KECK GEOLOGY CONSORTIUM

PROCEEDINGS OF THE TWENTY-FIFTH ANNUAL KECK RESEARCH SYMPOSIUM IN GEOLOGY

April 2012
Amherst College, Amherst, MA

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ISSN# 1528-7491

The Consortium Colleges The National Science Foundation ExxonMobil Corporation

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Funding Provided by:
Keck Geology Consortium Member Institutions
The National Science Foundation Grant NSF-REU 1005122
ExxonMobil Corporation

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FRESH-WATER DIATOMS AS BIOINDICATORS OF POLLUTION IN SELDEN COVE, CONNECTICUT RIVER

TIRZAH ABBOTT, Beloit College
Research Advisor: Carl Mendelson

INTRODUCTION

Since the start of the Industrial Revolution, fresh-water environments have been threatened by anthropogenic contaminants. Industrialization, urbanization, and agriculture add high levels metal of nutrient contaminants that can alter ecosystems in fluvial and lacustrine environments (Wyn et al., 2007). Mercury is released by high-temperature combustion, such as coal-fired power plants, municipal and medical waste incinerators, concrete production, and waste-water treatment plants (Varekamp, 2003). Agricultural runoff can change the chemistry of streams and rivers, causing a change in the productivity and abundance of the biota that occupy fresh-water habitats (Giller and Malmqvist, 1998). Changes in these habitats can be observed by studying the diversity and abundance of benthic microorganisms.

Fresh-water extant and fossil diatoms, in particular, may be used to understand past environments, especially on a short time scale. Diatoms are small, abundant, have a fairly short lifespan, and inhabit just about any environment that can provide moisture and sunlight (Barron, 1993). Diatoms secrete an amorphous silica test called a frustule, giving them a high preservation potential (Armstrong and Brasier, 2005). Most diatom species are extremely sensitive to changes in physical and chemical conditions and therefore are used extensively in reconstructing past environments (Armstrong and Brasier, 2005).

The Connecticut River valley is an excellent example of the effect of industrialization on fresh-water systems with increased human activity. The river is about 650 km long and flows from Quebec, forms the border between Vermont and New Hampshire, and flows through Massachusetts, and Connecticut. It carries large loads of land-derived sediment to where it empties in Long Island Sound (Horne and Patton, 1989). Alongside the river, small inlets and coves of standing water provide a space where fine sediments are deposited. Selden Cove, a small tidal pond beyond the reach of saline waters, is the focus of this study (O'Connell, this volume Fig. 1). Sediments from this cove have shown high mercury concentrations, up to ~1000 ppb, which exceeds the highest mean concentration of mercury found in Long Island Sound (Schneyer, this volume; Jacobacci 2011; Varekamp et al., 2003). Selden Cove is, therefore, an appropriate site to determine the effectiveness of diatoms as indicators of inorganic pollutants caused by the onset of the industrial revolution.

Many studies have shown that different diatom taxa are useful indicators of a variety of pollution. Species diversity and evenness in diatom assemblages typically decrease with increased stress on the ecosystem (Ruggiu et al., 1998). Sensitive species will decrease in abundance, whereas the few species more tolerant of heavy metal and agricultural pollution will dominate (Rugiu et al., 1998; Szabo et al., 2005). *Achnantidium minutissimum* and many *Nitzschia* species are tolerant to a wide variety of pollution and commonly dominate in environments that have experienced some kind of stress (Szabo et al., 2005). Although there haven't been many studies on the effect of mercury pollution on fresh-water diatoms, it is possible that the relative abundance of tolerant species may correlate with changes in mercury concentrations in the sediment of Selden Cove.

METHODS

Selden Cove is a fresh-water tidal pond located on the east bank of the Connecticut River in Lyme, Connecticut (O'Connell, Fig. 1). It is about 16 km north of the mouth of the Connecticut River and falls just beyond the reach of saline waters from Long Island Sound. Selden Creek, a 3-km-long inlet connecting the main river channel to the tidal pond, was the main source of water input until about 1854 when a flood event broke through the riverbank into Selden Cove. In the summer of 2011 a core (SDC 6) was taken at 41° 24' 42.12" N and 72° 25' 0.2994" W using a piston push-coring device. The core was photographed. Grain size, composition, and color (using a soil Munsell color chart) were recorded.

