Paleolimnological analysis of nutrient enrichment for criteria development in New Jersey and New York lakes

Final Report

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Introduction

New Jersey and New York are within the most populated areas on the east coast of the U.S.A. and agricultural, industrial, tourism and recreational activities are becoming a common source of stressors on their lacustrine ecosystems. As a result, a large range of terrestrial and atmospheric changes are affecting the lakes making the management of water quality in New Jersey and New York regions a challenging task.

Paleolimnological techniques were used to investigate the extent to which anthropogenic disturbances have impacted the current ecological conditions in lakes in New York and New Jersey. In the absence of instrumental records, lake sediments constitute a valuable source of information on biogeochemical processes taking place in lake systems. Paleolimnological techniques have already proved to be a powerful tool in assessing regional and temporal changes in water quality of lakes under the effect of multiple stressors (e.g., industrialization, watershed development), and for lake management purposes (Hall and Smol 1992, Dixit and Smol 1994, Reavie et al. 1995, Hall and Smol 1999, Bennion et al. 2000, Bennion et al. 2001, Bradshaw and Anderson 2001). Theses techniques are based on quantification of fossil biological indicators, such as diatom species.

Diatoms are one of the most powerful water quality indicators used in paleolimnological studies. Diatoms are ecologically diverse and their silica wall, called a frustule, is identifiable to the levels of species and variety. They colonize virtually every freshwater microhabitat and many diatom species have well-defined optima and tolerances for environmental variables such as lake pH, nutrient concentration, water salinity and color (Stoermer and Smol 1999). Variations in fossil diatom abundance and specific composition can be used to assess the amount of change that has occurred in lake systems in postindustrial versus pre-European settlement time periods.

A fast way to quantify the changes that have affected lake systems, beginning with European settlement, is to examine how much the composition and relative abundance of sedimentary diatom assemblages changed between the top of the core (representing present-day conditions) and at the bottom 30-40-cm of sediment cores, representing the preindustrial, undisturbed conditions (i.e., top-bottom approach). The top-bottom approach provides two ‘snap-shots’ of environmental conditions, before and after human impacts, and has proven successful in answering diverse environmental question such as the impact of acid rain, eutrophication or global warming (Cumming et al. 1992; Dixit et al. 1999; Quinlan and Smol 2002; Ruhland and Smol 2003; Smol et al. 2007).

Although many paleolimnological studies have investigated regional changes in nutrient or pH status of lakes in New Jersey and New York (e.g., Dixit and Smol 1994; Dixit et al. 1999), little is known about changes in deepwater oxygen levels. Many lakes currently have low end-of-summer hypolimnetic oxygen concentrations, but it is unknown if these lakes are naturally anoxic or if this is due to the impact of human activities. Subfossil remains of chironomids (Diptera: Chironomidae) are useful indicators of past environmental conditions in the deepwater zone of lakes, including hypolimnetic oxygen conditions (Francis 2001, Quinlan and Smol 2002; Walker 2002).

The project’s primary objective is to provide a paleolimnological pilot study to support nutrient and other biological criteria development in New Jersey and New York lakes. This study used diatom assemblages and chironomid remains from lake sediment cores as biological indicators of nutrient and eutrophication status of lakes. It also provides a historical perspective of past lake conditions, including hypolimnetic oxygen, that can be used to assess the amount and timing of change that has occurred, to quantify reference conditions, and to help set targets for ecological restoration.

The project has two main goals:

1) To assess lake reference conditions with respect to trophic indices within major Level 3 Ecoregions of New Jersey and New York and evaluate the timing and extent of the impact of post-industrial period.

2) To assess historical hypolimnetic oxygen levels in representative lake systems within major Level 3 Ecoregions of New Jersey and New York. Additionally, the proposed work will provide important verification/validation of the ecoregional construct as applied to nutrient criteria implementation.

To assess reference conditions and the amount of change since pre-industrial time, diatom species from top-bottom sediment cores from 27 lakes from New York and New Jersey were analyzed. Additionally, sediment cores from Greenwood and Cossayuna lakes were analyzed at decadal resolution for diatom species to determine the timing of environmental changes. Diatom species from surface sediments of 20 lakes from New Jersey have been quantified; these samples will be combined with the National Lake Assessment data set to develop transfer functions for nutrients, pH, and other environmental variables of interest, based on the most recent diatom taxonomy. Historical hypolimnetic oxygen assessment in top-bottom sediment cores and in Greenwood and Cossayuna lakes are presented in Appendix 1.

Methods

Methods for diatom and chironomid research followed the approach used in the EMAP-SW project (Dixit and Smol 1999) and the regional assessment of VWHO changes in Ontario (Canada) shield lakes (Quinlan and Smol 2000; Quinlan and Smol 2001a,b). The methods rely on paleolimnological protocols that were initially developed for large, multi-institution paleolimnological research projects which investigated the effects of acid rain on aquatic resources in the United States (PIRLA-I, Charles and Whitehead 1986; and PIRLA-II, Charles and Smol 1990), and the Environmental Monitoring and Assessment Program-Surface Waters (EMAP-SW, Dixit et al. 1999). Protocols for sample preparation and diatom analysis were improved and updated by the ANSP (http://diatom.acnatsci.org/nawqa/protocols.asp) (Charles et al. 2002) and adapted for the study of lake sediments.

Field sampling

A cross section of lakes was selected for sampling in both New Jersey and New York ecoregions within a range of known eutrophication conditions (e.g., high nutrient and/or algal biomass) (Table 1). Site selection was based on multiple data including: ongoing State monitoring programs, historical databases such as the Clean Lakes program, the EMAP lakes study, a recent (1990s) Region-2 lakes study, and lakes listed for TMDL (303d) development, characterization and/or restoration.

New Jersey DEP field crews, under the supervision of Johannus Franken, collected surface sediment samples in 1996 from 44 lakes using a Glew mini-corer (Glew 1991). Two surface samples (0.0 – 0.5 cm and 0.5-1.0 cm) were extruded from the sediment cores from at least one location in each lake. They also collected the water chemistry and morphological data that is used for this study (total phosphorus, total Kjeldahl nitrogen, total nitrite+nitrate nitrogen, ammonia nitrogen, dissolved oxygen, temperature, specific conductance, pH, alkalinity, hardness, Secchi depth, and chlorophyll *a*).

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A Glew-modified K-B corer (Glew 1989) was used to take sediment cores from the deepest basin of the lakes selected for stratigraphic and top-bottom study. The cores were extruded in the field, using a Glew (1988) extruder. Stratigraphic sediment cores were subsampled at 0.5-cm thick intervals for the top 10 cm of the cores and at 1-cm intervals to the core bottom. These cores were dated using Pb-210, and diatom species were analyzed in 10 sediment samples following a step by step approach to determine the timing, amount, and variability of changes in lakes' ecosystem.

Diatom analysis

Diatoms were permanently mounted on microscope slides and identified to lowest taxonomic level with a Leica DMR microscope equipped with DIC optics at 1000X magnification (Numerical Aperature of oil objective and condenser top lens = 1.3 and 1.4, respectively); a minimum of 500 valves were counted for surface sediments from 20 calibration lakes while for the top-bottom and stratigraphic samples, 300 valves were counted. All project data is stored in the Phycology Section's North American Diatom

Ecological Database (NADED). The diatom taxonomy was based on the references of Krammer and Lange-Bertalot (1986, 1988, 1991a, 1991b), Patrick and Reimer (1966, 1975), Camburn and Charles (2000), Cumming et al. (1995) and Tanaka (2007).

Dating

Sediment samples were measured for ^{210}Pb activity by gamma spectrometry. Sediment samples of ~0.5-1-g dry weight were measured at 2-cm intervals in the upper part of the core and at more widely spaced intervals down core. Core chronologies were established using the CRS (constant rate of supply) dating model (Appleby and Oldfield 1978). The Constant Initial Concentration models were also provided for each lake (Appendix 2).

Statistical analyses

To determine the gradient length represented by the diatom assemblages in the 40 study lakes, detrended correspondence analyses (DCA) with and without a square root transformation of the species data were performed. Following this analysis, the main directions of variation in diatom assemblages in the study lakes was determined using a correspondence analysis (CA) ordination, [using non-transformed species relative abundance data, since the gradient length in an initial DCA was > 2 standard deviation units (Hill and Gauch 1980).

The main directions of variation of environmental variables within the study sites of the water chemistry and physical variables (e.g., lake TP, Secchi), were explored using a species-centered principal component analysis (PCA) on a correlation matrix of log-transformed values. All ordination analyses were performed using the program CANOCO v. 4.5 (ter Braak and Šmilauer 1998).

To determine if statistically significant differences in species relative abundances were present in modern versus pre-industrial times, ANOVAs and paired t-tests were used. ANOVAs and t-tests were performed using the program JMP v. 7.0 (SAS Institute Inc.).

Inference models

We used the calibration dataset provide by Dr. Dixit (Dixit et al. 1999) to develop transfer functions for TP and pH for the two stratigraphic lakes, Cossayuna and Greenwood. Standard weighted averaging inference models were developed based on the EMAP data set (described in ter Braak and Juggins 1993, Dixit et al. 1999). Calculations were done using the computer program C^2 (Juggins 2003). Because only 13% of diatom species from the EMAP data set were represented in the top and bottom samples, transfer functions were not used for these samples. Instead, the National Lake Assessment (NLA) data set will be used to reconstruct nutrient and pH in pre-industrial sediment samples. Surface sediment samples from 20 lakes from New Jersey will be combined with the NLA data set to develop inference models that are based on the latest advances in diatom taxonomy and that will reflect the most recent environmental conditions in study lakes.

Results and discussion

Changes in modern versus pre-industrial diatom assemblages

A total of ~ 500 diatom species were identified in top and bottom sediment samples from 27 lakes. Overall, there is an increase in planktonic centric diatoms up to 70% in the top samples of 12 lakes that are dominated by meso-eutrophic species of *Fragilaria crotonensis*, *Aulacoseira ambigua*, *Cyclostephanos invisitatus*, *Stephanodiscus binderanus oestrupii*, along with more oligo-mesotrophic species of *Cyclotella comensis*, and *C. ocellata*. Decreases of planktonic diatoms between 5-40% took place in other 12 lakes, while 3 lakes did not display any change (Fig 1). The most abundant species in bottom samples are: *Aulacoseira subarctica*, *Cyclotella michiganiana*, *A. granulata*, *A. ambigua*, *Tabellaria* spp. and a diverse benthic flora of *Navicula* spp., *Gomphonema* spp., *Cymbella* spp., etc. Most *Navicula*, *Gomphonema*, *Cymbella,* and other species decrease or disappear in top samples. Many lakes experienced large increases in the eutrophic species *Fragilaria crotonensis* in top samples (Fig. 1).

Main directions of variation of diatom species

Correspondence analyses performed on bottom (Fig. 2) and top samples (Fig. 3) display the main directions in variation of diatom species. CA of bottom samples shows that lakes in pre-industrial time were having mainly two types of diatom assemblages: 1) a dominantly planktonic association in the upper quadrants of the CA plot with mesotrophic species of *Cyclotella michiganiana*, *C. bodanica lemanica*, *Aulacoseira ambigua*, *Tabellaria flocculosa* strain *IIIp, Stephanodiscus niagarae* along with more oligotrophic *Discostella stelligera*, *D. glomerata*, and in some lakes the eutrophic *A. granulata*; and 2) a dominantly benthic assemblage with *Gomphonema* spp., *Fragilaria capucina* complex, *Planothidium* spp., *Eunotia* spp., etc., in the lower quadrants. Most NY lakes are situated in the upper quadrants, such as Conesus, Otisco, Oneida, Peach, Silver, but also the NJ Muckshaw Pond and Round Valley Rec. Area. The lower quadrants comprise the rest of NJ lakes as well as some NY lakes such as Canadice, Canadaigua, and Park. Interesting are lakes that comprise abundant acidophilic species of *Eunotia* spp. such as Duck Pond (50%) and Union Lake (25%). The two cores taken from different basins of Lake Champlain are represented by two different types of diatom assemblages, one dominated by *Discostella stelligera*, *Aulacoseira granulata* and *Cyclostephanos tholiformis,* species living in deeper waters, and the second one exclusively represented by *Tabellaria fenestrata* and by *Gomphonema gracile*, species found to be indicator of environments with abundant macrophytes (Vermaire and Gregory-Eaves 2007) in the EMAP NE data set.

Along with the planktonic species from the upper quadrant occur benthic species of *Staurosira construens*, and *Staurosirella pinnata* that are ubiquitous species found in slightly eutrophic waters from British Columbia by Reavie et al. (2000) and that were found abundant (> 20%) in Silver Lake and Muckshaw Pond. Lake Canadice stands by itself in the corner of the lower right quadrant with a dominant *Aulacoseira subarctica* (88%) diatom assemblage.

The top core samples (Fig. 3) record important shifts in the composition of diatom assemblages in most lakes. The upper left quadrant is mainly represented by eutrophic species (*Fragilaria crotonensis*, *Cyclostephanos* spp., *Stephanodiscus parvus*) and the oligotrophic *Cyclotella ocellata*. Only lakes from NY are represented by this type of diatom assemblage (Otisco, Silver, Owasco, etc.). The upper right quadrant displays lakes with littoral to sublittoral species of *Staurosirella pinnata*, *Pseudostaurosira brevistriata*, and *Staurosira construens* var. *venter* (Muckshaw, Oneida, Cassadaga). In Muckshaw Pond, the abundance of *S. construens* increased from 33% to 60% in top samples while *Navicula* spp dramatically decreased or disappeared. In Cassadaga Lake, the diverse specific composition from bottom sample (*Asterionella formosa* 14%; *Aulacoseira* spp. 12%; *Fragilaria capucina* 9%; *Navicula* spp. 8%; *Nitzschia* spp. 14%) changes to an assemblage dominated by *Stephanodiscus binderanus oestrupii* (32%) and *P. brevistriata* (8%) while *Nitzschia* spp., *Navicula* spp., and other species decline or disappear. Oneida Lake experiences a opposite situation, with a bottom represented uniquely by *A. granulata* (50%) and *Opephora martyi* (50%) while the present day diatoms are more diverse, with a decline of *A. granulata* to 30%, and replacement of *O. martyi* by *S. binderanus oestrupii* (23%), *P. brevistriata* (7%) and other benthic species.

The lower left quadrant displays lakes from both NY and NJ that are characterized by mesotrophic diatom species: *Asterionella formosa*, *A. ambigua*, *Tabellaria flocculosa* IIIp, but also the oligotrophic *Discostella stelligera*, and *Fragilaria vaucheriae*, a species found associated with warmer temperature and longer growing season (Schmidt et al. 2004). Within these lakes we may mention Delaware Lake with a pre-industrial dominant benthic specific composition (97%; *Gomphonema* spp., *Planothidium frequentissimum*; *Navicula* spp) that changes to abundant mesotrophic planktonic species *A. ambigua* (45%) and other species in lower abundances (*Fragilaria capucina* 9%; eutrophic *Cyclotella meneghiniana* 5%). The top samples from Lake Champlain become much more similar in diatom species composition than the bottom samples. The shallow core completely changes from *G. gracile* and *T. fenestrata* to a more diverse composition with abundant eutrophic planktonic species *A. granulata*, *A. tenella*, *A. ambigua* (30%) along with benthic *Achnanthidium minutissimum* and *Fragilaria* species. The deeper basin top core preserves a similar specific composition with the bottom sample, except that *D. stelligera*, an indicator of increased summer stratification increases from 25% to 40% relative abundance.

The lower right quadrant represents lakes that are characterized by benthic diatom species, as well as lower abundance mesotrophic (*Cyclotella bodanica var. lemanica*) or eutrophic (*C. meneghiniana*) species. The top sample from Union lake is mainly represented by *A. ambigua* (15%), *Fragilaria capucina* (12%), and the circumneutral *Discostella stelligera* (9%), while acidophilic *Eunotia* spp drops to 4% and tychoplanktonic *Tabellaria quadriseptata*, considered an indicator of macrophytes (Reavie et al. 2000) or acidic pH (Chen et al. 2008), disappear. Similar trends are displayed by Duck Pond with disappearance of *Eunotia* spp from bottom sample and apparition of *D. stelligera* in the top sample. Green Pond displays changes similar to those found by Sebetich and Mesaros (1993) with a bottom dominated by *C. bodanica* var. *lemanica* and increased abundances of *S. construens* var. *venter* , *Stauroforma exiguiformis* and *D. stelligera* in the top sample.

Patterns in limnological characteristics of study lakes

Figure 4 displays the unconstrained ordination in reduced space of the 27 top-bottom study lakes. The first two axes explained 86% of variance in study lakes. Lake TP is strongly correlated to axis 1 and separates lakes with higher nutrient concentration in the left quadrants (e.g., Cossayuna, Peach, Silver) from more dilute, lower nutrient lakes situated in the right quadrants (e.g., Sly Pond, Little Simmer). Lake pH and conductivity contribute most to defining the second axis and roughly separate low conductivity or low pH lakes in the upper quadrants (e.g., Union, Duck Pond) from the lakes situated in the lower quadrants and that have higher pH or conductivity. Because of missing data in the chemistry files, other important environmental variables, such as lake depth, area, and TN were not included in the PCA ordination.

Analysis of the amount of change since pre-industrial times

The analysis of changes in diatom species in top versus bottom samples reveals important changes in lakes characteristics since pre-industrial times. First, some meso-eutrophic species (e.g., *Aulacoseira ambigua* in Anawana, Otisco, Conesus) *Fragilaria crotonensis* in Round Valley, *Tabellaria flocculosa* in Keula) were found in bottom samples, suggesting that some lakes are naturally nutrient rich (at least moderately so), or that sediment cores were not long enough to provide reference conditions. European settlement took place as early as the late-1600s toearly-1700s in the eastern US, and intense agricultural activity may have been already impacting study lakes in a time period that may be earlier than our bottom sediment cores. However, many of our study lakes experience important shifts in diatom species, suggesting changes from lower to higher nutrient levels than can be attributed to human impact. Variations in diatom composition and abundance in lacustrine ecosystems are typically strongly related to changes in water physico-chemical properties, such as pH, nutrient concentration, transparency, and lake stratification (Smol and Cumming 2000). Diatoms are excellent indicators of environmental conditions, with species that can have well defined optima and narrow tolerances to environmental gradients such as nutrients, pH, temperature, or lake stratification. We focused on species that are known from large-scale regional studies to represent well defined environmental conditions (Wilson et al. 1995; Reavie et al. 2000; Enache and Prairie 2002; Ginn et al. 2007; Cumming et al. unpublished data) and we focused on analyzing the changes undergone by these species in top versus bottom samples. Table 2 represents a summary of the amount of change > 5% for species that characterize high eutrophic conditions (TP optima >30 μg/L), eutrophic, mesotrophic, and oligotrophic or related to increased lake stratification conditions. For example, *Stephanodiscus parvus* and *Cyclotella meneghiniana* live in high nutrient [hyper-eutrophic lakes, *Aulacoseira ambigua* in eutrophic, while *Tabellaria flocculosa* and *Asterionella formosa* indicate mesotrophic conditions.

Increased lake stratification and the formation of a low-nutrient epilimnion are indicated by small size, light *Cyclotella* and *Discostella* species. This may be related to a lengthening of the ice-free season and enhanced lake stratification (Catalan et al. 2002; Sorvari et al. 2002; Rühland et al. 2003), a phenomenon that can be induced by increasing temperatures and drought (Smol et al. 2005; Rühland et al. 2008). On the other hand, taxa that are commonly associated with turbulent periods in the water column, conditions that are more likely to occur during extended periods of spring and/or autumnal mixing in dimictic lakes (Rühland and Smol 2005; Harris et al. 2006), such as heavy silicified *Aulacoseira* spp may decrease in periods of higher lake stratification and stability.

ANOVA and pair-wise t-tests were performed to investigate which species display statistically significant ($p<0.05$) changes in top versus bottom samples. Overall, the increase of centric planktonic diatoms and *Fragilaria crotonensis* were statistically significant, suggesting that significant changes took place in the limnological characteristics of our study lakes. On the other hand, a sharp decrease is recorded by benthic, circumneutral species of *Navicula*, suggesting that important changes took place in the lakes' substrate characteristics (Fig. 5).

Many diatom species did not display statistically significant changes, mainly because they were absent in many samples, but also due to the relatively small size of the data set; however, they can provide important indications of changes in individual lakes. For example, *Cyclotella meneghiniana* increases > 5% in Japanese Garden and Delaware lakes, while Conesus is characterized by an increase of ~45% of highly eutrophic *Cyclstephanos* spp (Fig. 6). This may suggest that Conesus has experienced higher nutrient concentrations since 2001, when chemistry data were collected. Similarly, large increases (>10%) in small *Stephanodiscus* species (*S. parvus, S. hantzschii, S. minutulus*) known to be related to high nutrient levels are recorded in Conesus, Otisco, and Silver lakes (Table 2, Fig. 6). *Fragilaria crotonensis*, a well-known indicator of lake eutrophication significantly increases in our study lakes. Highest increases are recorded in Owasco, Keula, Peach, Otisco, Silver and Hemlock (20-50% increase in top samples). Also, it is important to point out that diatom species indicate that lake eutrophication took place on a large scale and includes lakes that are not currently on the nutrient-impared EPA list (see Figure 1 for lakes within this study listed as impaired by EPA).

