Sediment particle size in Lake Champlain inlets

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Abstract

Lake Champlain is undergoing eutrophication in part due to rapid phosphorus enrichment from nonpoint sources. Phosphorus enters the lake at stream deltas, and the relationship between nutrient input into the lake, sediment deposition, and aquatic macrophytes in these delta areas is not fully understood. This study aimed to elucidate one element of this complex relationship by examining sediment particle size at five deltas along Lake Champlain. Sediment particle size was not found to change significantly as distance from shore increases. Sediment particle size was found to vary greatly at all sites, but at smaller stream deltas there was significantly more silt and clay and significantly less sand. It is now necessary to relate this back to the effects of phosphorus enrichment and undertake further study characterizing the presence of phosphorus in the sediment and the presence or absence of aquatic macrophytes at these sites.

Introduction

Agricultural runoff acts as a nonpoint source for fertilizer nutrients to enter the watershed. These nutrients are carried by streams to Lake Champlain, leading to the lake's present state of rapid phosphorus enrichment. This is an issue because phosphorus enrichment leads to eutrophication (Barko and James 1998). It is therefore interesting to consider how aquatic macrophytes may act to stabilize the sediment, as macrophytes play an important role in structuring lake environments on many levels (Barko and James 1998). Their stability and ability to resist high water flow is a function of sediment type. This also allows them to slow the inflow of phosphorus into the lake. The size of sediment particles is therefore of interest because sediment type may affect where macrophytes grow. Macrophytes also have an effect on the sediment that they grow in (Jaynes and Carpenter 1986). Therefore, determining if there is gradient of particle sizes as you move from a stream delta out into the lake may be very relevant to solving the problem of eutrophication in Lake Champlain, and a better understanding of sediment deposition at deltas will also help researchers to this end, giving them a better idea of how sediment initially enters the lake and settles as it moves outwards through a bed of macrophytes. In order to complete this study, we sampled lake sediment at five stream deltas along Lake Champlain during the summer of 2015.

Methods

Study sites

Sampling was carried out at five sites along the Main Lake of Lake Champlain in western Vermont (Figure 1). Two sites were rivers 80m or greater in width, and three were smaller streams that were 1-3m wide. The larger streams included the outlet of Otter Creek at Fort Cassin Point (44°13'33.95"N, 73°19'13.14"W), the outlet of the Lamoille River near Milton, VT (44°37'5.69"N 73°13'57.97"W). The three smaller streams were as follows: a stream along Turkey Lane in Panton, VT (44° 7'55.92"N, 73°22'6.09"W), a stream flowing out of a culvert in Shoreham, VT (43°54'8.36"N, 73°22'27.42"W), and a stream at a boat launch in Bridport, VT (43°55'33.75"N, 73°23'31.75"W).

Methodology

Sampling was carried out along 3 to 5 transects per site that fanned out from the delta (see Figure 2). Sampling began at about 5m from the outlet and was repeated at 15m, 25m, 35m, and 45m whenever possible. At each point sediment cores were taken using a nested coring device. Sediment cores were processed for organic matter and analyzed for particle size using a grain size analyzer belonging to the Middlebury College Geology Department.

Data Analysis

For each sample, data were divided into three sediment types based on particle size: sand (>63 µm), silt (4-63 µm), and clay (<4 µm). The percentage of each sediment type was then calculated and each transect was then visualized in Excel using this breakdown (Figure 3). All sites were compared via ANOVA. Additionally, sites were categorized as either large (Otter Creek and Lamoille River) or small (boat launch, culvert, and Turkey Lane), and data were analyzed via ANOVA to determine sediment differences based on site size. Data from all sites were also analyzed via regression to determine if there was a relationship between average particle size and distance from shore.

Figure 2. A map showing the Otter Creek study site with the transects visualized as red lines. The map was created on August 5, 2015 using ArcGIS software.