The total length of the core was about 3.4 m. Samples were taken in 30 cm intervals from the first drive of the core (SDC 6-1), yielding a total of 8 samples. Sediment was processed to concentrate diatoms following methods used in Szabo et al. (2005) and Meyer (2002). Strew slides were made with Zrax diatom mounting agent. Mercury concentrations down the core were recorded by Schneyer, (this volume) using a Teledyne Leeman Labs Hydra-C Mercury analyzer. The mercury spike at about 235 cm was assumed to represent an increase in mercury production in 1850 (Schneyer, this volume; Jacobacci, 2011; Varekamp et al. 2003). From each strew slide, 200 diatoms were identified to the genus or species level (when possible) using Spaulding et al. (2010) and Wehr and Sheath (2003). Percent abundance of each taxon was calculated at each interval. Diversity for each sample was calculated using the Shannon-Weaver diversity index (H'):

$$H' = -\sum_{i=1}^{k} p_i \log p_i$$

Where k is the number of taxa and pi is the proportional abundance of species i. The maximum H' also depends on the number of categories or taxa within each sample. Therefore, the relative diversity, or evenness (J') was calculated:

$$J' = \frac{H'}{H'_{max}}$$

where H'max = logk (Zar, 2010). Published studies from other areas were used to assess the tolerances of taxa and to assess paleoenvironment. A linear regression analysis was used to correlate indicator taxa with mercury concentration. Taxa with abundance greater than 5% were analyzed and relative tolerance to a wide variety of pollutants (Van Dam et al., 1994; Kelley et al., 2005).

Depth (cm)	H'	H'_{max}	J'
3	1.33	1.68	0.79
33	1.39	1.67	0.83
63	1.39	1.68	0.82
93	1.56	1.79	0.87
123	1.51	1.77	0.85
153	1.36	1.71	0.80
183	1.22	1.66	0.73
213	1.34	1.77	0.76

TABLE 1. Diatom idversity as a function of core depth. H' = Shannon-Weaver diversity index; H'max = maximum diversity, as defined in text; J' = relative diversity (evenness)

RESULTS

The sediment in the core was composed of about 90% silty clay with lenses of sand and organic matter. The color was consistent through the whole core (5y 3/1 black). Strew slides studied yielded 140 different diatom taxa, which were identified to the genus or species level. The diatom taxa included 138 pennate and 2 centric taxa. Diversity values show little to no significant change with depth (Tab. 1). Evenness (J') and diversity was the lowest at 183 cm. Insert Table 1. Species characterized by a relative abundance over 5% were considered significant and relative tolerances of those taxa were identified. Although diversity changed little with depth, the dominant taxa did change. Significant genera include Achnanthidium, *Nitzschia*, *Encyonema*, and *Tabellaria*. In addition, *A. minutissimum* was found to be a useful indicator species.

Achnanthidium minutissima increases from 14% (213) to 23.5% (183) and then decreases gradually to the top (Fig. 2. a). The abundance of *Achnanthidium* decreased from 153 – 63 cm from 20 – 1.5%. *Nitzschia* peaked at 213 cm (6%), fell to 4% at 153 cm then peaked where it was found in the highest abundance at 3 cm (9%), The total abundance of the genus *Cymbella* decreased at 183 cm to about 0.5%. *Encyonema* also peaked 213 cm down the core (5%) then decreased to 1% at 183 cm. There was no clear pattern in the change in abundance in *Tabelleria*.