An interesting phenomenon is displayed by increases in low-nutrient small *Cyclotella* and *Discostella* species, in lakes such as Canadaigua, Keula, Conesus. Some of these lakes, such as Keula and Conesus, also display increases in high-nutrient indicator species (see above). These species may indicate a prolonged summer stratification related to recent climate warming. Changes related to climate conditions are also indicated by increases in *Fragilaria capucina* and *F. vaucheriae*, considered related to longer growing season and higher temperatures (Schmidt et al. 2004).

Stratigraphic Lakes

Three lakes were selected for stratigraphic investigations: Greenwood, Cossayuna and Union Lake, because of existing historical records, their importance as recreation resort, or their impaired status. Because of sediment mixing, Union Lake did not provide a good core stratigraphy (Appendix 2) and hence was included in the top-bottom study. Both Cossayuna and Greenwood Lake sediment cores provided important information on past lake environments. Logging, agriculture, dam constructions, industry and related atmospheric pollution, as well as the recent residential, tourism, and recreation activities represent the main cause of anthropogenic impact on lake conditions in study area.

Cossayuna Lake

Cossayuna is a shallow lake (max. depth ~8m, mean depth 3m), 4.5-km length and 7,467 acre watershed area. Cossayuna Lake is part of the Upper Hudson River drainage basin and is distributed among the townships of Argyle, Greenwich, Salem, and Hebron. Critical impairment problems are related to eutrophication, oxygen depletion, and loss of habitat for fish. The lake experiences seasonal algae blooms and plant growth, with invasive Eurasian watermilfoil introduced in mid-1970. The area around Cossayuna Lake was settled in 1765 by Dutch families, followed by Scottish, English, and Irish. Soon, water power was developed at the outlet of Cossayuna Lake, where three dams were erected. Later, paper mills and farming became the backbone of the economy of the region. Cossayuna Lake was famous for its bass fishing, and one hundred years after the first settlers arrived it became a well-known recreation resort. Today, invasive Eurasian watermilfoil is a major management challenge and annual harvesting plans have been implemented (LA Group, PC, 2001). The main goals of the lake's community are to limit excessive nutrient loading that caused low levels of dissolved oxygen resulting in a loss of habitat for fish and to develop an aquatic vegetation management plan with longer-lasting benefits than annual plant harvesting.

Diatom assemblages and inferred TP and pH

Diatom species were identified and enumerated in a 39-cm sediment core. The bottom of the core is characterized by dominance of *Cyclotella michiganiana*, a low-nutrient planktonic species (Fig. 7). At 26 cm the core records an important increase in *Aulacoseira ambigua*, a eutrophic tychoplanktonic species, along with increases in *Staurosirella pinnata*, *Staurosira construens* var. *venter* and *Staurosira construens*. Another important change takes place at the top of the core with a decline of *A. ambigua* and increases in *Tablellaria flocculosa* and *Fragilaria crotonensis* along with smaller amounts of *Stephanodiscus* spp., *Asterionella formosa*, and *Discostella stelligera.* These changes define three diatom zones identified by cluster analysis (Grimm 1987): A, B, and C, from bottom to the top core (Fig. 7).

Diatom-inferred TP within the Zone A shows oligotrophic conditions were present at the core bottom, mainly triggered by high abundance of *C. michiganiana*. The disappearance of this species in modern samples is a common phenomenon found also in other top-bottom lakes within this study (Fig. 6). The occurrence of this taxon suggests that low nutrient levels characterize reference conditions in Cossayuna Lake. The CRS dating of this part of the core may indicate the early- to mid-1800s. At this time, dams had already been erected by the early settlers and they may contribute to increased water levels and summer stratification, which favored the occurrence of *C. michiganiana*.

Diatom species from zone B (especially *A. ambigua*, and *A. granulata*) indicate that important increases in nutrient levels took place in the late 1800-early 1900s. At this time, TP levels surge to ~ 30 µg/L while pH drops from 8.4 to 7.8. Lake eutrophication can be related to increased human activities in the region. Train service was introduced to Greenwich in 1869 and by 1895 the Greenwich and Schuylerville Electric Railroad were established, contributing to increased population, farming and industrial activities. During this period, Cossayuna Lake became also a famous recreation resort for the state's capital population as well.

A slight and short-lived decrease in TP levels takes place around 1980s, as indicated by the decline of *A. ambigua*. This may indicate the effect of the water pollution treatment that was introduced in 1970, or effects related to recent climate warming. Over this time, the pH also drops to 7.4, possibly indicating the effect from herbicide use to stop macrophyte proliferation over the last 2 decades. Cossayuna Lake has present-day measured TP of 35 µg/L, and pH 8.13, with similar values being inferred by diatom species (Fig. 9). Diatom inferences also suggest that if effective restoration plans are implemented, conditions close to the original oligotropic status of Cossayuna Lake should be reached.

Greenwood Lake

Greenwood Lake (41°11'20"; 74°79'20") is situated at the border of New Jersey and New York. The lake extends north to the Town of Warwick, NY, and south to the Township of West Milford, NJ. The lake is ~ 15.4 km long and 1.9 km wide with a 777 ha surface area, maximum depth 18m and steep slopes on the northern section and maximum depth 3m and extensive littoral area on the southern section. Similar to Cossayuna, Greenwood Lake experiences increased deterioration of environmental conditions with eutrophication, oxygen depletion, loss of habitat for fish, and algae blooms and aquatic weeds. Deterioration of Greenwood Lake water quality was observed as early as 1951 with nuisance densities of macrophytes, blooms of Spirogyra, and summer depletion of dissolved oxygen in hypolimnion. Recently, a water level management program has been implemented starting 1997 to enhance water quality, control aquatic weeds and improve the lake's overall environmental conditions (New Jersey DEP, 1997).

<u>Diatom assemblages and inferred TP and pH</u>

A total of 90 diatom species were identified and enumerated in a 35-cm sediment core. The bottom of the core is characterized by dominance of *Aulacoseira ambigua*, a eutrophic planktonic species (Fig. 10). At ~20 cm the core records an important decrease in *Aulacoseira ambigua*, along with increases in *A. subarctica*, and apparition of *Fragilaria crotonensis*. Another change takes place at the top of the core with further decline of *A. ambigua* and increases in *Tablellaria flocculosa* and *Fragilaria crotonensis* along with smaller amounts of *Stephanodiscus* spp., *Asterionella formosa*, *Cyclotella meneghiniana.* These changes define three diatom zones identified by cluster analysis (Grimm 1987): A, B, and C, from bottom to the top core.

Diatom-inferred TP shows eutrophic conditions were present at the core bottom, mainly triggered by high abundance of *A. ambigua* within the Zone A. The occurrence of this taxon suggests either that high nutrient levels characterize reference conditions in Greenwood Lake, or that the lake was already strongly impacted by the agricultural activities in the bottom core samples. The CRS dating of this part of the core may indicate the early 1800s. European settling started in 1707 when forests were cleared and agriculture was the principal occupation in the valley along with mining and forging of iron. A major foundry was established in 1754 and sawmills, forges and gristmills were constructed throughout the area. In 1765, a small dam was built on Greenwood Lake to provide some of these operations with water power (Hull 1975). By the mid-19th century Greenwood Lake was a popular resort for residents of New York City. Taking the lake's historical records into account, the eutrophic conditions indicated by diatoms in the lower part of the core may indicate the impact of the early anthropogenic activities in the Lake's area and not its reference conditions.

In 1836 a dam was constructed near the Wanaque River on the southeastern side of the lake that elevated the lake by 12 feet, raising it to its present level and area. The timing of this major dam construction appears to correspond with the important shift in diatom species composition from *A. ambigua* to *A. subarctica*. A. subarctica has lower TP preference than *A. ambigua* and this shift is consistent with higher water levels and increased stratification. Further apparition of eutrophic *Fragilaria crotonensis* at 15-cm core depth suggests increasing nutrient levels during the late 1800-early 1900. Inferred TP levels at that time were ~ 25 µg/L, which are close to the present-day TP levels.

Similar to Cossayuna Lake, Greenwood Lake’s sediment core displays a short-lived episode with lower nutrient levels during 1990s. Diatom-inferred present day TP is 25 μg/L which is slightly lower than the 28 μg/L measured TP.

Conclusions

Investigation of diatom assemblages in top-bottom sediment cores shows changes that can be linked to both anthropogenic activities and climate change. Most study lakes displayed important changes in their environmental conditions since pre-industrial times. An important aspect is that climate effects may be stronger than we expected but hidden by trophic changes. Some lakes that are not listed as impaired by the EPA display signs of euthrophication, as indicated by diatom assemblages. Also, given the early settlement of the eastern US, some cores may not be long enough to provide information on reference conditions. Stratigraphic cores from Cossayuna and Greenwood lakes revealed historical changes that can be related to major human events in the lake watersheds. Sediment stratigraphy revealed ologotrophic reference conditions for Cossayuna lake, while the sediment core from Greenwood Lake was not long enough to provide information on reference conditions.

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Fig. 8. Plots of observed versus diatom-inferred TP and pH based on transfer functions developed by Dixit et al. (1994; 1999) in the EMAP data set.

Fig 9. Diatom-based inferences of TP and pH in core stratigraphy of Cossayuna Lake based on transfer functions developed from the EMAP data set from Dixit et al. 1994, 1999.

Fig. 10. Relative abundances of diatom species in core stratigraphy of Greenwood Lake. Diatom taxa are arranged according to the first-axis species scores of a principal component analysis (PCA). A constrained cluster analysis (CONISS), based on a chord distance as the measure of dissimilarity (Grimm 1987) is used to indicate the distinct differences in assemblages in the 35-cm sediment record.

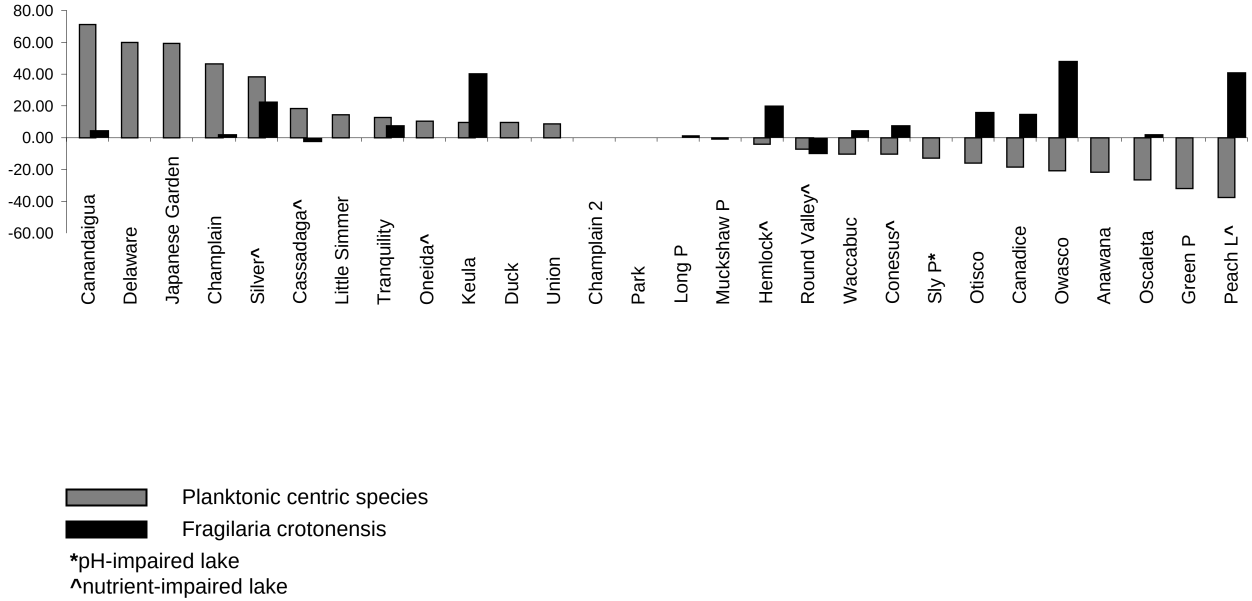
Fig. 11. Diatom-based inferences of TP and pH in core stratigraphy of Greenwood Lake based on transfer functions developed from the EMAP data set from Dixit et al. 1994, 1999.

Table 1 Measured limnological variables of study lakes

Lake Name	State	Mean Depth	Secchi	pH	Cond 25	TP	TKN	TDN
		(m)	(m)			(ug/L)	(mg/L)	(ug/L)
WACCABUC	NY	14.11		8.05	158.40	16.78		764.17
COSSAYUNA	NY	7.50		8.13	173.59	35.76		607.49
OSCALETA	NY	10.78		7.81	126.68	19.15	0.01	573.87
SILVER	NY	11.02		7.99	210.75	29.36		807.12
PEACH	NY	7.11		8.08	240.00	34.30		478.27
OWASCO	NY	48.90	4.70	8.41	304.92	7.57	0.37	
OTISCO	NY	17.90	4.25	8.21	308.60	11.70	0.29	
CANADICE	NY	24.33	6.25	7.55	154.12	8.55	0.18	
CONESUS	NY	18.30	3.50	8.02	325.63	17.84	0.47	
HEMLOCK	NY	24.40	4.60	8.13	210.14	9.73	0.27	
Long Pond	NY		3.70	7.50	28.61	5.00		191.00
Little Simer	NY		8.40	7.34	29.65	2.00		551.00
Anawana	NY		3.55	7.45	89.54	9.00		281.00
Canandaigua	NY		7.10	7.90	366.80	7.00		390.00
Cassadaga	NY		2.20	8.14	293.50	15.00		367.00
Keula	NY		7.30	7.90	300.50	6.00		236.00
Champlain	NY		0.85	7.72	196.00	29.00		246.00
Oneida	NY		0.80	8.30	102.20	39.00		875.00
Sly Pond	NY		6.80	6.65	42.01	3.00		166.00
Flamingo Lake	NJ	0.97	0.80	6.63	105.67	21.00	0.49	
Harrisville Lake	NJ	0.95	0.85	4.27	36.17	17.33	0.16	
Cooper River Lake	NJ	1.37	0.48	7.49	269.22	147.44	0.86	
Clint Millpond	NJ	1.37	0.50	4.34	77.33	59.00	0.85	
Dennisville Lake	NJ	1.07	1.07	5.68	70.67	18.50	0.33	
Cumberland Pond	NJ	1.07	1.07	4.41	42.00	45.00	0.27	
Campbells Pond	NJ	1.80	7.06	5.05	827.00	59.67	0.50	
Crystal Spring Lake	NJ	0.73	0.20	6.97	112.00	198.00	2.44	
Millhurst Pond	NJ	0.93	0.78	6.94	201.83	35.67	0.45	
Lefferts Lake	NJ	2.95	2.29	6.43	209.36	15.50	0.33	
Chesler Lake	NJ	7.03	2.68	8.26	498.90	11.50	0.30	
Greenwood Lake	NJ	5.49	1.81	7.54	185.00	28.63	0.47	
Echo Lake	NJ	8.81	1.42	7.06	142.29	31.83	0.67	
A. Clemente Inc. Pond	NJ	7.47	2.24	7.20	195.81	19.40	0.48	
Kittatinny Camp Lake	NJ	1.60	0.67	7.57	226.00	40.00	0.75	
Saginaw Lake	NJ	3.70	1.97	7.48	478.56	20.33	0.50	
Delaware Lake	NJ	3.70	0.93	8.31	439.11	114.33	1.42	
Duck Pond	NJ	1.23	1.23	6.52	105.33	33.67	0.66	
Green Pond	NJ	4.82	3.81	7.25	77.14	17.22	0.24	
Muckshaw Pond	NJ	2.40	2.40	7.57	348.20	16.67	0.47	
Japanese Garden	NJ	1.20	0.50	7.36	227.67	79.67	0.99	
Union	NJ	3.50		5.70	141.33	23.00	0.550	
Tranquility	NJ		1.05	8.60	404.00	34.00		729.00
Round Valley Rec	NJ		2.50	7.50	19.70	15.00		282.00

Table 2. Percent increase in selected diatom species with regard to various nutrient levels in lakes as recorded in the literature (see text for more information on diatom species TP optima in published data sets). Cyc. Mene = *Cyclotella meneghiniana*; Steph parvus = *Stephanodiscus parvus*; Cyclosteph = *Cyclostephanos*; Steph minu = *Stephanodiscus minutulus*; Aul ambi = *Aulacoseira ambigua*; Aul gran = *Aulacoseira granulata*; Frag crot = *Fragilaria crotonensis*; Ast form = *Asterionella formosa*; Tab flocc = *Tabellaria flocculosa*; Dis stell = *Discostella stelligera*; Cyc ocell = *Cyclotella ocellata*.

Lake	EPA listed impairment	Hypereutrophic				Eutrophic			Mesotrophic		Oligotrophic, stratification	
		Cyc mene	Steph parvus	Cyclosteph spp	Steph minu	Aul ambi	Aul gran	Frag crot	Ast form	Tab flocc	Dis stell	Cyc ocel
Delaware		6			6	44						
Japanese Garden		11		4		35					5	
Conesus	nutrients, oxygen depletion		5	44				7				15
Silver	nutrients		28		10			21			5	
Waccabuc						14			13			
Duck						8						
Champlain 1							18					
Owasco	pathogens							45				
Peach	P, pathogens							39	9			
Otisco								15				
Canadice	PCBS							14				
Hemlock	nutrients							18				
Keula	DDT, pesticides							37				29
Tranquility								7				
Oscaleta									21			
Cassadaga											6	
Round Valley	impaired										17	
Park											7	
Anawana									16	5	6	
Sly	pH								14		8	
Canandaigua												56
Champlain 2											14	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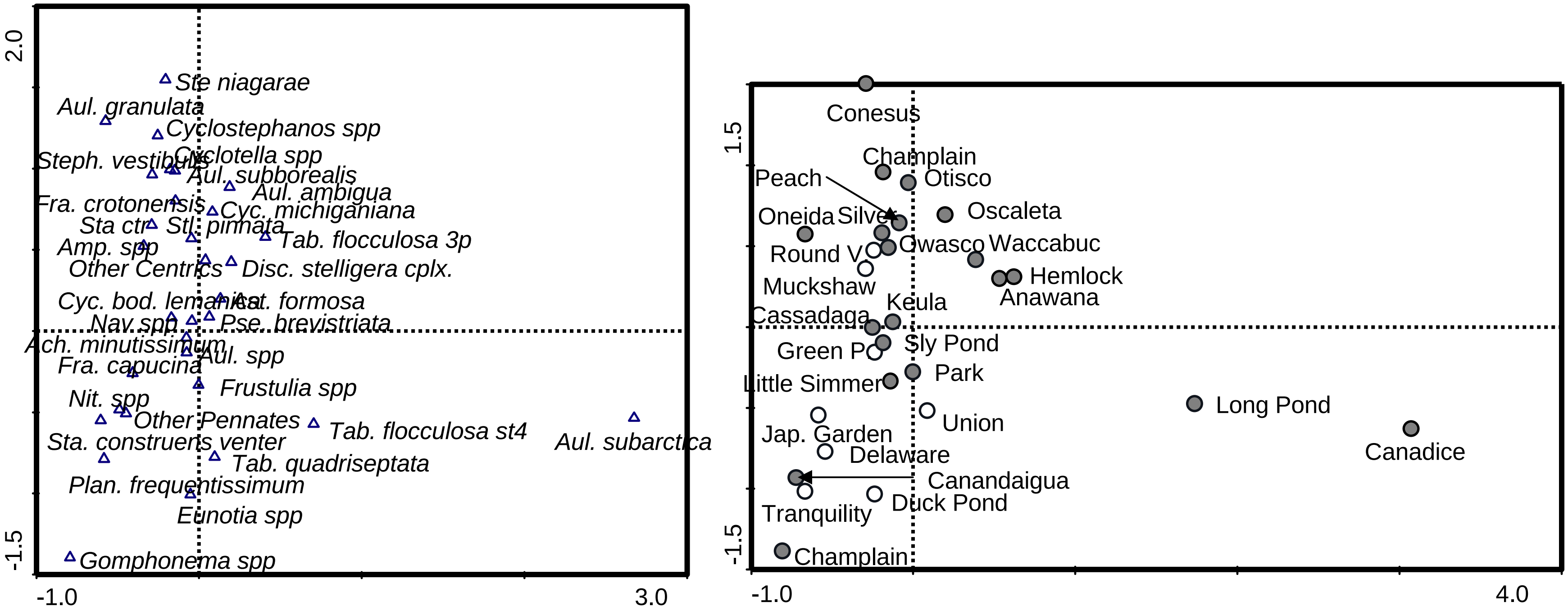
Canandaigua
Delaware
Japanese Garden
Champlain
Silver^
Cassadaga^
Little Simmer
Tranquility
Oneida^
Keula
Duck
Union
Champlain 2
Park
Long P
Muckshaw P
Hemlock^
Round Valley^
Waccabuc
Conesus^
Sly P*
Otisco
Canadice
Owasco
Anawana
Oscaleta
Green P
Peach L^
Planktonic centric species
Fragilaria crotonensis
*pH-impaired lake
^nutrient-impaired lake