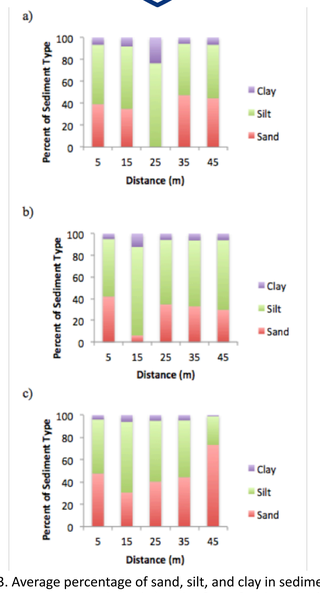

Figure 3. Average percentage of sand, silt, and clay in sediment samples along three transects (a, b, and c) at the Otter Creek study site (N=15 sediment samples). Data were collected by sampling along transects starting at 5m from shore and repeating every 10m until reaching 45m. Each bar represents the sediment composition of one sample. Data were analyzed using the Middlebury College Geology Dept.'s grain size analyzer and graphed in Microsoft Excel (Microsoft Corporation 2010).

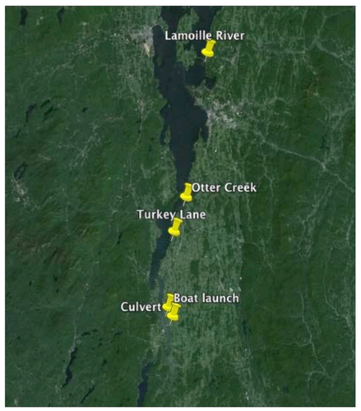

Figure 1. A map locating all five study sites along the eastern shore of Lake Champlain (USA). The map was created on August 5, 2015 using Google Earth imagery from April 9, 2013 centered around the coordinates 44°19'13.96" N, 73°17'32.06" W.

Results

86 total samples were collected from the study sites: 15 samples each from Otter Creek and the Lamoille River, 12 from the boat launch, 19 from the culvert, and 25 from Turkey Lane. Average particle size in a sample ranged from 3µm to 286µm, but individual particles were measured that were smaller than 1µm and greater than 600µm (see Figure 4 and supplementary raw data). The majority of samples (87%) were not well sorted, meaning they displayed a wide range of sediment particle size.

When sites were compared individually based on their sand/silt/clay breakdowns, the culvert, the boat launch, and Turkey Lane were the same for all sediment types. Average percentages of sand for these sites were all different from Otter Creek and the Lamoille River, however Otter Creek and the Lamoille River were also different from each other. Average percentages of silt were the same for the three smaller streams and Otter Creek, but all sites were different from the Lamoille River. Average percentages of clay for the smaller streams were all different from Otter Creek and the Lamoille River, and Otter Creek and the Lamoille River were the same.

When sites were categorized as either large or small, significant differences were found in sediment composition based on site size. Small sites had significantly less sand and more silt and clay (see supplementary analysis). No significant relationship was found between average particle size and distance from the shore for any sites but Turkey Lane. Turkey Lane showed a significant positive relationship between sediment particle size and distance from the shore (Figure 5).

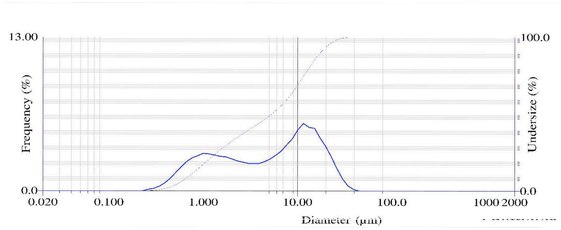

Figure 4. Sediment particle diameters in a sediment sample taken at a distance of 5m along transect A at the culvert study site (N=1). Sediment samples were collected using a nested coring device and analyzed with the Middlebury College Geology Dept.'s grain size analyzer. This figure serves as an example of the raw data produced by the analyzer for each individual sample.