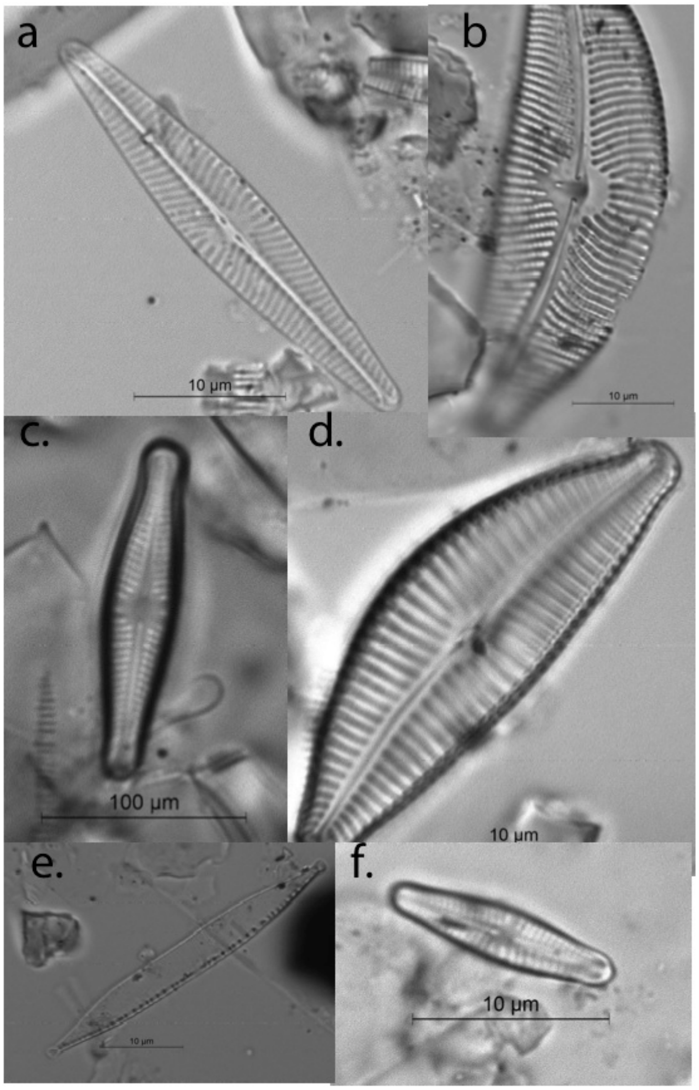

FIGURE 1. Dominant diatom taxa in core. (a) Navicula*, (b)*Cymbella*, (c)*Achnanthidium*, (d)* A. minutissimum*, (e)* Nitzschia*, and (f)*Encyonema.

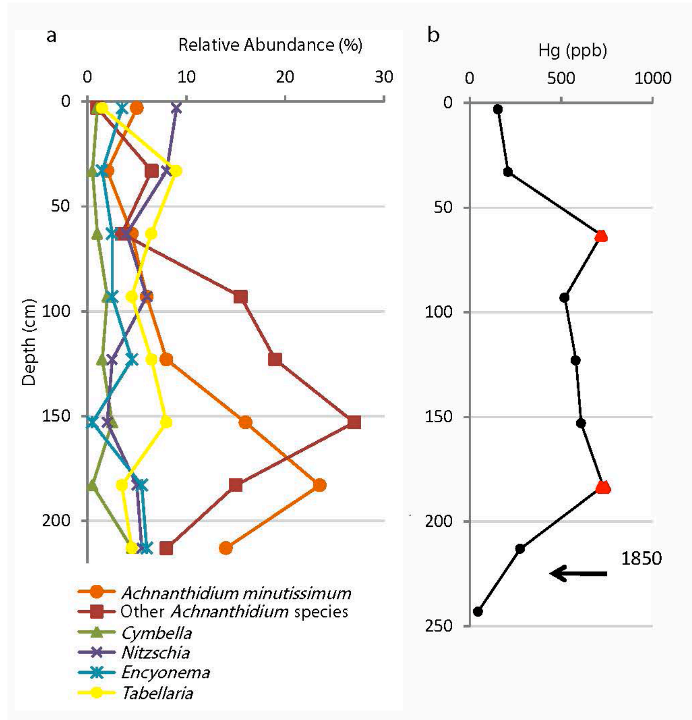

FIGURE 2. a) Relative abundance of sensitive and tolerant indicator taxa in core SDC 6-1. b) Mercury concentrations as a function of core depth (from Schneyer, this volume). Two peaks at 63 cm and 183 cm are represented by red triangles.

Studies by Jacobacci (2011), and Varekamp et al. (2003) indicate that the initial increase in Hg can be estimated at about 1850. Jacobacci (2011) also found that the relative sedimentation rate in Selden Cove to be about 1-1.4 cm/year. Above 235 cm, mercury concentrations increased in Selden Cove, with two peaks at 183 cm and 63 cm (Fig. 2.b). In the most recent sediments (above 63 cm), mercury decreases to approximately the same levels that occurred in 1850. A linear regression analysis showed a weak correlation between mercury concentrations and sensitive taxa (Fig. 3). The most noticeable change with mercury concentration was seen in *Nitzschia* ($r^2 = 0.6$) but it is not significant ($p = 0.02$, using significance level of 0.05).