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Ste niagarae
Aul. granulata
Cyclostephanos spp
Cyclotella spp
Steph. vestibulis
Aul. subborealis
Aul. ambigua
Fra. crotonensis
Cyc. michiganiana
Sta ctr
Stl. pinnata
Tab. flocculosa 3p
Amp. spp
Other Centrics
Disc. stelligera cplx.
Cyc. bod. lemanica
Ast. formosa
Nav spp
Pse. brevistriata
Ach. minutissimum
Fra. capucina
Aul. spp
Frustulia spp
Nit. spp
Other Pennates
Tab. flocculosa st4
Aul. subarctica
Sta. construens venter
Tab. quadriseptata
Plan. frequentissimum
Eunotia spp
Gomphonema spp
1.5
-1.5
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4.0
Conesus
Champlain
Peach
Otisco
Oneida
Silver
Oscaleta
Round V
Owasco
Waccabuc
Muckshaw
Hemlock
Anawana
Keula
Cassadaga
Sly Pond
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Park
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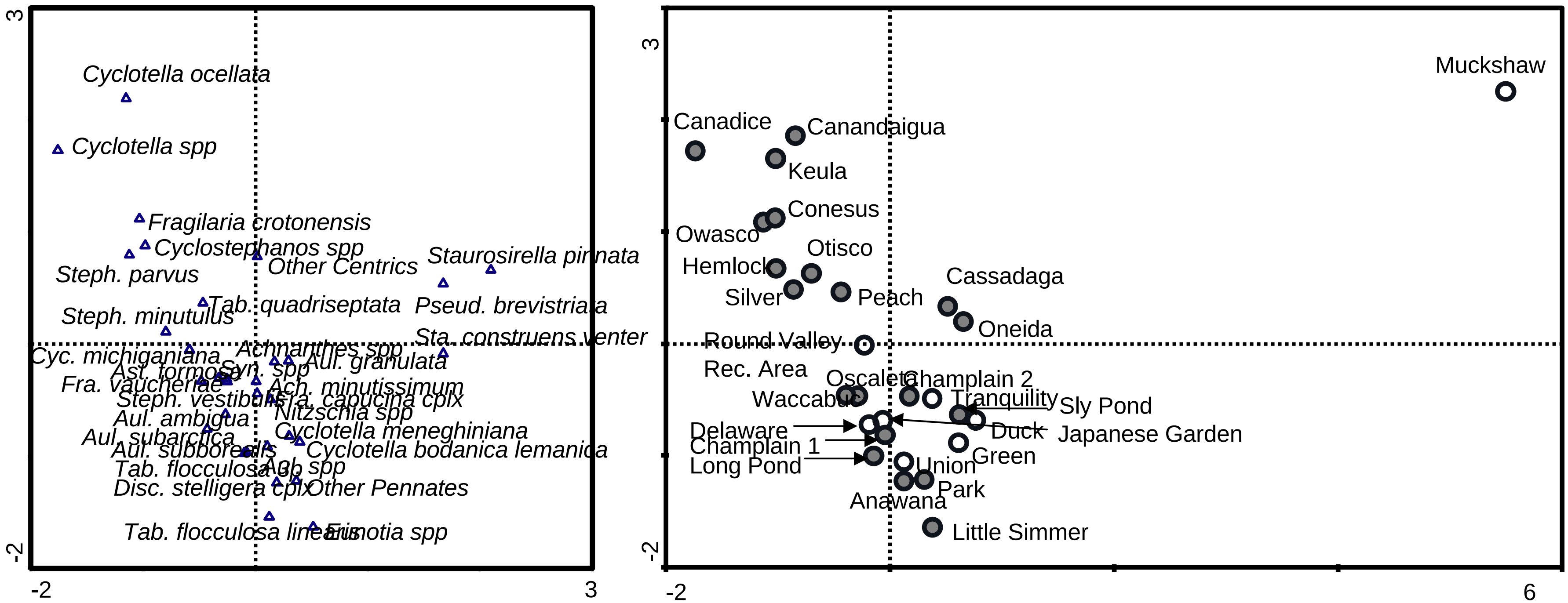
Long Pond
Union
Jap. Garden
Canadice
Delaware
Canandaigua
Tranquility
Duck Pond
Champlain



3
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3
Cyclotella ocellata
Cyclotella spp
Fragilaria crotonensis
Cyclostephanos spp
Steph. parvus
Other Centrics
Staurosirella pinnata
Tab. quadriseptata
Pseud. brevistriata
Steph. minutulus
Sta. construens venter
Achnanthes spp
Cyc. michiganiana
Aul. granulata
Ast. formosa
Syn. spp
Fra. vaucheriae
Ach. minutissimum
Steph. vestibulis
Fra. capucina cplx
Nitzschia spp
Aul. ambigua
Cyclotella meneghiniana
Aul. subarctica
Aul. subborealis
Cyclotella bodanica lemanica
Tab. flocculosa
Aul. spp
Disc. stelligera cplx
Other Pennates
Tab. flocculosa linearis
Eunotia spp
3
-2
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Muckshaw
Canadice
Canandaigua
Keula
Conesus
Owasco
Otisco
Hemlock
Cassadaga
Silver
Peach
Oneida
Round Valley
Rec. Area
Oscaleta
Champlain 2
Waccabuc
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Sly Pond
Delaware
Duck
Japanese Garden
Champlain 1
Green
Long Pond
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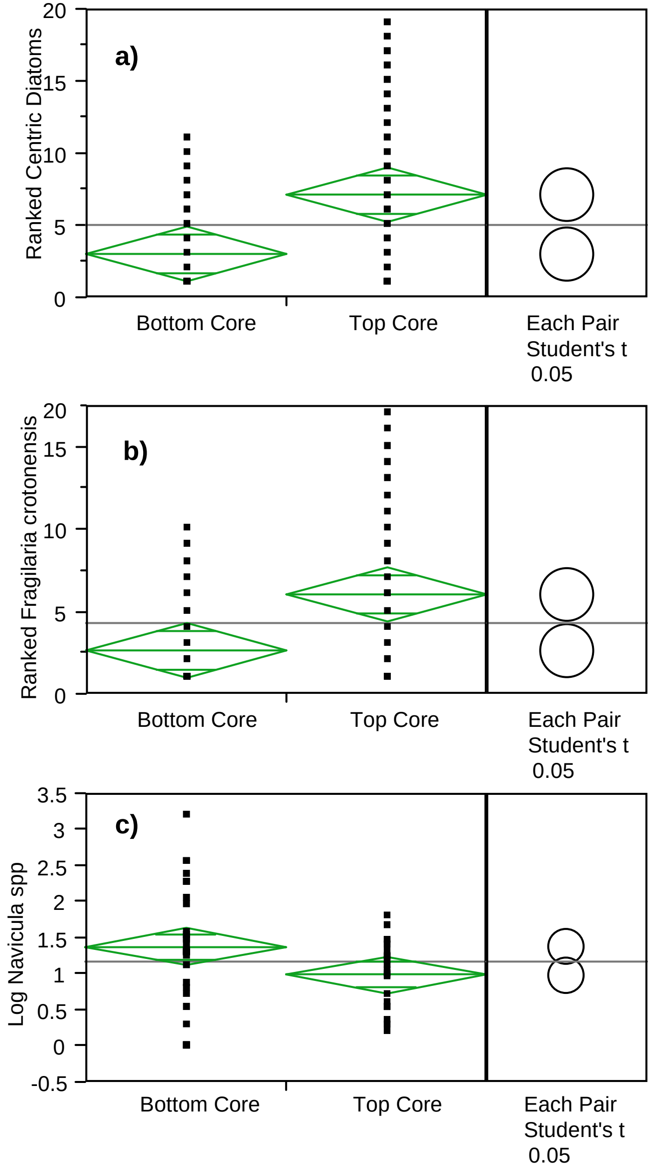
Park
Anawana
Little Simmer



a)
Ranked Centric Diatoms
0
5
10
15
20
Bottom Core
Top Core
Each Pair
Student's t
0.05
b)
Ranked Fragilaria crotonensis
0
5
10
15
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Bottom Core
Top Core
Each Pair
Student's t
0.05
c)
Log Navicula spp
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2
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3.5
Bottom Core
Top Core
Each Pair
Student's t
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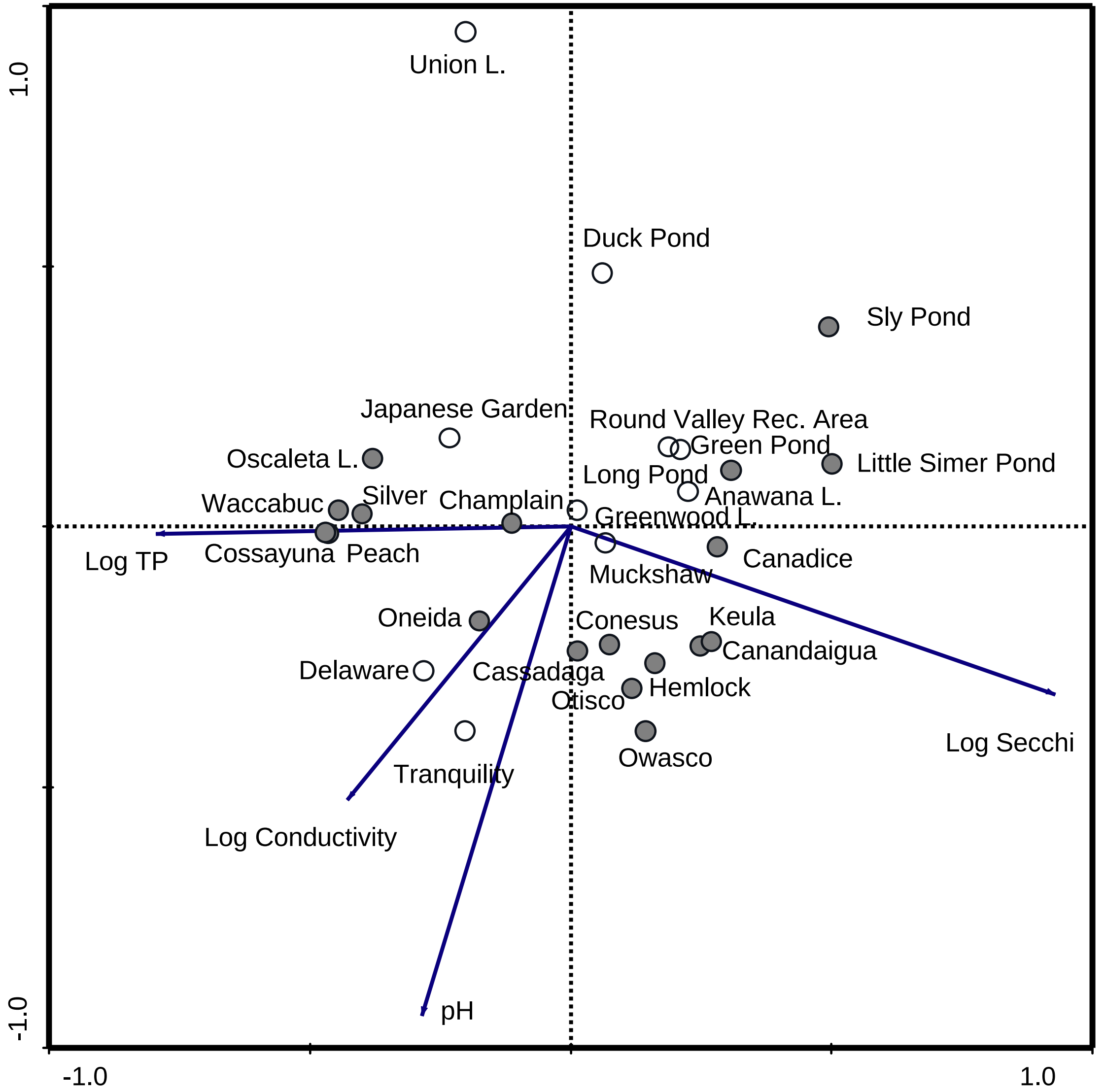

1.0
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Union L.
Duck Pond
Sly Pond
Japanese Garden
Round Valley Rec. Area
Green Pond
Oscaleta L.
Little Simer Pond
Long Pond
Anawana L.
Waccabuc
Silver
Champlain
Greenwood L.
Log TP
Cossayuna
Peach
Canadice
Muckshaw
Oneida
Conesus
Keula
Canandaigua
Delaware
Cassadaga
Hemlock
Otisco
Owasco
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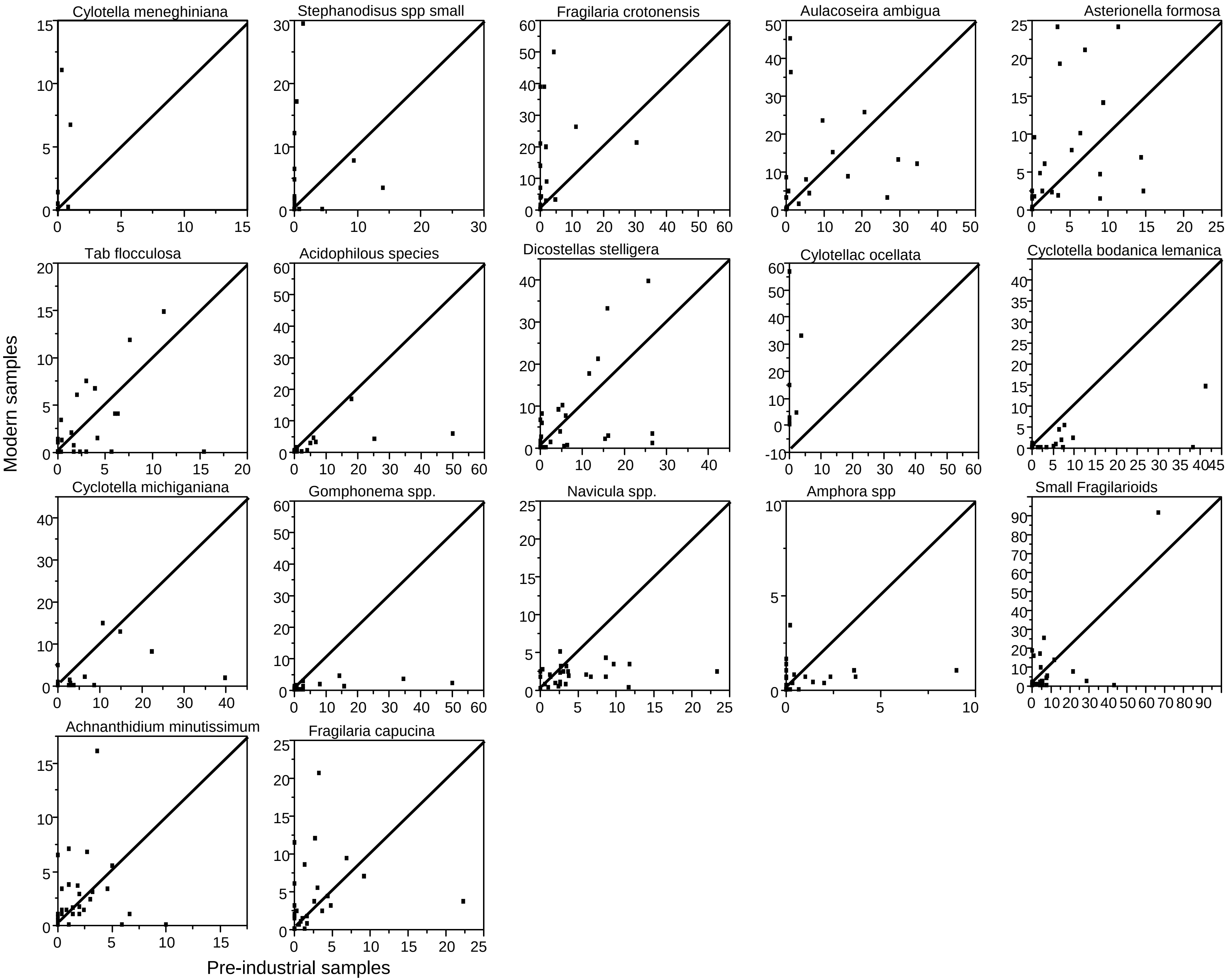
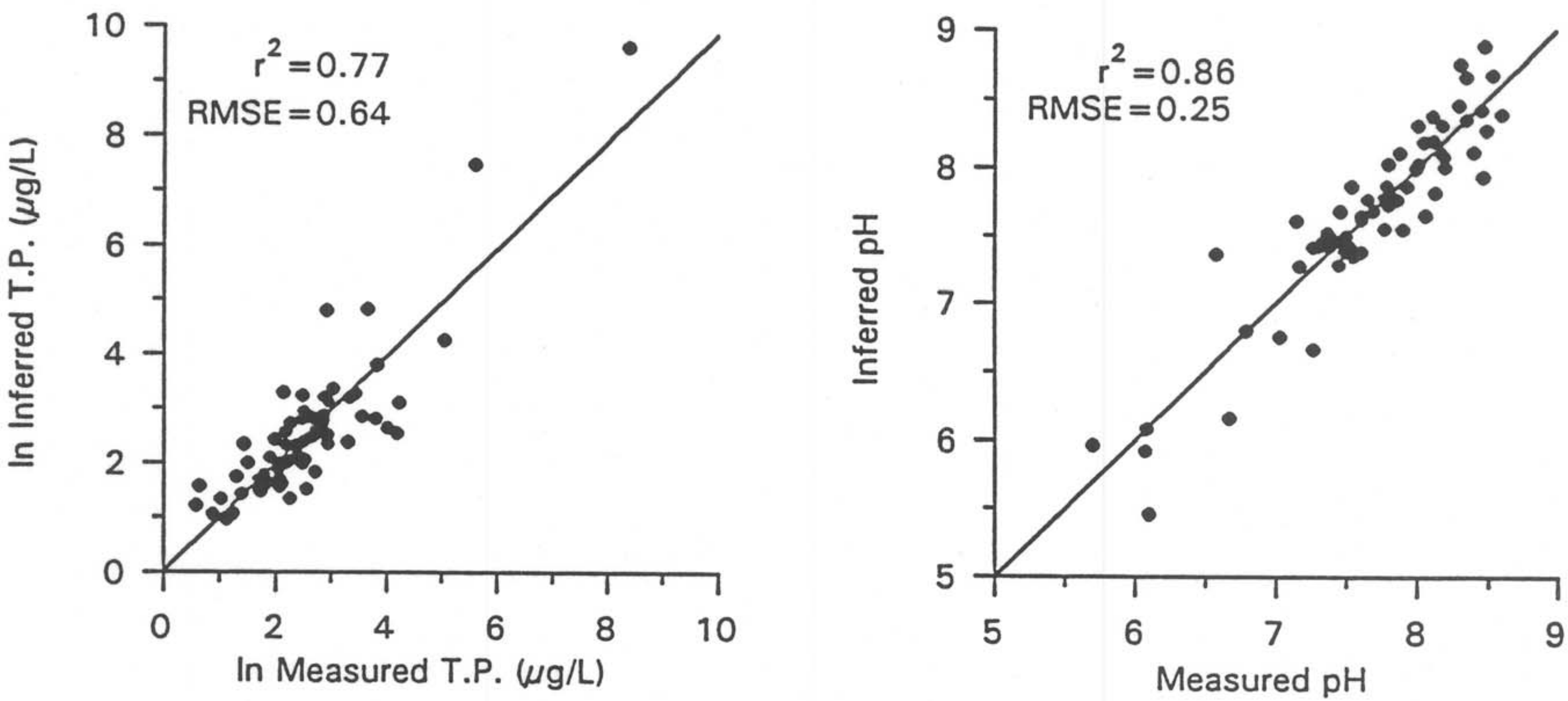
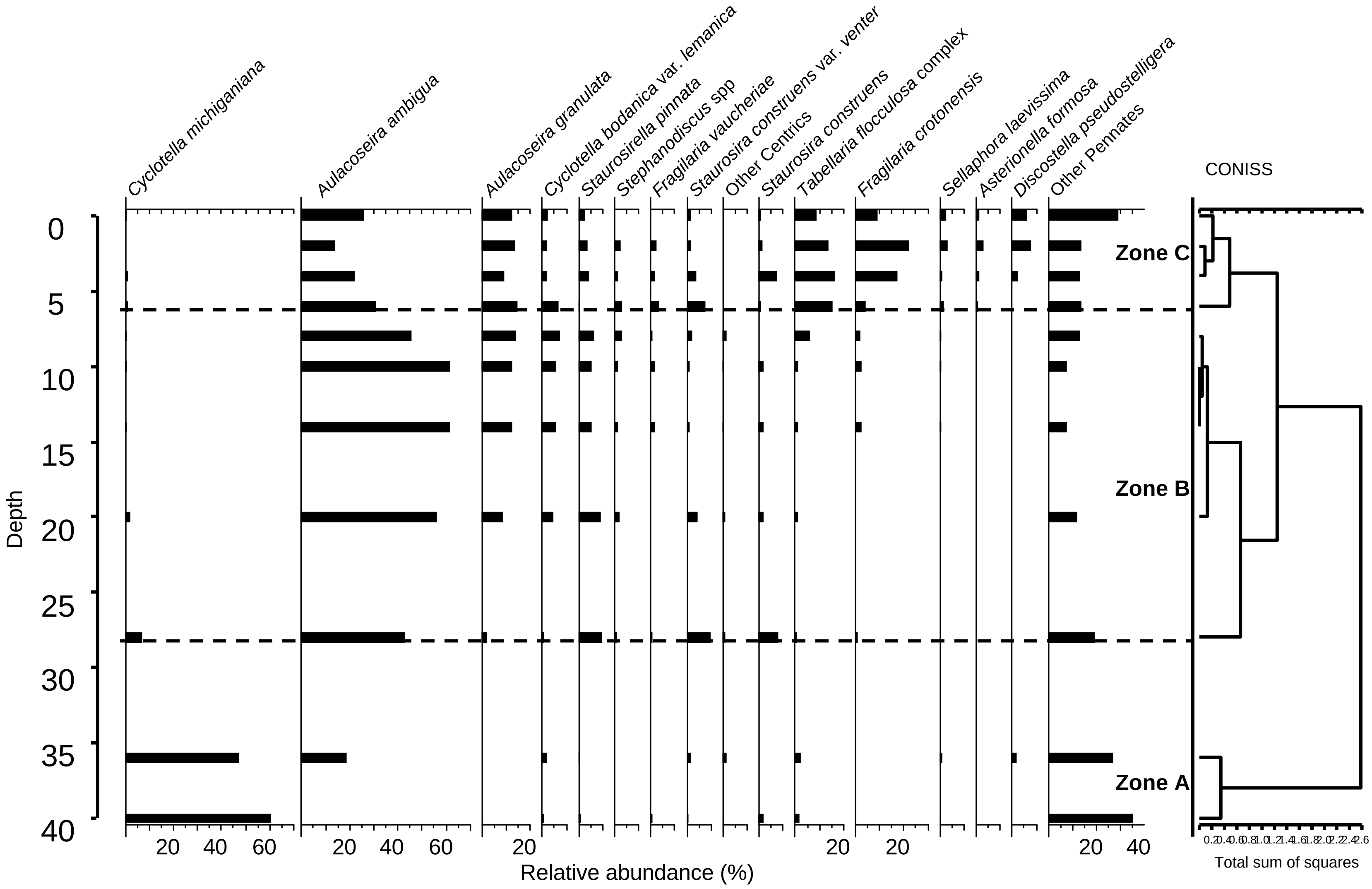
Tranquility
Log Conductivity
pH