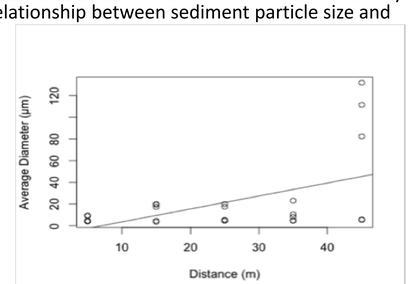

Figure 5: The relationship between average sediment particle size and distance from shore for the Turkey Lane study site (N=25 sediment samples). Data were collected by sampling along five transects starting at 5m from shore and repeating every 10m until reaching 45m. Data were analyzed using R statistical software (R Core Team 2013). A significant positive relationship was found between particle size and distance from shore ($F=7.88$, $df=23$, $p=0.01$).

Discussion

- Our study had some logistical limitations, and a repeat study with higher replication and transects that extend further into the lake would be recommended.
- As our study does not provide sufficient evidence that sediment particle size changes significantly as you increase distance from shore, it is probably not the determinate factor in macrophyte rooting, and it is therefore of interest to examine other possible factors.
- Future work at Lake Champlain deltas could include investigation of phosphorus levels in the sediment, a broader consideration of substrate beyond sediment particle size, and a more complete characterization of aquatic macrophytes.
- In addition, transplant experiments would be recommended to more fully test the ability of aquatic macrophytes to slow phosphorus entering the lake.

References

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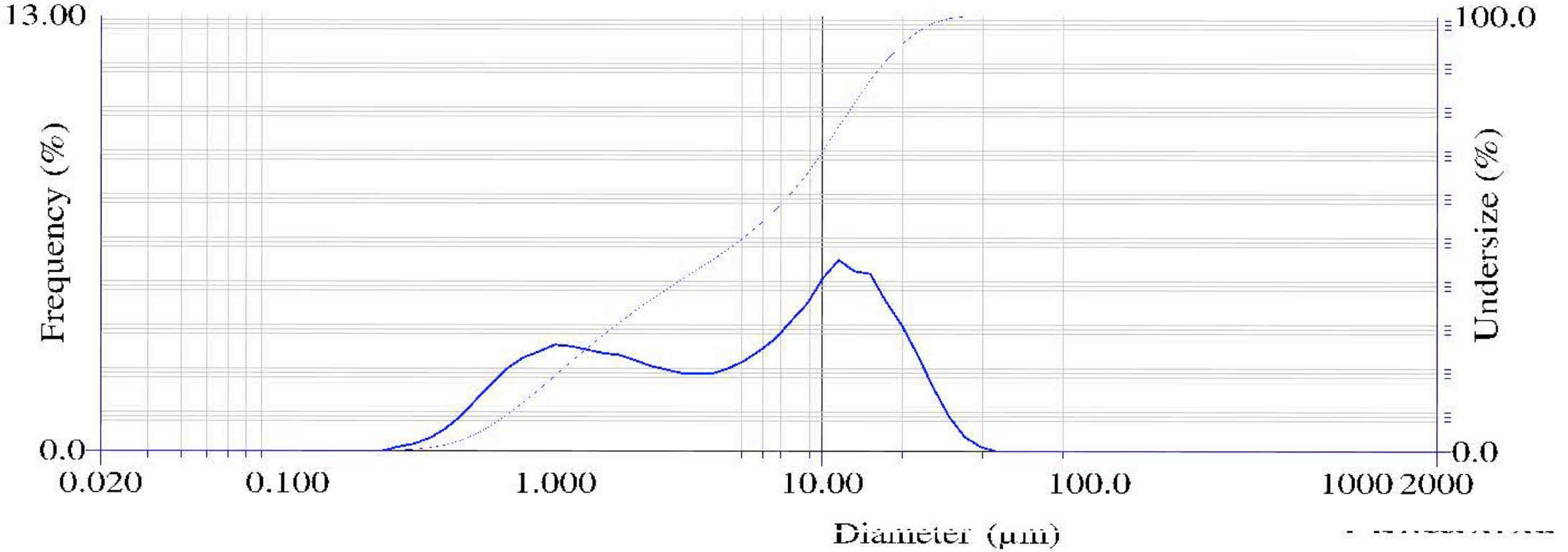
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