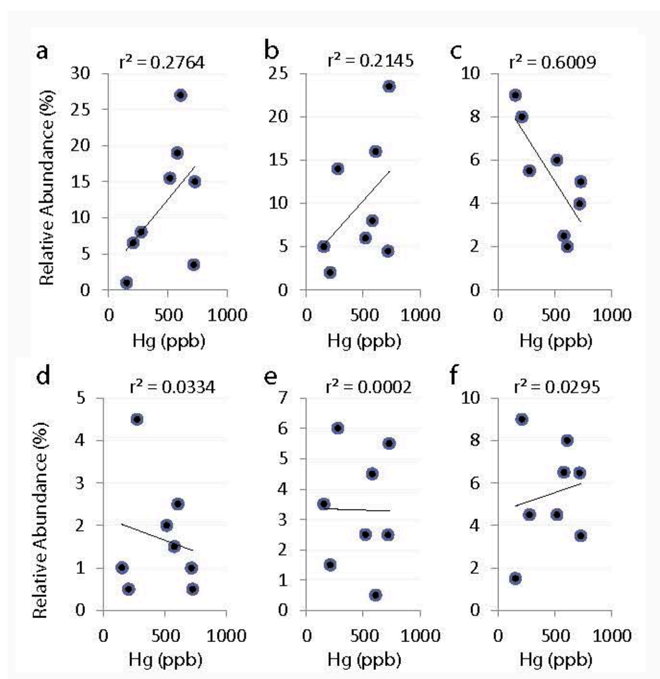

FIGURE 3. Correlation of diatom relative abundance and mercury concentrations in SDC 6-1. a) Achnanthidium*, b)* Achnanthidium minutissimum*, c)* Nitzschia*, d)* Cymbella*, e)* Encyonema*, and f).* Tabelleria.

DISCUSSION

Shallow aqueous environments such as Selden Cove show changes in diatom assemblages that can be used to assess past environments. Although many of the selected taxa do not show a response to changes in the in Hg concentration, they do share similar trends at 200 - 5 cm. Jacobacci (2011) documented that the opening of the new channel into Selden Cove in 1854 seems to be reflected by the increase in Hg concentration shortly after 1850 (Fig. 2). Szabo et al. (2005), found that *Achnanthidium minutissimum* will dominate in areas that have been affected by heavy metal pollution. They also suggest that tolerant species such as *A. minutissimum* will be the first to radiate and gain dominance in highly stressed environments, causing a decrease in the abundance of other, more sensitive taxa. Although *A. minutissimum* does have a direct correlation with the increase in mercury, they do increase after the introduction of mercury into Selden Cove. The increase in abundance of *A. minutissimum* at 183 cm could be considered an indicator of the opening of the new channel and possibly the onset of industrialization. At the same depth (183 cm) there was a relative decrease in *Cymbella*, a genus that is typically very sensitive to environmental changes (Van Dam et al. 1994). *Cymbella* is relatively low in abundance throughout the rest of the core, possibly indicating mild to moderate pollution.

The general trend seen in the abundance of *Nitzschia* with depth is especially interesting. *Nitzschia* is considered to be fairly tolerant to most types of pollution. Perhaps it was impacted by the increase in mercury, but it is likely to have been affected by other forms of pollution as well. *Nitzschia* are most often found in greatest abundance in waters with high inorganic, agricultural pollution (Spaulding et al., 2012). Although the negative correlation seen between Hg concentration and relative abundance wasn't statistically credible, it could still suggested that *Nitzschia* may not be as successful in sediment with high Hg concentrations.

CONCLUSION

A. minutissimum, a diatom species tolerant of heavy metal pollution, was found in the greatest abundance shortly after the opening of the new channel into Selden Cove. Although the relative abundance of *A. minutissimum* doesn't correlate with Hg concentrations, the spike in both *A. minutissimum* and Hg concentration at 183 cm may suggest that there was a change in environment causing the dominate species to shift to more tolerant taxa. This study may also suggest that *Nitzschia*, a genus that is generally tolerant to many types of pollution, may be affected by changes in Hg concentrations.

To further emphasize the initial results of this study, methods used by Van Dam et al. (1993) and the Pollution Tolerance Indices (PTI) will be used. These methods are used to determine the pH, salinity, nitrogen uptake, oxygen requirements, and trophic status of past environments.

ACKNOWLEDGMENTS

Thank you Keck Geology consortium for this opportunity! Thanks Suzanne O'Connell, Peter Patton, and Joel Labella at Wesleyan University for working with me to collect the cores and help in designing this project. I also thank my advisor at Beloit College, Carl Mendelson, for being a wonderful mentor and guiding me through this process. I would like to profusely thank Carol Mankiewicz for providing me with materials to identify diatoms, helping me identify species, and for helping me make slides. Finally, I thank you Elizabeth George, Mike Cuttler, Jon Schneyer, Hannah Blatchford, and Danielle Martin.

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