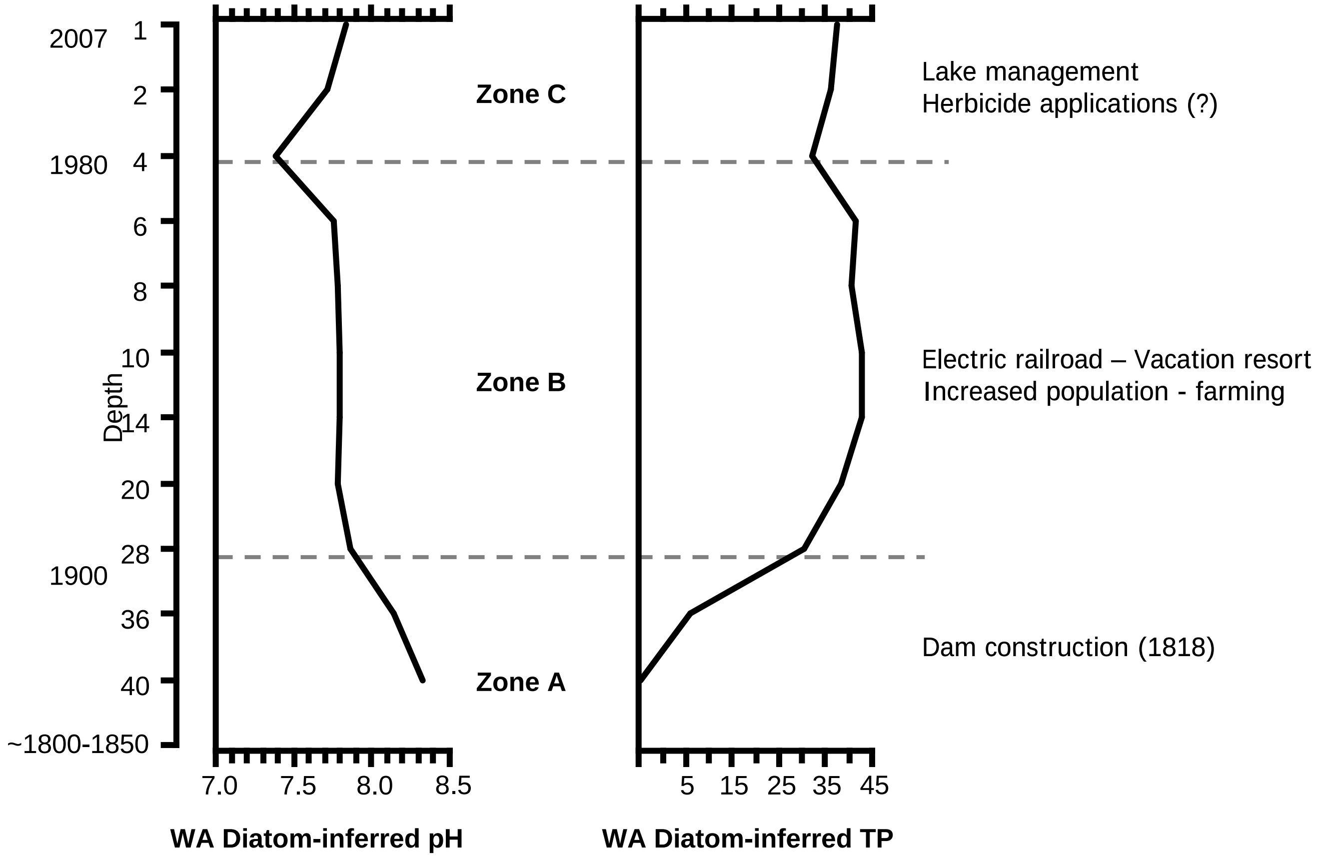

Cylotella meneghiniana
Stephanodisus spp small
Fragilaria crotonensis
Aulacoseira ambigua
Asterionella formosa
Tab flocculosa
Acidophilous species
Dicostellas stelligera
Cylotellac ocellata
Cyclotella bodanica lemanica
Cyclotella michiganiana
Gomphonema spp.
Navicula spp.
Amphora spp
Small Fragilarioids
Achnanthidium minutissimum
Fragilaria capucina
Modern samples
Pre-industrial samples



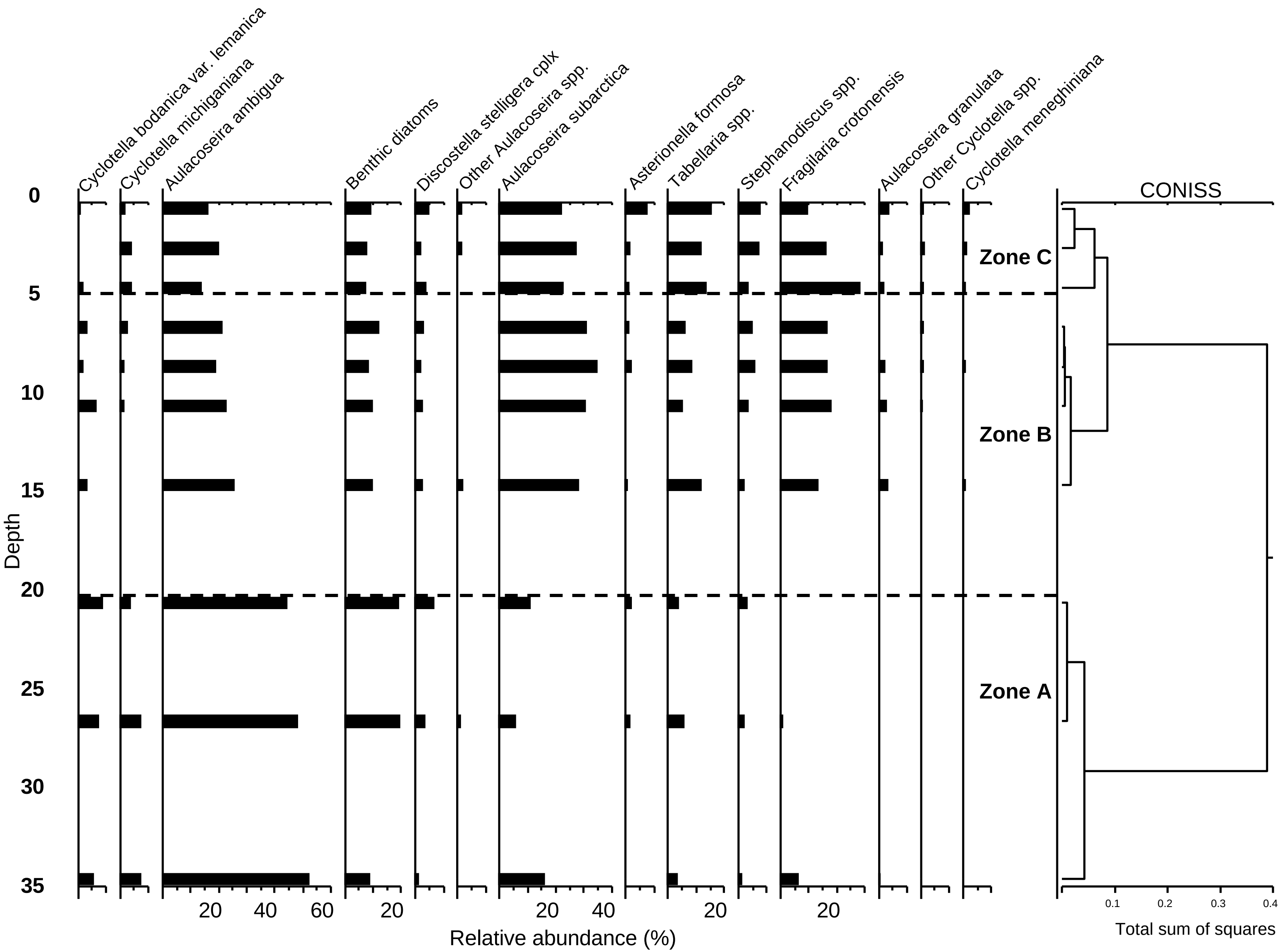
r² = 0.77
RMSE = 0.64
ln Inferred T.P. (µg/L)
ln Measured T.P. (µg/L)
0
2
4
6
8
10
r² = 0.86
RMSE = 0.25
Inferred pH
Measured pH
5
6
7
8
9



Cyclotella michiganiana
Aulacoseira ambigua
Aulacoseira granulata
Cyclotella bodanica var. lemanica
Staurosirella pinnata
Stephanodiscus spp
Fragilaria vaucheriae
Staurosira construens var. venter
Other Centrics
Staurosira construens
Tabellaria flocculosa complex
Fragilaria crotonensis
Sellaphora laevissima
Asterionella formosa
Discostella pseudostelligera
Other Pennates
CONISS
Zone C
Zone B
Zone A
Depth
0
5
10
15
20
25
30
35
40
20 40 60
20 40 60
20
20
20
20 40
Relative abundance (%)
0.2 0.4 0.6 0.8 1.0 1.2 1.4 1.6 1.8 2.0 2.2 2.4 2.6
Total sum of squares



2007
1980
1900
~1800-1850
Depth
1
2
4
6
8
10
14
20
28
36
40
7.0
7.5
8.0
8.5
WA Diatom-inferred pH
Zone C
Zone B
Zone A
5
15
25
35
45
WA Diatom-inferred TP
Lake management
Herbicide applications (?)
Electric railroad – Vacation resort
Increased population - farming
Dam construction (1818)



Cyclotella bodanica var. lemanica
Cyclotella michiganiana
Aulacoseira ambigua
Benthic diatoms
Discostella stelligera cplx
Other Aulacoseira spp.
Aulacoseira subarctica
Asterionella formosa
Tabellaria spp.
Stephanodiscus spp.
Fragilaria crotonensis
Aulacoseira granulata
Other Cyclotella spp.
Cyclotella meneghiniana
CONISS
Zone C
Zone B
Zone A
Depth
0
5
10
15
20
25
30
35
20
40
60
20
20
40
20
20
Relative abundance (%)
0.1
0.2
0.3
0.4
Total sum of squares

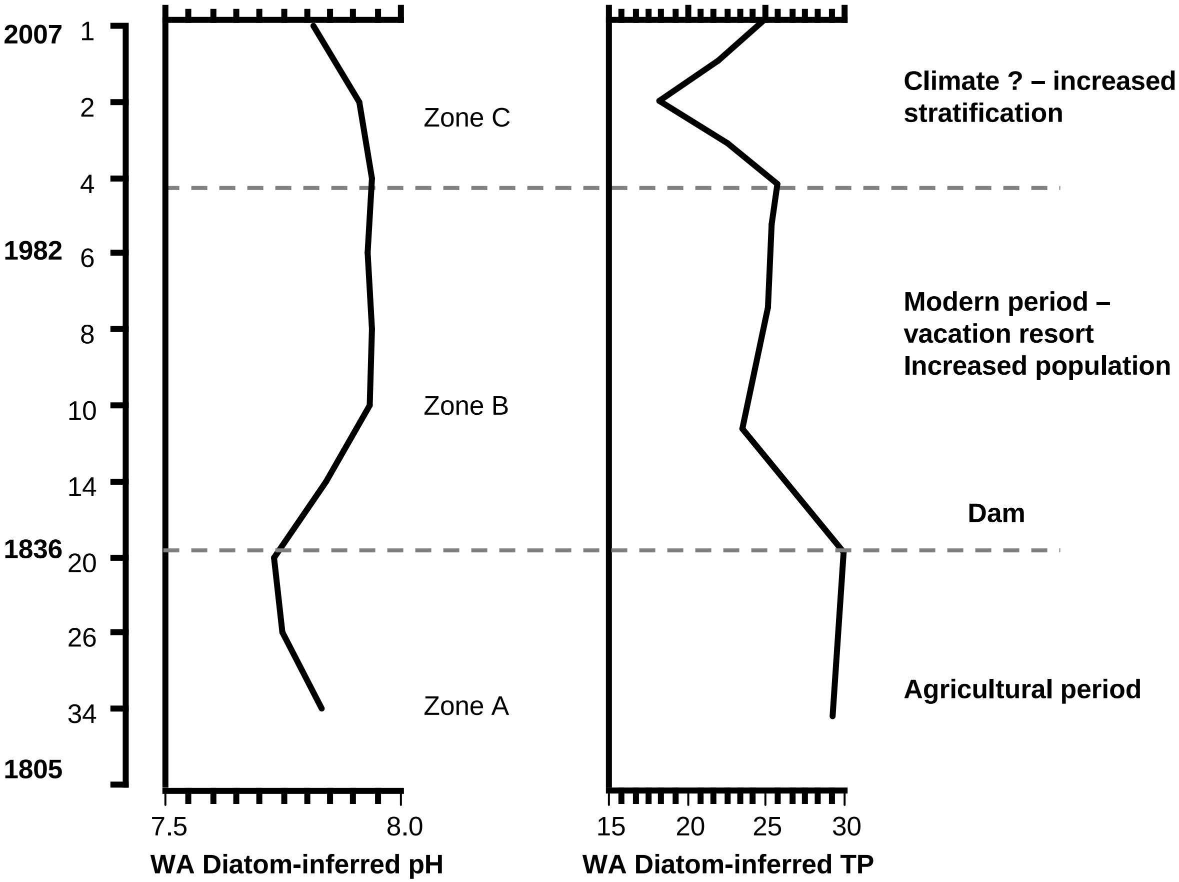

2007
1982
1836
1805
1
2
4
6
8
10
14
20
26
34
Zone C
Zone B
Zone A
7.5
8.0
WA Diatom-inferred pH
15
20
25
30
WA Diatom-inferred TP
Climate ? – increased stratification
Modern period – vacation resort Increased population
Dam
Agricultural period

table format is to fit landscape-style onto a Microsoft Word page as an enhanced metafile 'paste special'

				Top Sum																				
Interval	0 - 0.5	0.5 - 1.0	1.0 - 1.5	0 - 1.5	2-2.5	4-4.5	6-6.5	8-8.5	10-11	14-15	20-21	26-27	34-35	0-1	1-2	2-3	4-5	6-7	10-12	14-16	20-22	28-30	36-38	40-42
Lake	GW	GW	GW	GW	GW	GW	GW	GW	GW	GW	GW	GW	GW	CO	CO	CO	CO	CO	CO	CO	CO	CO	CO	CO
Chironomini larvula / 1st instar			4	4	5	2			3	2	4	2				1		1	5	1		1		
Chironomus sp.								1	2	1				3	2	3.5	4.5	2	3.5	4	6	3	2	
Chironomus plumosus	1	2	1	4	5	5	3	4.5	3	8	12.5	14	6	16.5	16	44.5	25.5	21.5	17.5	19	10	13	13	7.5
Chironomus anthracinus		1		1	2	6	3	3	5	5	1.5	5	6	9	16	8	5	8.5	3	5	2		2	13
Cladopelma sp.															0.5									
Cladopelma lateralis										1				2	1	2	4	5	8	8.5	4	4	3	5.5
Cryptochironomus																1		1		1	1	1		1
Cryptotendipes																							1	1
Dicrotendipes		3	3	6	3	4	1	1	4	1	5.5	3	7	7.5	2	8	8	6	8	18	10	13	15.5	15
Einfeldia sp.																			1	1				
Einfeldia dissidens																						1		
Einfeldia natchitocheae																								
Endochironomus sp.																				1	2			
Endochironomus albipennis														1		4			2	5	1	1	3	2
Glyptotendipes sp.						1			0.5	2	6.5	5	1.5	1.5	3.5	4	1	3	3	5.5	2	10.5	3	
Glyptotendipes barbipes																								
Glyptotendipes pallens			1	1	2	1																		
Glyptotendipes severini														1					1	4			1	
Cyphomella/Harnischia/Paracladoplema												1												
Hyporhygma																								
Lauterborniella/Zavrelia														2								2	4	2
Microchironomous																								
Microtendipes sp.																						0.5		
Microtendipes pedellus					3						1			1		1	1.5			3	3	2	3.5	
Pagastiella																						1	2	
Parachironomous sp.																								
Parachironomus varus					1				2	0.5				3		1	4	3	1		2	1		
Parachironomus vitosis														1					1					
Paralauterborniella																								
Paratendipes sp.																								
Paratendipes albimanus			1	1							1	1	1											
Paratendipes nudisquama																					1			
Polypedilum sp.						1																		
Polypedilum convictum												1												
Polipedilum nubifer						0.5	1	0.5		1	2	1				2		3.5		3	1	2	1	
Polipedilum nubeculosum		1		1			2		1					1	2		2		1	2	3	1	5	2
Polypedilum sordens												1					2			1		1.5		2
Sergentia																					1			
Stenochironomus											1													
Stictochironomus																								
Tribelos																								1
Xenochironomus																								
Zavreliella																	0.5	1	1.5	1	1	6	1	3
Cladotanytarsus sp.													1											
Cladotanytarsus sp. grp. A						1	1			1	1	1					1			2	1	2	1	
Cladotantytarsus mancus group		1	1	2	1				1	2	1	1	1		1			1	1	2	2	3	6	7

				Top Sum																				
Interval	0 - 0.5	0.5 - 1.0	1.0 - 1.5	0 - 1.5	2-2.5	4-4.5	6-6.5	8-8.5	10-11	14-15	20-21	26-27	34-35	0-1	1-2	2-3	4-5	6-7	10-12	14-16	20-22	28-30	36-38	40-42
Lake	GW	GW	GW	GW	GW	GW	GW	GW	GW	GW	GW	GW	GW	CO	CO	CO	CO	CO	CO	CO	CO	CO	CO	CO
Constempellina																								2
Corynocera oliveri		1		1					1		1		0.5							2				
Micropsectra sp.																				1		2		
Micropsectra AR radialis									1		1	1												
Micrspectra contracta													1											
Micropsectra insignolobis							1														1	1		
Micropsectra pallidula												1								1	1			
Paratanytarsus sp.					2	3.5	1	1	1				2	1		1	2		5	4		2	1	1.5
Pseudochironomus			0.5	0.5	1.5			1	0.5			3.5	1.5				2				0.5	0.5	0.5	1
Stempellina								0.5				1							1	2	2	9	6	7.5
Stempellinella-Zavrelia																							1	
Tanytarsus sp.	1	8	10	19	19.5	48.5	26.5	56	23.5	20	6.5	4	3	3.5	2	10.5	7.5	5	7.5	12	15.5	23	29	9
Tanytarsus chinyensis												1	1										1	
Tanytarsus glabrescens		1		1				2	8	3						1	1		3	3	1	4	2	5
Tanytarsus gracilentus									1															
Tanytarsus lactescens								1			2	1	1										2	1
Tanytarsus lugens	1	6	5.5	12.5	9.5	26	34	45.5	56.5	69.5	10	2	2				2	3	4	3	2	2	3	1
Tanytarsus pallidicornis						1			3			1							1	1	2	1	2	
Tanytarsus mendax (type B)						1	1				2	3				0.5	1	2	2	2	5	2	7	5
Tanytarsus nemerosus																								
Brillia/Euryhapsis																								
Bryophaenocladius/Gymnometriocnemus													2.5			0.5								
Chaetocladius piger																								
Corynoneura/Thienemanniella		1		1	2		2	2	1		5.5	3	4		1		2	5	6	7	2	3	3	2
Cricotopus/Orthocladius			1	1		1	1		2	2.5	1.5	1	3		1	2	2	4		2		2.5	1	4.5
Diplocladius																								
Eukiefferiella/Tventia																		1						
Heterotrissocladius undifferentiated																								
Heterotrissocladius grimshawi																								
Heterotrissocladius maeri																								
Heterotrissocladius marcidus																								
Heterotrissocladius subpilosus												1												
Hydrobaenus conformis					2						1													
Hydrobaenas johannseni																								
Limnophyes																								
Nanocladius sp.														1				1				1		
Nanocladius balticus																								
Nanocladius (plecopteracoluthus) branchicolus						2							3		2		0.5			1		2		
Nanocladius rectinervis									1						1			1		1				1
Paracricotopus																								
Parakiefferiella undifferentiated												1												
Parakiefferiella sp. A																								1
Parakieffierella sp. B					1.5								1											1
Parakiefferiella nigra																								
Paralimnophyes																								
Propsilocerus																0.5								

