 — data collection
    - Weeks 7–8 — data analysis and poster development
- Late Summer 2014 — begin manuscript preparation
- Fall 2014 — complete and submit manuscript
- Spring 2015 — presentation of results at professional meetings, manuscript revision

Plans for Dissemination

Publications

The results of this project will contribute to a larger research project in my lab that is looking broadly at the effects of CPOM on the biodiversity and carbon cycling in small man-made ponds. The results of the proposed project will be combined with other data collected throughout the year to produce a manuscript describing the overall impact of CPOM on sediment metabolic processes. The preparation of the manuscript will begin during the summer of 2014 with submission anticipated during the fall of 2014. The student collaborator on the project will have the opportunity to contribute to the manuscript preparation through writing, data analysis, and figure/table preparation.

Presentations

The results of this project will be presented the student at 2 professional meetings. The first of these is the 2015 annual meeting of the Association of Southeastern Biologists, which is a regional meeting that focuses on ecological research in the southeastern United States. The second is the 2015 annual meeting of the Society for Freshwater Science, which is a national meeting that focuses on freshwater ecology.

The results of the project will also be presented at the Cook-Cole College Research Symposium in the Fall of 2014.

Open Science Practices

In addition to peer–reviewed publications and presentations at professional meetings, the project will be conducted using the best practices of open science.

The project activities and data will be documented in an open lab notebook hosted in a publicly available Github repository (https://github.com/KennyPeanuts/pond_diversity_fcn).

Data visualizations and unpublished results will be archived on figshare (http://figshare.com/authors/Kenneth_Fortino/101417).

Literature Cited

Brainard A. S. and G. W. Fairchild. 2012. Sediment characteristics and accumulation rates in constructed ponds. Journal of Soil and Water Conservation. 67(5): 425–432.

Carpenter, J. H. 1965. The Chesapeake Bay Institute technique for the Winkler dissolved oxygen method. Limnology and Oceanography 10:141-143.

Downing, J. A., Prairie, Y. T., Cole, J. J., Duarte, C. M., Tranvik, L. J., Striegl, R. G., McDowell, W. H., Kortelainen, P., Caraco, N. F., Melack, J. M., and Middleburg, J. J. 2006. The global abundance and size distribution of lakes, ponds, and impoundments. Limnology and Oceanography 51:2388-2397.

IPCC, 2007: Climate Change 2007: Synthesis Report. Contribution of Working Groups I, II and III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, Pachauri, R.K and Reisinger, A. (eds.)]. IPCC, Geneva, Switzerland, 104 pp.

Naeem S., D. L. Bunker, A. Hector, M. Loreau, and C. Perrings. 2009. Introduction: the ecological and social implications of changing biodiversity. An overview of a decade of biodiversity and ecosystem functioning research. in Naeem S., D. L. Bunker, A. Hector, M. Loreau, and C. Perrings. eds. "Biodiversity, Ecosystem Functioning, and Human Wellbeing: An Ecological and Economic Perspective." Oxford University Press, USA.

Tranvik, L. J., Downing, J. A., Cotner, J. B., Loiselle, S. A., Striegle, R. G. , Ballatore, T. J., Dillon, P., Finlay, K., Fortino K., Knoll, L. B., Kortelainen, P. L., Kutser, T., Larsen, S., Laurion, I., Leech, D. M., McCallister, S.L., McKnight, D.M., Melack, J. M., Overholt, E., Porter, J. A., Prairie, Y., Renwick, W. H., Roland, F., Sherman, B. S., Schindler, D. W., Sobek, S., Tremblay, A., Vanni, M., Verschoor, A. M., von Wachenfeldt, E., Weyhenmeyer, G. S. 2009. Lakes and reservoirs as regulators of carbon cycling and climate. Limnology and Oceanography, 54:2298-2314.

Webster, J. R. and E. F. Benfield. 1986. Vascular plant breakdown in freshwater ecosystems. Annual Review of Ecology and Systematics. 17:567–594.

Wetzel, R. G. 2001. Limnology. Academic Press, USA.

Zalasiewicz, J, M. Williams, A. Smith, T. L. Barry, A. L. Coe, P. R. Bown, P. Brenchley, D. Cantrill, A. Gale, P. Gibbard, F. J. Gregory, M. W. Hounslow, A. C. Kerr, P. Pearson, R. Knox, J. Powell, C. Waters, M. Oates, and P. Stone. 2008. Are we now living in the Anthropocene? GSA Today 18(2):4–8.