				Top Sum																				
Interval	0 - 0.5	0.5 - 1.0	1.0 - 1.5	0 - 1.5	2-2.5	4-4.5	6-6.5	8-8.5	10-11	14-15	20-21	26-27	34-35	0-1	1-2	2-3	4-5	6-7	10-12	14-16	20-22	28-30	36-38	40-42
Lake	GW	GW	GW	GW	GW	GW	GW	GW	GW	GW	GW	GW	GW	CO	CO	CO	CO	CO	CO	CO	CO	CO	CO	CO
Psectrocladius sp.																1					1	1.5	2	2.5
Psectrocladius (Monopsectrocladius) barbatipes																								2
Psectrocladius (Monopsectrocladius) calcaratus																								
Psectrocladius (Monopsectrocladius) septentrionalis														1						2.5				1
Psectrocladius (Psectrocladius) psilopterus																								
Psectrocladius (Psectrocladius) sordidellus		1		1		1		1										2	3	3	1			
Synorthocladius		1.5	1.5	3	0.5	1	2		0.5	1.5	2	5	5.5							2	1.5		2	2
Zalutschia sp.									2.5	1.5														
Zalutschia zalutschicola		1.5		1.5	1.5	1.5	0.5		1	0.5														
Ablabesmyia			1	1			1		2		1	3	2		1		3	2	2	1	4	6	9	15
Coelotanypus																								
Conchapelopia																					1			1
Guttipelopia															1						1	1		1
Hayesomyia																						1	1	
Hudsonimyia																								
Labrundinia											1	3	1			1	1		3	1				1
Tribe Macropelopinii		1		1				1			1	2					5	1	2	6	3	12	9	9
Natarsia									1															
Nilotanypus																				2				
Tribe Pentaneurini			1	1	2	1		1				2					1	1	3	2	1	2	4	7
Procladius		1		1							1	4	3	1	1	3	2	2	5	10	3	4	10	10
Tanypus																								
Thienemannimyia											1	1							2				1	
Protanypus																								
Chaoboridae mandible*Chaoborus* sp.		2	5	7	5	5	7	5	16	17	22	25	15	3	5	5	9	7	5	7	2	10	6	2
Chaoboridae mandible*Chaoborus flavicans*								3																
Chaoboridae mandible*Chaoborus sayomyia*		6	4	10	9	10		7													1	1	1	1
Chaboridae mandible*Chaoborus trivittatus*																								
Ceratopogonidae head capsule*Bezzia*								1		1	1	1		1	1	2	1	1	1	4		2	3	1
Ceratopogonidae head capsule*Dasyhelea*			1	1												1							1	2
Ephemeroptera mandible						1					2	2	1					1	1	2	1		1	
Tanypodinae undifferentiated														1					1	1		3	1	
Tanytarsini undifferentiated		0.5	1.5	2	2	5.5	0.5	7.5	9	9		1				2	2	1	3.5	1		2	5.5	1
Chironomidae unidentifiable		0.5	0.5	1		3.5	2	3.5	2.5	3	1	1.5	2	2		0.5		3	3	8	2	2	5.5	2
Chironomini unidentifiable																					1	0.5		
Orthocladinae unidentifiable																0.5	1	1						
sum Chironomidae	3	32	33.5	68.5	66	118	83.5	133	139.5	135	75.5	83	62.5	60	54	104	94	91.5	114.5	168.5	104.5	159.5	175.5	159
sum identifiable Chironomidae	3	31.5	33	67.5	66	114.5	81.5	129.5	137	132	74.5	81.5	60.5	58	54	103	93	87.5	111.5	160.5	101.5	157	170	157
sum other subfossil aquatic Insecta	0	8	10	18	14	16	7	16	16	18	25	28	16	4	6	8	10	9	7	13	4	13	12	6

table format is to fit landscape-style onto a Microsoft Word page as an enhanced metafile 'paste special'

	Top Sum									
Interval	0 - 1.5	2-2.5	4-4.5	6-6.5	8-8.5	10-11	14-15	20-21	26-27	34-35
Lake	GW	GW	GW	GW	GW	GW	GW	GW	GW	GW
Tanytarsus sensu latu (s.lat.)	23	23.5	59.5	29	67.5	46.5	32	11.5	10	6.5
Tanytarsus chinyensis grp	0	0	0	0	0	0	0	0	1	1
Tanytarsus cf. *glabrescens* group	0	0	0	0	0	0	0	0	0	0
Tanytarsus lugens grp	12.5	9.5	26	34	45.5	56.5	69.5	10	2	2
Cladotanytarsus sp grp A	0	0	1	1	0	0	1	1	1	0
Cladotanytarsus mancus grp	2	1	0	0	0	1	2	1	1	2
Micropsectra type	0	0	0	1	0	1	0	1	2	1
Stempellina	0	0	0	0	0.5	0	0	0	1	0
Stempellinella/Zavrelia	0	0	0	0	0	0	0	0	0	0
Pseudochironomus	0.5	1.5	0	0	1	0.5	0	0	3.5	1.5
Chironomus	5	7	11	6	8.5	10	14	14	19	12
Chironomini larvula	4	5	2	0	0	3	2	4	2	0
Cladopelma	0	0	0	0	0	0	1	0	0	0
Cryptochironomus	0	0	0	0	0	0	0	0	0	0
Cryptotendipes	0	0	0	0	0	0	0	0	0	0
Cyphomella/Harnischia/Paracladopelma	0	0	0	0	0	0	0	0	1	0
Dicrotendipes	6	3	4	1	1	4	1	5.5	3	7
Einfeldia sp grp B	0	0	0	0	0	0	0	0	0	0
Einfeldia sp grp D	0	0	0	0	0	0	0	0	0	0
Endochironomus	0	0	0	0	0	0	0	0	0	0
Glyptotendipes	1	2	2	0	0	0.5	2	6.5	5	1.5
Hyporhygma	0	0	0	0	0	0	0	0	0	0
Lauterborniella/Zavrelia	0	0	0	0	0	0	0	0	0	0
Microchironomus	0	0	0	0	0	0	0	0	0	0
Microtendipes	0	3	0	0	0	0	0	1	0	0
Nilothauma	0	0	0	0	0	0	0	0	0	0
Omisus	0	0	0	0	0	0	0	0	0	0
Pagastiella	0	0	0	0	0	0	0	0	0	0
Parachironomus	0	1	0	0	0	2	0.5	0	0	0
Paralauterborniella	0	0	0	0	0	0	0	0	0	0
Paratendipes	1	0	0	0	0	0	0	1	1	1
Polypedilum	1	0	1.5	3	0.5	1	1	2	3	0
Sergentia	0	0	0	0	0	0	0	0	0	0
Sergentia (Phaenopsectra)	0	0	0	0	0	0	0	0	0	0
Stenochironomus	0	0	0	0	0	0	0	1	0	0
Stictochironomus	0	0	0	0	0	0	0	0	0	0
Tribelos	0	0	0	0	0	0	0	0	0	0
Xenochironomus	0	0	0	0	0	0	0	0	0	0
Procladius	2	0	0	0	1	0	0	2	6	3
Tribe Pentaneurini	2	2	1	1	1	3	0	3	9	3
Labrundinia	0	0	0	0	0	0	0	0	0	0
Nilotanypus	0	0	0	0	0	0	0	0	0	0

	Top Sum									
Interval	0 - 1.5	2-2.5	4-4.5	6-6.5	8-8.5	10-11	14-15	20-21	26-27	34-35
Lake	GW	GW	GW	GW	GW	GW	GW	GW	GW	GW

Tanypus	0	0	0	0	0	0	0	0	0	0
Protanypus	0	0	0	0	0	0	0	0	0	0
Monodiamesa	0	0	0	0	0	0	0	0	0	0
Brillia/Euryhapsis	0	0	0	0	0	0	0	0	0	0
Bryophaenocladius/Gymnometriocnemus	0	0	0	0	0	0	0	0	0	2.5
Chaetocladius	0	0	0	0	0	0	0	0	0	0
Corynoneura/Thienemanniella	1	2	0	2	2	1	0	5.5	3	4
Cricotopus/Orthocladius	1	0	1	1	0	2	2.5	1.5	1	3
Diplocladius	0	0	0	0	0	0	0	0	0	0
Doithrix	0	0	0	0	0	0	0	0	0	0
Eukiefferiella/Tventia	0	0	0	0	0	0	0	0	0	0
Heterotanytarsus	0	0	0	0	0	0	0	0	0	0
Heterotrissocladius	0	0	0	0	0	0	0	0	1	0
Hydrobaneus	0	2	0	0	0	0	0	1	0	0
Limnophyes	0	0	0	0	0	0	0	0	0	0
Nanocladius	0	0	2	0	0	1	0	0	0	3
Parachaetocladius	0	0	0	0	0	0	0	0	0	0
Paracladius	0	0	0	0	0	0	0	0	0	0
Paracricotopus	0	0	0	0	0	0	0	0	0	0
Parakiefferiella sp. A	0	0	0	0	0	0	0	0	0	0
Parakiefferiella sp. B	0	1.5	0	0	0	0	0	0	1	1
Parakiefferiella cf. *triqueta*	0	0	0	0	0	0	0	0	0	0
Parakiefferiella cf. *nigra*	0	0	0	0	0	0	0	0	0	0
Paralimnophyes	0	0	0	0	0	0	0	0	0	0
Parametriocnemus	0	0	0	0	0	0	0	0	0	0
Paraphaenocladius	0	0	0	0	0	0	0	0	0	0
Propsilocerus	0	0	0	0	0	0	0	0	0	0
Psectrocladius (Allopsectrocladius/Mesopsectrocladius)	0	0	0	0	0	0	0	0	0	0
Psectrocladius (Monopsectrocladius)	0	0	0	0	0	0	0	0	0	0
Psectrocladius (Psectrocladius)	1	0	1	0	1	0	0	0	0	0
Psectrocladius cf. *septentrionalis*	0	0	0	0	0	0	0	0	0	0
Pseudosmittia/Smittia	0	0	0	0	0	0	0	0	0	0
Rheocricotopus	0	0	0	0	0	0	0	0	0	0
Stilocladius	0	0	0	0	0	0	0	0	0	0
Symbiocladius	0	0	0	0	0	0	0	0	0	0
Synorthocladius	3	0.5	1	2	0	0.5	1.5	2	5	5.5
Zalutschia cf. *zalutschicola*	1.5	1.5	1.5	0.5	0	1	0.5	0	0	0
Zalutschia sp.	0	0	0	0	0	2.5	1.5	0	0	0
Chaoborus mandibles - sum	17	14	15	7	15	16	17	22	25	15
sum identifiable Chironomidae	67.5	66	114.5	81.5	129.5	137	132	74.5	81.5	60.5

0-1 CO	1-2 CO	2-3 CO	4-5 CO	6-7 CO	10-12 CO	14-16 CO	20-22 CO	28-30 CO	36-38 CO	40-42 CO
4.5	2	15	13.5	8	22	25	23.5	34	48.5	24.5
0	0	0	0	0	0	0	0	0	1	0
0	0	0	0	0	0	0	0	0	0	0
0	0	0	2	3	4	3	2	2	3	1
0	0	0	1	0	0	2	1	2	1	0
0	1	0	0	1	1	2	2	3	6	7
0	0	0	0	0	0	2	2	3	0	0
0	0	0	0	0	1	2	2	9	6	7.5
0	0	0	0	0	0	0	0	0	1	0
0	0	0	2	0	0	0	0.5	0.5	0.5	1
28.5	34	56	35	32	25	29	18	16	17	20.5
0	0	1	0	1	5	1	0	1	0	0
2	1.5	2	4	5	8	8.5	4	4	3	5.5
0	0	1	0	1	0	1	1	1	0	1
0	0	0	0	0	0	0	0	0	1	1
0	0	0	0	0	0	0	0	0	0	0
7.5	2	8	8	6	8	18	10	13	15.5	15
0	0	0	0	0	0	0	0	1	0	0
0	0	0	0	0	0	0	0	0	0	0
1	0	4	0	0	2	6	3	1	3	2
2.5	3.5	4	1	3	4	9.5	2	10.5	4	0
0	0	0	0	0	0	0	0	0	0	0
2	0	0	0.5	1	1.5	1	1	8	5	5
0	0	0	0	0	0	0	0	0	0	0
1	0	1	1.5	0	0	3	3	2.5	3.5	0
0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	1	2	0
4	0	1	4	3	2	0	2	1	0	0
0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	1	0	0	0
1	2	2	4	3.5	1	6	4	4.5	6	4
0	0	0	0	0	0	0	1	0	0	0
0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	1
0	0	0	0	0	0	0	0	0	0	0
1	1	3	7	3	7	16	6	16	19	19
1	2	1	5	3	11	5	7	13	16	25
0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	2	0	0	0	0

0-1 CO	1-2 CO	2-3 CO	4-5 CO	6-7 CO	10-12 CO	14-16 CO	20-22 CO	28-30 CO	36-38 CO	40-42 CO

0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0
0	0	0.5	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0
0	1	0	2	5	6	7	2	3	3	2
0	1	2	2	4	0	2	0	2.5	1	4.5
0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	1	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0
1	3	0	0.5	2	0	2	0	3	0	1
0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	1
0	0	0	0	0	0	0	0	0	0	1
0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0
0	0	0.5	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0
1	0	0	0	0	0	2.5	0	0	0	3
0	0	1	0	2	3	3	2	1.5	2	2.5
0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	2	2	1.5	0	2	2
0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0
3	5	5	9	7	5	7	3	11	7	3
58	54	103	93	87.5	113.5	160.5	101.5	157	170	157

	Top Sum								
Interval	0-1	40-41	0-0.5	0.5-1	39.5-40.5	0-0.5	0.5-1	35-36	0-0.5
Lake	1	1	2	2	2	3	3	3	4
Tanytarsus sensu latu (s.lat.)	5.5	16.5	17.5	49.5	135.5	26	33	11	13
Tanytarsus chinyensis grp	0	0	0	0	0	0	1	1	0
Tanytarsus cf. *glabrescens* group	0	0	0	0	0	0	0	0	0
Tanytarsus lugens grp	0	0	0	3	1	0	0	1	0
Cladotanytarsus sp grp A	0	0	0	1.5	0	1	2	0	0
Cladotanytarsus mancus grp	0	0	0	2	0	0	3.5	0	0
Micropsectra type	0	3.5	1	3	2	1.5	1	1.5	0
Stempellina	1	0	0	0	0	1.5	0	0	0
Stempellinella/Zavrelia	0	0	0	0	0	0	0	0	0
Pseudochironomus	0	0	1	0.5	15	0	1.5	1.5	1
Chironomus	10.5	0	4.5	16.5	10	6.5	11.5	3	7
Chironomini larvula	11	0	0	3	1	0	3	0	1
Cladopelma	1	0	0	11.5	3.5	2	1.5	0	10
Cryptochironomus	0	0	2	2	0	0	1	1.5	1
Cryptotendipes	1	0	1	0.5	0	1	0	0	0
Cyphomella/Harnischia/Paracladopelma	0	0	0	0	0	0	0	1	0
Dicrotendipes	2.5	1	6	24	163	10.5	24	3	2
Einfeldia sp grp B	3	0	0	5	0	0	0	0	0
Einfeldia sp grp D	0	0	0	0	0	0	0	0	4
Endochironomus	0	2	0	11.5	1	0	0	0	0
Glyptotendipes	2.5	0	1	11	6	0	0	0	2
Hyporhygma	0	0	0	1	2	1	0	0	0
Lauterborniella/Zavrelia	0	0	2	16.5	63	1.5	4	0	3
Microchironomus	0	0	0	0	0	0	0	0	0
Microtendipes	0	0	4	9.5	22.5	1.5	1	0	0
Nilothauma	0	0	0	0	0	0	0	0	0
Omisus	0	0	0	0	0	0	0	0	0
Pagastiella	0	0	0	0	0	0	0	0	0
Parachironomus	2	0	1.5	4	2	1	3	0	1
Paralauterborniella	0	0	0	0	0	0	0	0	0
Paratendipes	0	0	0	1	2	2	1	0	0
Polypedilum	3	1	3.5	25.5	9.5	2	1	0	7
Sergentia	0	0	0	1	0	0	0	0	0
Sergentia (Phaenopsectra)	0	0	0	0	0	0	0	0	0
Stenochironomus	0	0	0	0	0	0	0	0	0
Stictochironomus	0	0	0	0	1	0	0	0	0
Tribelos	0	0	0	1	0	0	3	0	0
Xenochironomus	0	0	0	0	1	1	0	0	0
Procladius	0	1	2	8	2	4	4	19	20
Tribe Pentaneurini	5	5	2	31	54	7	13	8	18
Labrundinia	0	0	0	0	0	0	0	0	0
Nilotanypus	0	0	0	0	0	0	0	0	2

	Top Sum								
Interval	0-1	40-41	0-0.5	0.5-1	39.5-40.5	0-0.5	0.5-1	35-36	0-0.5
Lake	1	1	2	2	2	3	3	3	4

Tanypus	0	0	0	0	0	0	0	0	0
Protanypus	0	0	0	0	0	0	0	0	0
Monodiamesa	0	0	0	0	0	0	0	0	0
Brillia/Euryhapsis	0	0	0	0	1	0	0	0	0
Bryophaenocladius/Gymnometriocnemus	0	1.5	0	0	0	0	0	0	0
Chaetocladius	0	0	0	3	0	0	0	0	0
Corynoneura/Thienemanniella	2	1.5	2	12	1	1	0	0	0
Cricotopus/Orthocladius	1	3.5	2.5	3.5	2.5	1.5	7	1	3
Diplocladius	0	0	0	0	0	0	0	0	0
Doithrix	0	0	0	0	0	0	0	0	0
Eukiefferiella/Tventia	0	0	0	0	0	0	0	0	0
Heterotanytarsus	0	0	0	0	0	0	0	0	0
Heterotrissocladius	0	0	0	0.5	0	0	1	1.5	0
Hydrobaneus	0	0	0	0	0	0	0	0	0
Limnophyes	0	12	0	0	0	0	0	0	2
Nanocladius	0	0	0	4	1	4.5	3.5	0	0
Parachaetocladius	0	0	0	0	0	0	0	0	0
Paracladius	0	0	0	0	0	0	0	0	0
Paracricotopus	0	3	0	0	0	0	0	0	0
Parakiefferiella sp. A	0	0	0	1	12	2	3	2	2
Parakiefferiella sp. B	0	1	0	0	3.5	1.5	2	0.5	1
Parakiefferiella cf. *triqueta*	0	0	0	0	0	0	0	0	0
Parakiefferiella cf. *nigra*	0	0	0	0	0	0	0	0	0
Paralimnophyes	0	0.5	0	0	0	0	0	0	0
Parametriocnemus	0	0	0	0	0	0	0	0	0
Paraphaenocladius	0	0	0	0	0	0	0	0	0
Propsilocerus	0	0	0	0	0	0	0	0	0
Psectrocladius (Allopsectrocladius/Mesopsectrocladius)	0	0	0	0	0	0	0	0	0
Psectrocladius (Monopsectrocladius)	0	0	0	0	2	1	0.5	0	0
Psectrocladius (Psectrocladius)	0.5	0	3	9.5	6	4	7	3.5	3.5
Psectrocladius cf. *septentrionalis*	0	0	0	0	0	0	0	0	0
Pseudosmittia/Smittia	0	0	0	0	0	0	0	0	0
Rheocricotopus	0	0	0	0	0	0	0	0	0
Stilocladius	0	0	0	0	0	0	0	0	0
Symbiocladius	0	0	0	0	0	0	0	0	0
Synorthocladius	0	0	0	3	1	0	0	2	0
Zalutschia cf. *zalutschicola*	0	0	0	0	0	6.5	11	1	0
Zalutschia sp.	0	0	0.5	0.5	0	0	1	0	0
Chaoborus mandibles - sum	31	0	0	5	1	2	4	0	2
sum identifiable Chironomidae	52.5	54	59	282	529	96	152	66	107.5

															Top Sum		
0.5-1	33-34	0-0.5	0.5-1	42-43	0-1.0	29-30	0-1	49-50	0-1	27-28	0-1	50-51	0-1	Bott. 2	0-2	34-35	0 - 1.0
4	4	5	5	5	6	6	7	7	8	8	9	9	10	10	11	11	12
13	140	15	23.5	94.5	6	28.5	1	5	7	35	8	15.5	7.5	3.5	30.5	20	4
0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1	3	8	13	24	2	1.5	0	0	0	0	1	3	2	1	0	0	0
2	1	0	0	0	1	5	0	0	0	0	2	4	0	0	0	1	1
3	6	18	12	50.5	0	5	1	1	0	4	0	1	1	1	2	3	5
0	2	0	0	0	1	1	0	1	20	9.5	0	1	0	0	0	1	0
0	0	0	0	24	0	3	1	1	0	1	0	1	0	0	0	0	1
0	0	1	0	8	0	2	0	1	0	0	0	0	0	0	0	0	0
0.5	0.5	0	0.5	0.5	2	7	0	0.5	0.5	2	2.5	5	0	0	1.5	5	2
13.5	26	1	2	2	3	17.5	25.5	26.5	1	1	4.5	7.5	14	31.5	6	8	2
4	0	0	0	1	0	2	1	0	0	0	0	0	3	2	1	10	0
15.5	14	1.5	1	0	2	4	1	1	0	0	1	1	0	1	0	2	0
4	5	0	2	2	0	1	0.5	0	0	1	0	0	0	1	1	0	0
1	3	0	0	0	0	0	0	2	0	0	1	0	0	0	2	1	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10	20	0	3	2	3	19.5	2.5	5	3	2.5	9.5	7	4.5	2	7	3	5
5	0	0	0	7	0	0	9	0	0	0	0	0	0	0	0	2	0
5.5	0	0	0	0	0	0	2	1	0	0	0	0	0	0	0	0	0
2	3	1	1	0	1	3	0	0.5	1	0.5	17.5	1	0	1.5	0	0	3.5
3	1	1	0	1	1	3	0	0	0	0	10	1.5	0	2	2	15.5	2
0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
1	1	1	0	2	0	3	0	1	0	0	1	3	0	0	0	0	0
0	5	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
0	0	0	0	0.5	0	4	1	0.5	1.5	2.5	3	4	0	0	0	1	3
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	4	0	4	0	1	1	1	1	0	0	5	0	0	0	0	1	1
0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	3	0	0	0	0	0	5.5	0	0	0
7	5	1	1	2	4.5	9	1	3	1	1.5	3	7	2	2	3.5	4	3
0	0	0	0	1	0	0	0	0	0	2	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0
0	0	0	0	0	0	0.5	0	2	2	2	0	0	0	0	1	0	0
0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
29	12	8	6	31	2	12	1	5	0	1	5	13	4	1	9	7	1
26	21	3	8	8.5	7	22	3	5	1	4	14	19	1	0	9	10	11
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

															Top Sum		
0.5-1	33-34	0-0.5	0.5-1	42-43	0-1.0	29-30	0-1	49-50	0-1	27-28	0-1	50-51	0-1	Bott. 2	0-2	34-35	0 - 1.0
4	4	5	5	5	6	6	7	7	8	8	9	9	10	10	11	11	12

0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0.5	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0.5	0	0	0	0
0	1	0	0	2	0	22	1	2	1	1	9	8	1	0	5	1	9
2	3.5	1	0.5	2	0	3	0	1	1	1	5.5	0.5	0	0	7	1	2.5
0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	1	0	0	0	0	0	0	0	8.5	15	0	0	0	1	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0
1	2	0	0	0	0	4.5	0.5	0	0	1	0	0	0	0	0	1	0
1	0	0	1	1	4	4.5	0	0	0	0	1.5	1	2	1	1	2	1
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	1.5	3	0	0	0	0	1	0	0	0	1	1	1
1	5	0	2	1	1.5	4	0	1.5	0.5	2	3	3	0	0	4	2.5	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	4	7	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0.5	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	1	1	0	0	0	0	1	0	0	0	0	0.5	0
1.5	2.5	0	3	1	2	4.5	1.5	0	0	1	0	0	3.5	0	0	3.5	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	1	5	2	0	1	0	2	0	1	0	0	0	2
0	0	0	0	0	0	0	0	0	0	0	0.5	0	0	0	6.5	5.5	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.5	0	0
3	0	2	3	4	3	41	9	79	0	0	4	2	4	1	3	7	6
161.5	293.5	65.5	88.5	277.5	53.5	214.5	64.5	77.5	63	106	120.5	117	57	69	112.5	127.5	72

31-32
12
17.5
0.5
0
3
1
3.5
2
1
0
3.5
12.5
1
2
1
0
0
6
0
0
1
1
0
3.5
0
1
0
0
0
4
0
0
4
0
0
0
0
0
0
3
17
0
0

31-32
12

0
0
0
0
1
0
12
2.5
0
0
0
0
1
0
2
3
0
0
0
1
2
0
0
0
0
0
0
0
0
0
0
0
0
0
0
4
0
0.5
6
130

Pb-210 dating

Cossayuna Lake

Summary

1) The % water in this core was quite consistent at ~80% from top to bottom. Consequently, length-based and mass-based sedimentation models will give nearly identical results. For this analysis, all sed rates were expressed on a length/time basis.
2) The Pb-210 and Cs-137 data both indicate a surface mixed layer of several cm in depth. Taking this into account and applying a CIC model yields a "best fit" accumulation rate of ca. 0.3 cm/y, but the data is reasonably consistent with rates up to ~0.5 cm/y (see Pb plot d).
3) Using the same mixed layer depths and including drainage basin/in lake holdup, the Cs-137 data is fit beautifully with an average net accumulation rate of 0.55 cm/y (see Cs plot d). A significantly lower net accumulation rate would be most difficult to support in light of the Cs-137 data.
4) Overall, the radionuclide data for this core indicates a surface mixed layer of ~3.5 cm and a net accumulation rate of ~0.5 cm/y.
5) For illustration, I also ran a CRS model on the Pb-210 data (see CRS worksheet). This would be analagous to a Binford (or Hemond) approach. The model does not accommodate mixing. It allows changes in accumulation rate to fit each point on the profile and generates a specific date of deposition for each section. In this case, the predicted accumulation rates range over a factor of 3. At a depth of 21.5 cm (peak Cs-137 activity) it yields a date of 1933 (!?). I am not a big fan of this model. It works best in "uncomplicated" cores where it gives the same results as CIC.

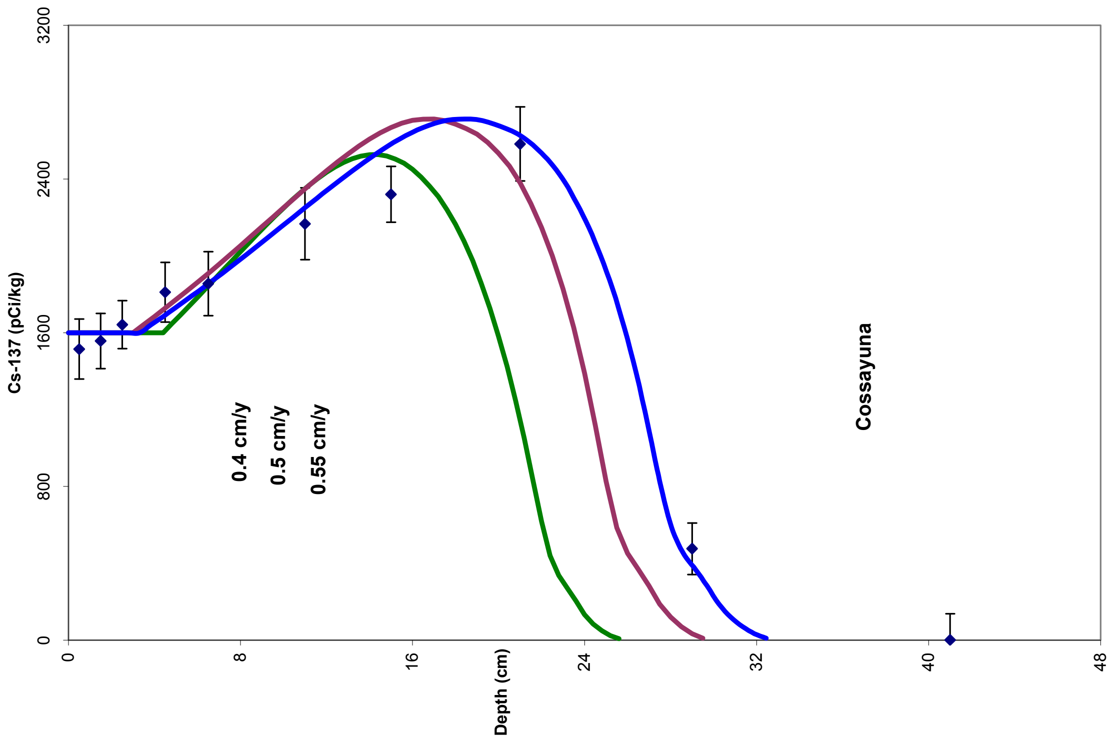
Cossayuna Lake Radionuclide Data

RPI	Upper	Lower	Be-7	1σ	Cs-137	1σ	Pb-210_{supp}	1σ	Pb-210_{xs}	1σ
Control #	(cm)	(cm)	(pCi/g)		(pCi/kg)		(dpm/g)		(dpm/g)	
R1606A*	0	1	5.53	2.00	1514	156	*2.84*	*0.28*	29.07	2.51
R1606B*	1	2	2.71	1.72	1557	144	*2.84*	*0.28*	30.84	2.38
R1606C	2	3	-1.03	1.79	1642	124	2.84	0.28	32.43	2.22
R1606E	4	5			1811	155	3.06	0.38	32.73	2.55
R1606G	6	7			1855	166	2.57	0.39	28.68	2.39
R1606K	10	12			2167	187	2.31	0.41	19.64	2.18
R1606M	14	16			2320	145	1.52	0.23	14.48	1.28
R1606P	20	22			2582	193	2.00	0.36	8.36	1.57
R1606T	28	30			476	134	1.88	0.44	2.73	1.78
R1606Z	40	42			1	136	1.87	0.51	-0.38	1.89

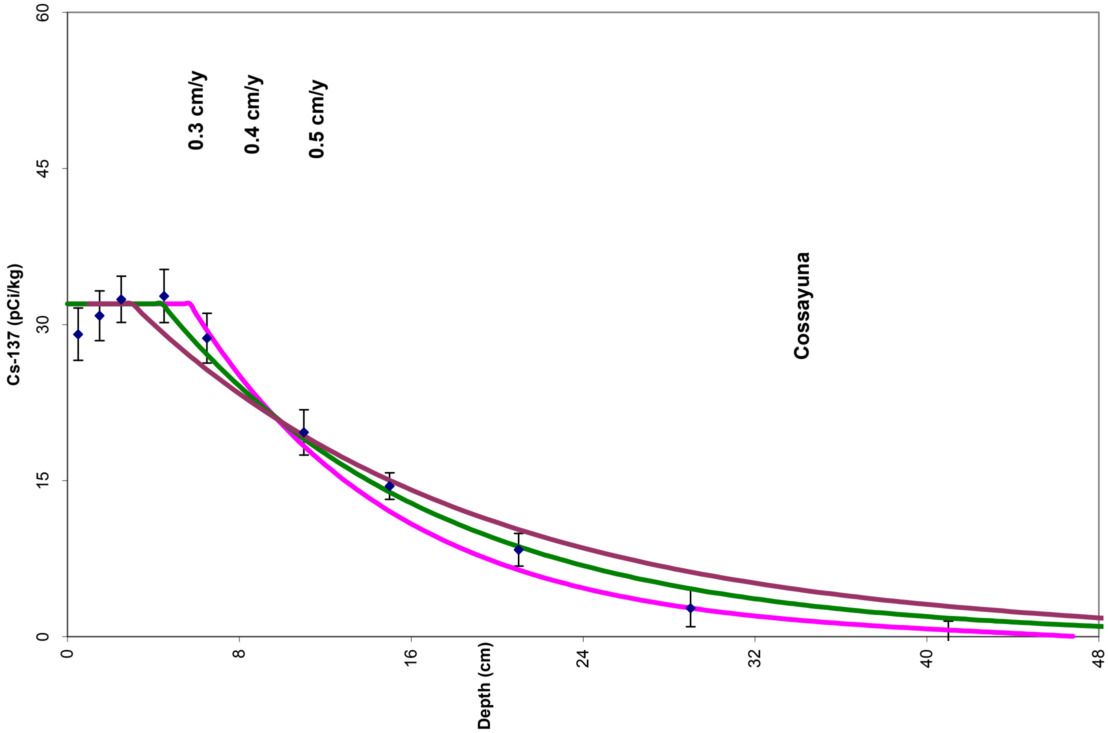
Cossayuna % water

Top	Bottom	Dry Mass	∑ Mass	wt % H_2O
cm	cm			
0	1	4.277	4.277	83.11%
1	2	5.088	9.365	80.36%
2	3	5.070	14.435	80.42%
3	4	5.047	19.482	80.49%
4	5	5.217	24.699	79.93%
5	6	5.286	29.985	79.70%
6	7	5.901	35.886	77.72%
7	8	5.669	41.555	78.46%
8	9	5.697	47.252	78.37%
9	10	5.947	53.199	77.57%
10	12	8.187	61.386	83.75%
12	14	9.442	70.828	81.59%
14	16	9.389	80.217	81.68%
16	18	9.346	89.563	81.75%
18	20	10.209	99.772	80.30%
20	22	9.909	109.681	80.80%
22	24	10.759	120.440	79.40%
24	26	11.028	131.468	78.96%
26	28	10.920	142.388	79.13%
28	30	11.176	153.564	78.72%
30	32	10.306	163.870	80.14%
32	34	9.990	173.860	80.66%
34	36	9.192	183.052	82.01%
36	38	9.510	192.562	81.47%
38	40	7.826	200.388	84.39%
40	42	7.390	207.778	85.16%
42	44			

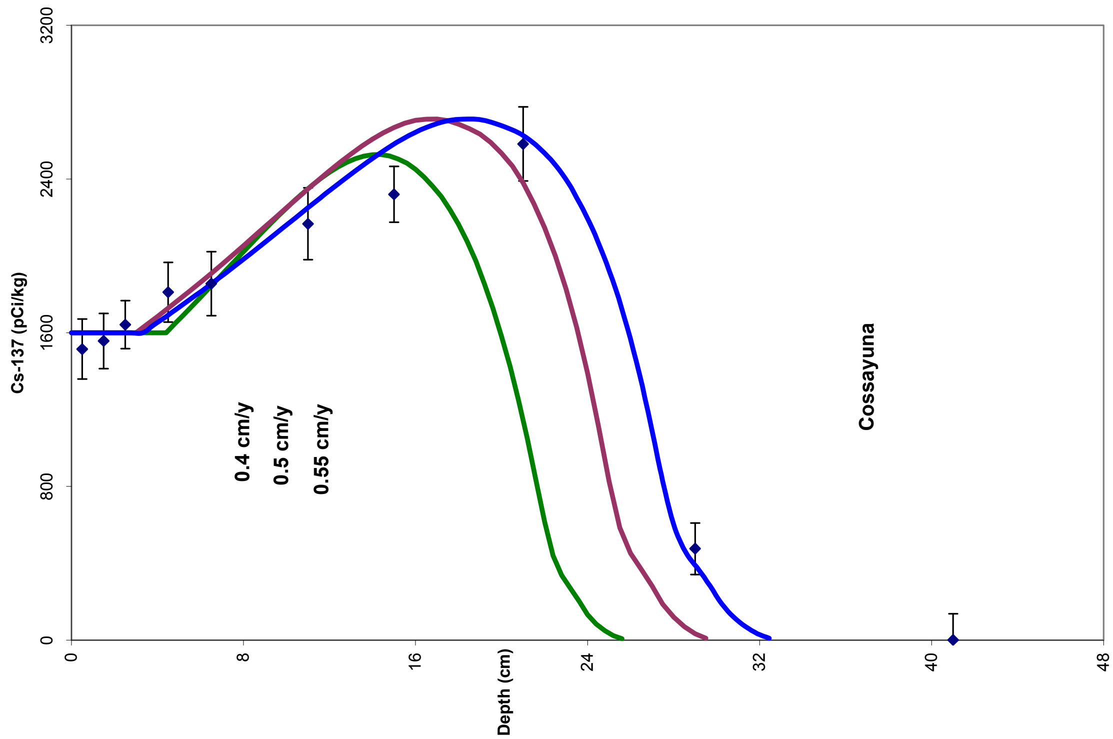
Cs-137 Plot


Cs-137 (pCi/kg)
Depth (cm)
0.4 cm/y
0.5 cm/y
0.55 cm/y
Cossayuna
0
800
1600
2400
3200
0
8
16
24
32
40
48

Pb-210 Plot d


Cs-137 (pCi/kg)
0
15
30
45
60
0.3 cm/y
0.4 cm/y
0.5 cm/y
Cossayuna
0
8
16
24
32
40
48
Depth (cm)

Pb-210 Plot m



Cs-137 (pCi/kg)
Depth (cm)
0.4 cm/y
0.5 cm/y
0.55 cm/y
Cossayuna
0
800
1600
2400
3200
0
8
16
24
32
40
48

CRS model

Fraction	±1 σ	CRS ΔT (years)	1σ pos	1σ neg	mean yrs/section	CRS Date (at bottom)	1σ pos	1σ neg	CRS ave date	1σ pos	1σ neg	Ave depth (cm)
0.048	0.005	1.59	0.17	0.16	1.59	2005.4	2005.2	2005.6	2006.2	2006.1	2006.3	0.5
0.109	0.009	3.72	0.31	0.31	2.13	2003.3	2003.0	2003.6	2004.3	2004.1	2004.6	1.5
0.205	0.014	7.38	0.57	0.56	3.66	1999.6	1999.0	2000.2	2001.5	2001.0	2001.9	2.75
0.337	0.022	13.22	1.10	1.07	5.84	1993.8	1992.7	1994.8	1996.7	1995.9	1997.5	4.5
0.528	0.035	24.10	2.45	2.28	10.88	1982.9	1980.4	1985.2	1988.3	1986.6	1990.0	7
0.694	0.046	38.00	5.20	4.47	13.90	1969.0	1963.8	1973.5	1975.9	1972.1	1979.3	10.75
0.826	0.053	56.13	11.58	8.49	18.13	1950.9	1939.3	1959.4	1959.9	1951.5	1966.4	15.5
0.944	0.062	92.66	#NUM!	24.00	36.53	1914.3	#NUM!	1938.3	1932.6	#NUM!	1948.8	21.5

Cossayuna Model A Pb-210

Model Activity	Scaled Activity	Model Year	depth (cm)
0.000667	0.03397	1870	46.8
0.001323	0.067329	1871	46.5
0.001967	0.100142	1872	46.2
0.002602	0.132471	1873	45.9
0.003229	0.16438	1874	45.6
0.003849	0.195926	1875	45.3
0.004463	0.227167	1876	45
0.005071	0.258159	1877	44.7
0.005676	0.288957	1878	44.4
0.006279	0.319614	1879	44.1
0.006879	0.350181	1880	43.8
0.007479	0.380709	1881	43.5
0.008079	0.411249	1882	43.2
0.00868	0.441847	1883	42.9
0.009283	0.472554	1884	42.6
0.009889	0.503414	1885	42.3
0.010499	0.534475	1886	42
0.011114	0.565783	1887	41.7
0.011735	0.597382	1888	41.4
0.012363	0.629318	1889	41.1
0.012997	0.661635	1890	40.8
0.013641	0.694377	1891	40.5
0.014293	0.727588	1892	40.2
0.014956	0.761313	1893	39.9
0.015629	0.795595	1894	39.6
0.016314	0.830478	1895	39.3
0.017012	0.866006	1896	39
0.017724	0.902224	1897	38.7
0.01845	0.939176	1898	38.4
0.019191	0.976906	1899	38.1
0.019948	1.015459	1900	37.8
0.020723	1.054882	1901	37.5
0.021515	1.09522	1902	37.2
0.022326	1.13652	1903	36.9
0.023157	1.178829	1904	36.6
0.024009	1.222195	1905	36.3
0.024883	1.266667	1906	36
0.025779	1.312294	1907	35.7
0.026699	1.359126	1908	35.4
0.027644	1.407215	1909	35.1
0.028614	1.456614	1910	34.8
0.029612	1.507375	1911	34.5
0.030637	1.559553	1912	34.2
0.03169	1.613203	1913	33.9
0.032774	1.668384	1914	33.6

0.03389	1.725153	1915	33.3
0.035037	1.783569	1916	33
0.036218	1.843694	1917	32.7
0.037434	1.905591	1918	32.4
0.038686	1.969324	1919	32.1
0.039976	2.034959	1920	31.8
0.041304	2.102564	1921	31.5
0.042672	2.172208	1922	31.2
0.044081	2.243962	1923	30.9
0.045534	2.317901	1924	30.6
0.047031	2.3941	1925	30.3
0.048574	2.472636	1926	30
0.050164	2.553589	1927	29.7
0.051803	2.637041	1928	29.4
0.053493	2.723077	1929	29.1
0.055236	2.811785	1930	28.8
0.057033	2.903252	1931	28.5
0.058886	2.997573	1932	28.2
0.060796	3.094841	1933	27.9
0.062767	3.195155	1934	27.6
0.064799	3.298615	1935	27.3
0.066896	3.405326	1936	27
0.069058	3.515394	1937	26.7
0.071288	3.62893	1938	26.4
0.073589	3.746047	1939	26.1
0.075962	3.866862	1940	25.8
0.078411	3.991497	1941	25.5
0.080937	4.120077	1942	25.2
0.083543	4.252728	1943	24.9
0.086231	4.389584	1944	24.6
0.089005	4.530782	1945	24.3
0.091867	4.676462	1946	24
0.094819	4.82677	1947	23.7
0.097866	4.981855	1948	23.4
0.101009	5.141871	1949	23.1
0.104253	5.306979	1950	22.8
0.107599	5.477343	1951	22.5
0.111053	5.653132	1952	22.2
0.114616	5.834521	1953	21.9
0.118293	6.021691	1954	21.6
0.122087	6.214827	1955	21.3
0.126002	6.414123	1956	21
0.130042	6.619775	1957	20.7
0.134211	6.831989	1958	20.4
0.138513	7.050976	1959	20.1
0.142952	7.276953	1960	19.8
0.147533	7.510144	1961	19.5
0.15226	7.750782	1962	19.2
0.157138	7.999106	1963	18.9
0.162172	8.255362	1964	18.6

0.167367	8.519805	1965	18.3
0.172728	8.792697	1966	18
0.17826	9.07431	1967	17.7
0.183969	9.364924	1968	17.4
0.18986	9.664826	1969	17.1
0.19594	9.974315	1970	16.8
0.202214	10.2937	1971	16.5
0.208689	10.62329	1972	16.2
0.21537	10.96342	1973	15.9
0.222266	11.31443	1974	15.6
0.229382	11.67667	1975	15.3
0.236725	12.05048	1976	15
0.244303	12.43625	1977	14.7
0.252124	12.83437	1978	14.4
0.260195	13.24521	1979	14.1
0.268524	13.6692	1980	13.8
0.277119	14.10674	1981	13.5
0.28599	14.55829	1982	13.2
0.295144	15.02427	1983	12.9
0.304591	15.50517	1984	12.6
0.31434	16.00145	1985	12.3
0.324401	16.51361	1986	12
0.334784	17.04215	1987	11.7
0.345499	17.5876	1988	11.4
0.356557	18.1505	1989	11.1
0.367968	18.73142	1990	10.8
0.379745	19.33092	1991	10.5
0.391899	19.9496	1992	10.2
0.404441	20.58808	1993	9.9
0.417385	21.24698	1994	9.6
0.430743	21.92697	1995	9.3
0.444529	22.62872	1996	9
0.458755	23.35292	1997	8.7
0.473437	24.10029	1998	8.4
0.488588	24.87158	1999	8.1
0.504225	25.66754	2000	7.8
0.520362	26.48898	2001	7.5
0.537015	27.33671	2002	7.2
0.554201	28.21155	2003	6.9
0.571936	29.1144	2004	6.6
0.59024	30.04613	2005	6.3
0.609129	31.00768	2006	6

Cossayuna Model B Pb-210

Model Activity	Scaled Activity	Model Year	depth (cm)
0.001112	0.047778	1870	59.2
0.002167	0.093104	1871	58.8
0.003171	0.136231	1872	58.4
0.004129	0.177392	1873	58
0.005047	0.216804	1874	57.6
0.005928	0.254665	1875	57.2
0.006778	0.291161	1876	56.8
0.0076	0.326463	1877	56.4
0.008397	0.36073	1878	56
0.009174	0.394107	1879	55.6
0.009934	0.426734	1880	55.2
0.010679	0.458737	1881	54.8
0.011412	0.490235	1882	54.4
0.012136	0.521339	1883	54
0.012853	0.552155	1884	53.6
0.013566	0.582778	1885	53.2
0.014277	0.613302	1886	52.8
0.014987	0.643814	1887	52.4
0.015699	0.674395	1888	52
0.016414	0.705123	1889	51.6
0.017135	0.736072	1890	51.2
0.017862	0.767313	1891	50.8
0.018597	0.798913	1892	50.4
0.019343	0.830937	1893	50
0.0201	0.863448	1894	49.6
0.020869	0.896506	1895	49.2
0.021653	0.930169	1896	48.8
0.022452	0.964496	1897	48.4
0.023268	0.999541	1898	48
0.024102	1.035359	1899	47.6
0.024955	1.072004	1900	47.2
0.025828	1.109529	1901	46.8
0.026723	1.147987	1902	46.4
0.027642	1.187429	1903	46
0.028584	1.227908	1904	45.6
0.029551	1.269476	1905	45.2
0.030546	1.312185	1906	44.8
0.031568	1.356087	1907	44.4
0.032619	1.401235	1908	44
0.0337	1.447681	1909	43.6
0.034812	1.49548	1910	43.2
0.035958	1.544686	1911	42.8
0.037137	1.595354	1912	42.4
0.038352	1.647541	1913	42
0.039604	1.701304	1914	41.6
0.040893	1.7567	1915	41.2

0.042222	1.81379	1916	40.8
0.043592	1.872634	1917	40.4
0.045004	1.933294	1918	40
0.04646	1.995834	1919	39.6
0.047961	2.06032	1920	39.2
0.049509	2.126818	1921	38.8
0.051105	2.195397	1922	38.4
0.052752	2.266127	1923	38
0.05445	2.339082	1924	37.6
0.056202	2.414335	1925	37.2
0.058009	2.491962	1926	36.8
0.059873	2.572044	1927	36.4
0.061796	2.65466	1928	36
0.063781	2.739894	1929	35.6
0.065828	2.827833	1930	35.2
0.06794	2.918564	1931	34.8
0.070119	3.012179	1932	34.4
0.072367	3.108772	1933	34
0.074688	3.208439	1934	33.6
0.077082	3.311281	1935	33.2
0.079552	3.417399	1936	32.8
0.082101	3.526901	1937	32.4
0.084731	3.639896	1938	32
0.087445	3.756495	1939	31.6
0.090246	3.876816	1940	31.2
0.093137	4.000979	1941	30.8
0.096119	4.129107	1942	30.4
0.099197	4.261327	1943	30
0.102373	4.397772	1944	29.6
0.105651	4.538576	1945	29.2
0.109034	4.683881	1946	28.8
0.112524	4.833831	1947	28.4
0.116126	4.988574	1948	28
0.119844	5.148265	1949	27.6
0.12368	5.313061	1950	27.2
0.127639	5.483128	1951	26.8
0.131724	5.658634	1952	26.4
0.135941	5.839753	1953	26
0.140292	6.026665	1954	25.6
0.144782	6.219556	1955	25.2
0.149416	6.418617	1956	24.8
0.154198	6.624046	1957	24.4
0.159133	6.836048	1958	24
0.164226	7.054831	1959	23.6
0.169482	7.280614	1960	23.2
0.174906	7.513622	1961	22.8
0.180503	7.754084	1962	22.4
0.18628	8.00224	1963	22
0.192241	8.258336	1964	21.6
0.198394	8.522626	1965	21.2

0.204743	8.795373	1966	20.8
0.211295	9.076848	1967	20.4
0.218057	9.367329	1968	20
0.225035	9.667105	1969	19.6
0.232237	9.976473	1970	19.2
0.239669	10.29574	1971	18.8
0.247339	10.62523	1972	18.4
0.255254	10.96525	1973	18
0.263423	11.31616	1974	17.6
0.271853	11.6783	1975	17.2
0.280553	12.05203	1976	16.8
0.289531	12.43771	1977	16.4
0.298796	12.83574	1978	16
0.308358	13.24651	1979	15.6
0.318226	13.67042	1980	15.2
0.32841	14.10789	1981	14.8
0.33892	14.55937	1982	14.4
0.349766	15.02529	1983	14
0.360959	15.50612	1984	13.6
0.37251	16.00234	1985	13.2
0.384431	16.51444	1986	12.8
0.396733	17.04292	1987	12.4
0.409429	17.58832	1988	12
0.422532	18.15118	1989	11.6
0.436053	18.73204	1990	11.2
0.450008	19.33149	1991	10.8
0.464408	19.95013	1992	10.4
0.47927	20.58856	1993	10
0.494608	21.24742	1994	9.6
0.510436	21.92737	1995	9.2
0.52677	22.62908	1996	8.8
0.543628	23.35324	1997	8.4
0.561025	24.10058	1998	8
0.578978	24.87183	1999	7.6
0.597506	25.66776	2000	7.2
0.616627	26.48917	2001	6.8
0.63636	27.33686	2002	6.4
0.656725	28.21167	2003	6
0.677741	29.11449	2004	5.6
0.699429	30.04619	2005	5.2
0.721812	31.00771	2006	4.8

Cossayuna Model B Cs-137

Model Activity	Scaled Activity	Model Year	depth (cm)
0.001927	7.401817	1954	25.6
0.006032	23.16539	1955	25.2
0.01277	49.03925	1956	24.8
0.021976	84.394	1957	24.4
0.034824	133.7345	1958	24
0.053127	204.0223	1959	23.6
0.07052	270.8182	1960	23.2
0.087876	337.4702	1961	22.8
0.114456	439.5445	1962	22.4
0.160834	617.65	1963	22
0.217605	835.6694	1964	21.6
0.273159	1049.015	1965	21.2
0.324289	1245.371	1966	20.8
0.370565	1423.082	1967	20.4
0.412107	1582.617	1968	20
0.449555	1726.429	1969	19.6
0.483425	1856.502	1970	19.2
0.514029	1974.029	1971	18.8
0.540772	2076.73	1972	18.4
0.563568	2164.273	1973	18
0.583659	2241.429	1974	17.6
0.600965	2307.888	1975	17.2
0.61504	2361.941	1976	16.8
0.627265	2408.89	1977	16.4
0.637987	2450.066	1978	16
0.64626	2481.837	1979	15.6
0.652046	2504.058	1980	15.2
0.656121	2519.704	1981	14.8
0.657954	2526.745	1982	14.4
0.657802	2526.163	1983	14
0.655914	2518.911	1984	13.6
0.65238	2505.339	1985	13.2
0.647434	2486.347	1986	12.8
0.641218	2462.472	1987	12.4
0.633912	2434.417	1988	12
0.625665	2402.744	1989	11.6
0.616607	2367.96	1990	11.2
0.606837	2330.44	1991	10.8
0.596463	2290.602	1992	10.4
0.585585	2248.826	1993	10
0.574291	2205.453	1994	9.6
0.56266	2160.787	1995	9.2
0.550765	2115.105	1996	8.8
0.538668	2068.652	1997	8.4
0.526429	2021.648	1998	8
0.514097	1974.29	1999	7.6
0.501719	1926.754	2000	7.2

0.489334	1879.193	2001	6.8
0.476979	1831.747	2002	6.4
0.464686	1784.536	2003	6
0.452482	1737.668	2004	5.6
0.440391	1691.237	2005	5.2
0.428436	1645.324	2006	4.8

Cossayuna Model C Pb-210

Model Activity	Scaled Activity	Model Year	depth (cm)
0.004905	0.186366	1900	56.5
0.009267	0.352072	1901	56
0.013168	0.500261	1902	55.5
0.016678	0.633632	1903	55
0.01986	0.754505	1904	54.5
0.022765	0.864875	1905	54
0.025439	0.966459	1906	53.5
0.02792	1.060736	1907	53
0.030243	1.148981	1908	52.5
0.032436	1.232292	1909	52
0.034524	1.31162	1910	51.5
0.036529	1.387788	1911	51
0.038469	1.461508	1912	50.5
0.040361	1.533401	1913	50
0.04222	1.604005	1914	49.5
0.044057	1.673792	1915	49
0.045883	1.743177	1916	48.5
0.047708	1.812521	1917	48
0.049541	1.882147	1918	47.5
0.051389	1.952341	1919	47
0.053258	2.023358	1920	46.5
0.055155	2.095428	1921	46
0.057085	2.168759	1922	45.5
0.059053	2.24354	1923	45
0.061064	2.319945	1924	44.5
0.063123	2.398138	1925	44
0.065232	2.478268	1926	43.5
0.067396	2.560479	1927	43
0.069618	2.644905	1928	42.5
0.071902	2.731679	1929	42
0.074251	2.820924	1930	41.5
0.076668	2.912764	1931	41
0.079157	3.00732	1932	40.5
0.081721	3.104709	1933	40
0.084362	3.205051	1934	39.5
0.087084	3.308463	1935	39
0.08989	3.415063	1936	38.5
0.092783	3.524971	1937	38
0.095766	3.638308	1938	37.5
0.098842	3.755195	1939	37
0.102016	3.875758	1940	36.5
0.105289	4.000123	1941	36
0.108666	4.128419	1942	35.5
0.11215	4.260781	1943	35
0.115745	4.397343	1944	34.5
0.119454	4.538245	1945	34

0.12328	4.68363	1946	33.5
0.127229	4.833646	1947	33
0.131303	4.988443	1948	32.5
0.135508	5.148178	1949	32
0.139847	5.313011	1950	31.5
0.144324	5.483106	1951	31
0.148944	5.658634	1952	30.5
0.153712	5.839771	1953	30
0.158632	6.026697	1954	29.5
0.163709	6.219599	1955	29
0.168949	6.418667	1956	28.5
0.174356	6.624102	1957	28
0.179937	6.836107	1958	27.5
0.185695	7.054893	1959	27
0.191638	7.280677	1960	26.5
0.197772	7.513684	1961	26
0.204101	7.754145	1962	25.5
0.210633	8.0023	1963	25
0.217373	8.258394	1964	24.5
0.22433	8.522682	1965	24
0.231509	8.795427	1966	23.5
0.238918	9.076899	1967	23
0.246564	9.367377	1968	22.5
0.254454	9.667151	1969	22
0.262597	9.976517	1970	21.5
0.271001	10.29578	1971	21
0.279673	10.62526	1972	20.5
0.288623	10.96529	1973	20
0.297859	11.3162	1974	19.5
0.307391	11.67833	1975	19
0.317228	12.05206	1976	18.5
0.32738	12.43774	1977	18
0.337857	12.83577	1978	17.5
0.348669	13.24653	1979	17
0.359827	13.67044	1980	16.5
0.371342	14.10791	1981	16
0.383225	14.55938	1982	15.5
0.395489	15.0253	1983	15
0.408145	15.50614	1984	14.5
0.421206	16.00235	1985	14
0.434685	16.51445	1986	13.5
0.448596	17.04294	1987	13
0.462952	17.58833	1988	12.5
0.477767	18.15119	1989	12
0.493056	18.73205	1990	11.5
0.508834	19.3315	1991	11
0.525118	19.95013	1992	10.5
0.541922	20.58857	1993	10
0.559265	21.24743	1994	9.5
0.577162	21.92738	1995	9

0.595632	22.62908	1996	8.5
0.614693	23.35324	1997	8
0.634364	24.10058	1998	7.5
0.654664	24.87183	1999	7
0.675615	25.66776	2000	6.5
0.697235	26.48917	2001	6
0.719548	27.33686	2002	5.5
0.742574	28.21168	2003	5
0.766338	29.11449	2004	4.5
0.790861	30.04619	2005	4
0.81617	31.00771	2006	3.5

Cossayuna Model C Cs-137

Model Activity	Scaled Activity	Model Year	depth (cm)
0.002844	10.98187	1954	29.5
0.008753	33.80406	1955	29
0.018258	70.50753	1956	28.5
0.030958	119.5561	1957	28
0.048467	187.1718	1958	27.5
0.073268	282.9496	1959	27
0.095674	369.4768	1960	26.5
0.117203	452.6151	1961	26
0.151649	585.6394	1962	25.5
0.214022	826.5145	1963	25
0.289142	1116.614	1964	24.5
0.359487	1388.275	1965	24
0.42088	1625.363	1966	23.5
0.473402	1828.191	1967	23
0.517875	1999.939	1968	22.5
0.55578	2146.321	1969	22
0.588288	2271.863	1970	21.5
0.616166	2379.52	1971	21
0.638774	2466.828	1972	20.5
0.65623	2534.24	1973	20
0.670582	2589.667	1974	19.5
0.681798	2632.979	1975	19
0.689298	2661.943	1976	18.5
0.695219	2684.808	1977	18
0.700049	2703.461	1978	17.5
0.702345	2712.329	1979	17
0.702084	2711.319	1980	16.5
0.700435	2704.951	1981	16
0.696581	2690.069	1982	15.5
0.690907	2668.157	1983	15
0.683765	2640.577	1984	14.5
0.675258	2607.723	1985	14
0.665694	2570.789	1986	13.5
0.655232	2530.386	1987	13
0.644087	2487.348	1988	12.5
0.632416	2442.276	1989	12
0.62035	2395.678	1990	11.5
0.607967	2347.859	1991	11
0.595367	2299.199	1992	10.5
0.582632	2250.018	1993	10
0.569831	2200.585	1994	9.5
0.557024	2151.125	1995	9
0.544259	2101.827	1996	8.5
0.531576	2052.849	1997	8
0.519009	2004.318	1998	7.5
0.506586	1956.343	1999	7
0.494329	1909.01	2000	6.5

0.482257	1862.389	2001	6
0.470384	1816.537	2002	5.5
0.458721	1771.496	2003	5
0.447277	1727.3	2004	4.5
0.436058	1683.975	2005	4
0.425069	1641.538	2006	3.5

Cossayuna Model D Cs-137

Model Activity	Scaled Activity	Model Year	depth (cm)
0.002844	10.98187	1954	29.5
0.008753	33.80406	1955	29
0.018258	70.50753	1956	28.5
0.030958	119.5561	1957	28
0.048467	187.1718	1958	27.5
0.073268	282.9496	1959	27
0.095674	369.4768	1960	26.5
0.117203	452.6151	1961	26
0.151649	585.6394	1962	25.5
0.214022	826.5145	1963	25
0.289142	1116.614	1964	24.5
0.359487	1388.275	1965	24
0.42088	1625.363	1966	23.5
0.473402	1828.191	1967	23
0.517875	1999.939	1968	22.5
0.55578	2146.321	1969	22
0.588288	2271.863	1970	21.5
0.616166	2379.52	1971	21
0.638774	2466.828	1972	20.5
0.65623	2534.24	1973	20
0.670582	2589.667	1974	19.5
0.681798	2632.979	1975	19
0.689298	2661.943	1976	18.5
0.695219	2684.808	1977	18
0.700049	2703.461	1978	17.5
0.702345	2712.329	1979	17
0.702084	2711.319	1980	16.5
0.700435	2704.951	1981	16
0.696581	2690.069	1982	15.5
0.690907	2668.157	1983	15
0.683765	2640.577	1984	14.5
0.675258	2607.723	1985	14
0.665694	2570.789	1986	13.5
0.655232	2530.386	1987	13
0.644087	2487.348	1988	12.5
0.632416	2442.276	1989	12
0.62035	2395.678	1990	11.5
0.607967	2347.859	1991	11
0.595367	2299.199	1992	10.5
0.582632	2250.018	1993	10
0.569831	2200.585	1994	9.5
0.557024	2151.125	1995	9
0.544259	2101.827	1996	8.5
0.531576	2052.849	1997	8
0.519009	2004.318	1998	7.5
0.506586	1956.343	1999	7

0.494329	1909.01	2000	6.5
0.482257	1862.389	2001	6
0.470384	1816.537	2002	5.5
0.458721	1771.496	2003	5
0.447277	1727.3	2004	4.5
0.436058	1683.975	2005	4
0.425069	1641.538	2006	3.5

Pb-210 dating

Greenwood Lake

Summary

1) For GWL C2, the "revised" % water data showed much less variability between 2 and 10 cm. Over this depth interval, however, water contents (65-70%) were significantly lower than in samples just above and below (ca. 80%)(??). Because of variations in water content, both length and mass-based accumulation were considered.
2) The Pb-210 and Cs-137 data are consistent with a surface mixed layer of up to 6.5 cm, but the Cs-137 data indicates that the maximum mixed layer depth is ca. 4 cm.
3) Using reasonable mixed layer depths, Pb-210 data gives a net accumulation rate of between ca. 0.2 and 0.6 cm/yr (see GWL PB plot). Data from the upper part of the core are consistent with the higher rate, while the lower rate is required to fit the data from the deeper sections. Cs-137 data (modeled including drainage basin holdup) indicates that the best choice of a single net accumulation rate is ca. 0.35 cm/yr (see GWL CS plot). A bit of Cs-137 diffusion, which could be added to the model, would improve the fit.
4) On a mass accumulation rate basis, Pb-210 data indicates between 0.06 and 0.135 g/cm2y, again with the higher rates in the upper part of the core (see Pb mass plot). The Cs-137 data is consistent with an intermediate rate (0.09 g/cm2y), with perhaps a bit of diffusion (see Cs mass plot).
5) The Pb-210 data are also presented on a semi-log plot (see ln xs Pb-210) with a "mixed layer and two sed rate" model. The upper section of the core (just below the mixed layer) gives a "best fit" rate of 0.72 cm/y, but the Cs-137 profile indicates that such a rate is much too high. A rate more consistent with the Cs-137 profile (0.4 cm/y) is shown to also provide a reasonable fit to the data. The bottom sections of the core give a much slower "best fit" rate (consistent with discussions above) of 0.15 cm/y.
6) I also ran a CRS model on the Pb-210 data (see CRS). The mixed layer "appears" as a very high near surface sedimentation rate. Similar to the Pb-210 models discussed above, the lowest accumulation rates are found in the deepest sections AND, for this core, the CRS model gives a reasonable date for peak Cs-137 activity.

Greenwood Lake Radionuclide Data

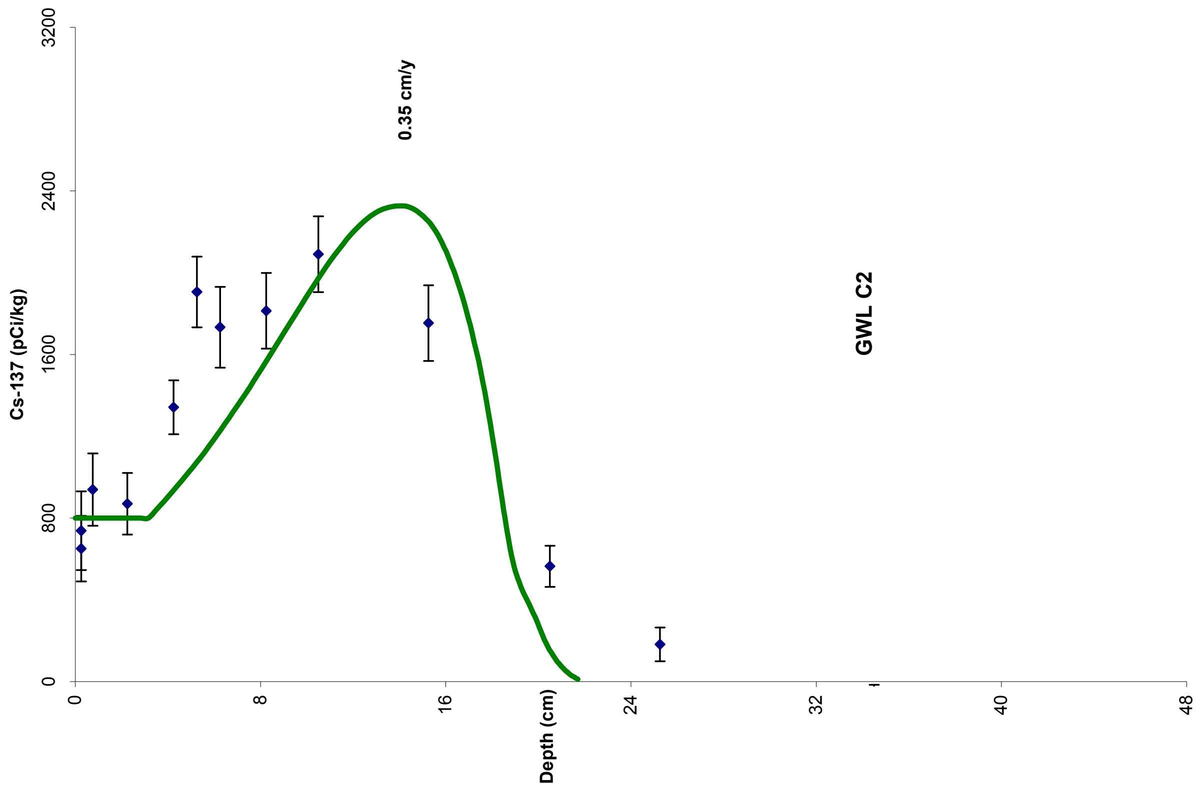
Be-7	1σ	Cs-137	1σ	$Pb\text{-}210_{supp}$	1σ	$Pb\text{-}210_{xs}$	1σ
(pCi/g)		(pCi/kg)		(dpm/g)*		(dpm/g)	
10.98	**1.75**	**650**	**160**	*3.90*	*0.69*	**40.55**	**3.34**
9.14	**3.14**	**738**	**192**	**3.90**	**0.69**	**50.17**	**4.07**
6.64	**1.88**	**939**	**177**	*3.90*	*0.69*	**50.58**	**4.07**
		870	**151**	**2.73**	**0.51**	**46.57**	**3.47**
		1342	**132**	**2.40**	**0.36**	**40.70**	**2.78**
		1906	**173**	**3.01**	**0.46**	**45.23**	**3.20**
		1733	**198**	**3.45**	**0.55**	**43.88**	**3.55**
		1813	**185**	**1.76**	**0.49**	**34.73**	**2.91**
		2091	**185**	**2.67**	**0.45**	**33.02**	**2.76**
		1753	**185**	**2.29**	**0.47**	**12.97**	**2.15**
		564	**101**	**2.81**	**0.34**	**3.15**	**1.33**
		182	**82**	**1.77**	**0.31**	**2.38**	**1.17**
		-87	**71**	**1.90**	**0.28**	**0.20**	**1.05**

Greenwood Lake - % water

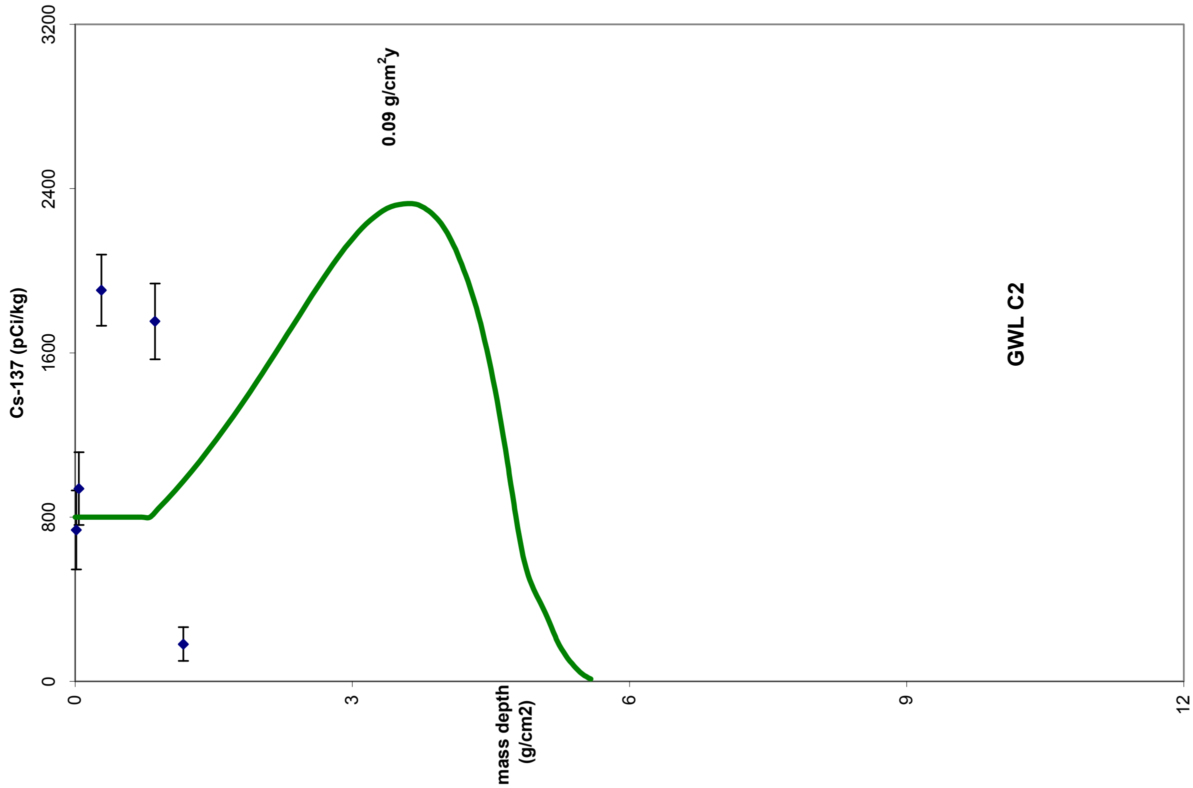
Core C2	Top	Bottom	Dry Mass	∑Mass	wt % H_2O
1	0	0.5	0.77215	0.77215	93.39%
2	0.5	1	0.89152	1.66367	92.43%
3	1	1.5	2.31549	3.97916	81.89%
4	1.5	2	2.64498	6.62414	79.69%
5	2	2.5	4.4036	11.0277	69.16%
6	2.5	3	4.428	15.4557	69.03%
7	3	3.5	4.38	19.8357	69.29%
8	3.5	4	4.703	24.5387	67.55%
9	4	4.5	4.7323	29.271	67.39%
10	4.5	5	4.866	34.137	66.69%
11	5	5.5	4.754	38.891	67.28%
12	5.5	6	4.353	43.244	69.44%
13	6	6.5	5.03983	48.2839	65.79%
14	6.5	7	4.395	52.6789	69.21%
15	7	7.5	4.879	57.5579	66.62%
16	7.5	8	4.853	62.4109	66.76%
17	8	8.5	4.97715	67.388	66.11%
18	8.5	9	4.921	72.309	66.41%
19	9	9.5	5.156	77.465	65.20%
20	9.5	10	4.762	82.227	67.24%
21	10	11	5.939	88.166	77.60%
22	11	12	6.037	94.203	77.29%
23	12	13	6.0093	100.212	77.37%
24	13	14	6.514	106.726	75.80%
25	14	15	6.5676	113.294	75.64%
26	15	16	5.815	119.109	77.99%
27	16	17	6.8313	125.94	74.83%
28	17	18	7.197	133.137	73.74%
29	18	19	7.3488	140.486	73.29%
30	19	20	7.379	147.865	73.20%
31	20	21	7.46055	155.326	72.96%
32	21	22	7.659	162.985	72.39%
33	22	23	7.712	170.697	72.23%
34	23	24	7.546	178.243	72.71%
35	24	25	7.662	185.905	72.38%
36	25	26	6.605	192.51	75.52%
37	26	27	7.853	200.363	71.83%
38	27	28	7.778	208.141	72.04%

39	28	29	7.861	216.002	71.81%
40	29	30	7.638	223.64	72.45%
41	30	31	8.261	231.901	70.67%
42	31	32	8.131	240.032	71.04%
43	32	33	8.558	248.59	69.84%
44	33	34	8.54	257.13	69.89%
45	34	35	9.04704	266.177	68.51%

Greenwood Lake Cs -137 Length Plot



Greenwood Lake Cs-137 Mass Plot



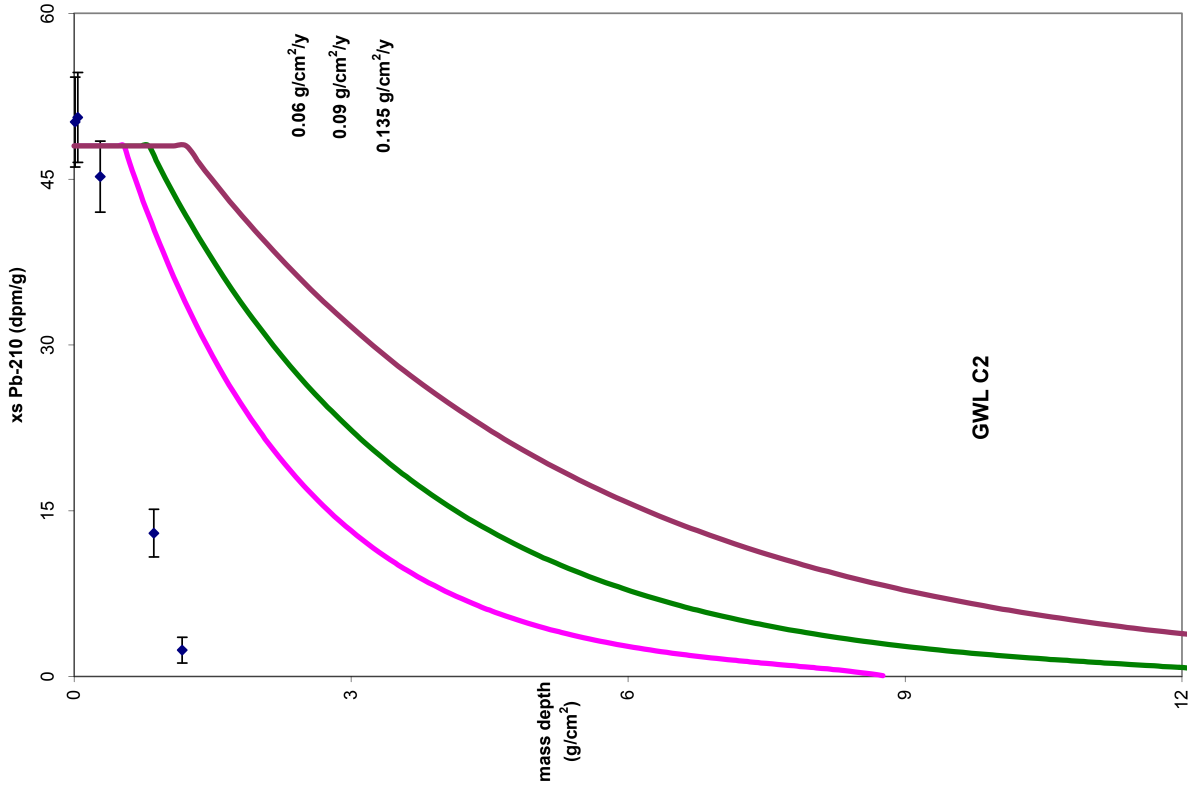
Greenwood Lake Model A Pb-210

Model Activity	Scaled Activity	Model Year	depth (cm)		
0.001335	0.082024	1870	51.1	34.06667	76.65
0.002579	0.158471	1871	50.75	33.83333	76.125
0.003742	0.229982	1872	50.4	33.6	75.6
0.004835	0.297137	1873	50.05	33.36667	75.075
0.005865	0.360462	1874	49.7	33.13333	74.55
0.006841	0.420431	1875	49.35	32.9	74.025
0.007769	0.477477	1876	49	32.66667	73.5
0.008656	0.531989	1877	48.65	32.43333	72.975
0.009508	0.584322	1878	48.3	32.2	72.45
0.010329	0.634798	1879	47.95	31.96667	71.925
0.011125	0.683713	1880	47.6	31.73333	71.4
0.0119	0.731333	1881	47.25	31.5	70.875
0.012658	0.777902	1882	46.9	31.26667	70.35
0.013402	0.823646	1883	46.55	31.03333	69.825
0.014136	0.868768	1884	46.2	30.8	69.3
0.014863	0.913458	1885	45.85	30.56667	68.775
0.015586	0.957889	1886	45.5	30.33333	68.25
0.016308	1.002222	1887	45.15	30.1	67.725
0.01703	1.046606	1888	44.8	29.86667	67.2
0.017755	1.091179	1889	44.45	29.63333	66.675
0.018486	1.136071	1890	44.1	29.4	66.15
0.019223	1.181401	1891	43.75	29.16667	65.625
0.01997	1.227285	1892	43.4	28.93333	65.1
0.020727	1.27383	1893	43.05	28.7	64.575
0.021497	1.321137	1894	42.7	28.46667	64.05
0.022281	1.369304	1895	42.35	28.23333	63.525
0.02308	1.418423	1896	42	28	63
0.023896	1.468584	1897	41.65	27.76667	62.475
0.024731	1.519873	1898	41.3	27.53333	61.95
0.025585	1.572375	1899	40.95	27.3	61.425
0.02646	1.62617	1900	40.6	27.06667	60.9
0.027358	1.681339	1901	40.25	26.83333	60.375
0.028279	1.737961	1902	39.9	26.6	59.85
0.029225	1.796113	1903	39.55	26.36667	59.325
0.030198	1.855872	1904	39.2	26.13333	58.8
0.031197	1.917316	1905	38.85	25.9	58.275
0.032226	1.980521	1906	38.5	25.66667	57.75
0.033284	2.045563	1907	38.15	25.43333	57.225
0.034374	2.112521	1908	37.8	25.2	56.7
0.035496	2.181471	1909	37.45	24.96667	56.175
0.036651	2.252494	1910	37.1	24.73333	55.65
0.037842	2.325668	1911	36.75	24.5	55.125
0.039069	2.401074	1912	36.4	24.26667	54.6
0.040334	2.478796	1913	36.05	24.03333	54.075
0.041637	2.558916	1914	35.7	23.8	53.55
0.042981	2.641521	1915	35.35	23.56667	53.025
0.044367	2.726698	1916	35	23.33333	52.5

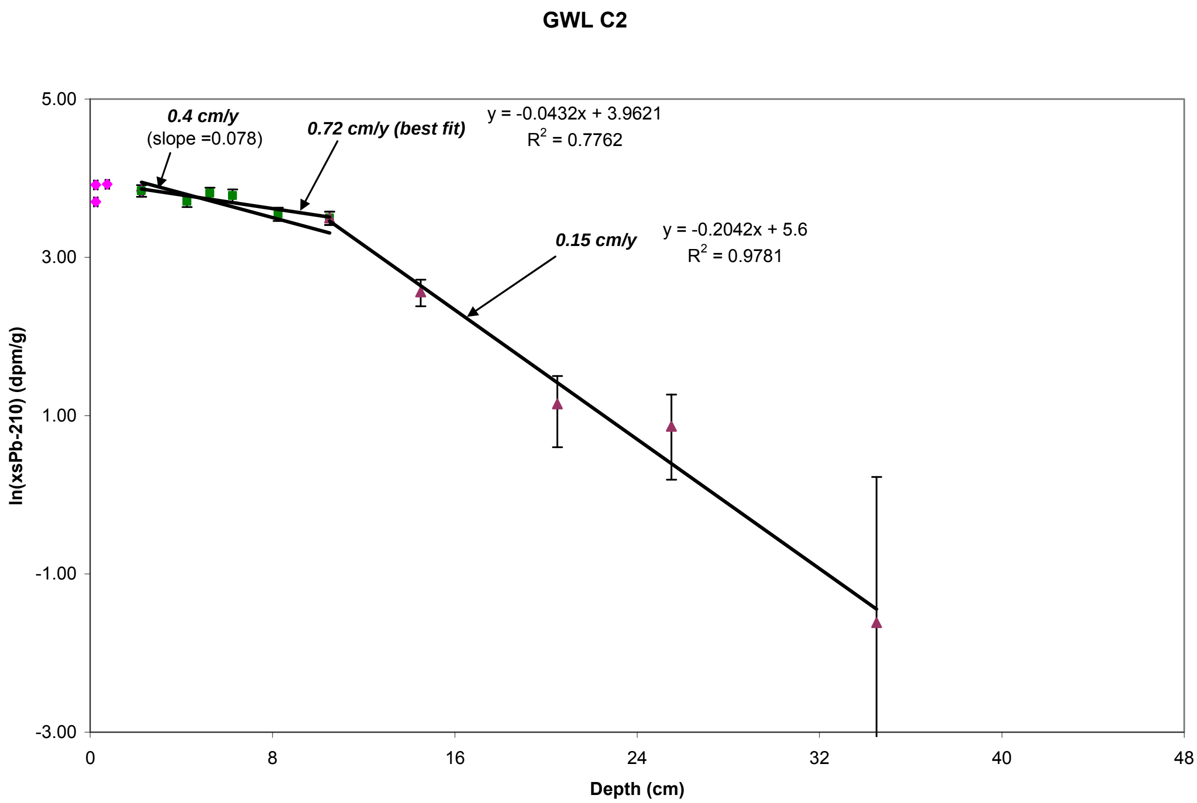
0.045797	2.814536	1917	34.65	23.1	51.975
0.047271	2.905126	1918	34.3	22.86667	51.45
0.048791	2.998564	1919	33.95	22.63333	50.925
0.050359	3.094945	1920	33.6	22.4	50.4
0.051977	3.194368	1921	33.25	22.16667	49.875
0.053646	3.296935	1922	32.9	21.93333	49.35
0.055368	3.402749	1923	32.55	21.7	48.825
0.057144	3.511919	1924	32.2	21.46667	48.3
0.058977	3.624555	1925	31.85	21.23333	47.775
0.060868	3.740771	1926	31.5	21	47.25
0.062819	3.860683	1927	31.15	20.76667	46.725
0.064832	3.984412	1928	30.8	20.53333	46.2
0.06691	4.112082	1929	30.45	20.3	45.675
0.069053	4.243822	1930	30.1	20.06667	45.15
0.071265	4.379763	1931	29.75	19.83333	44.625
0.073548	4.52004	1932	29.4	19.6	44.1
0.075903	4.664795	1933	29.05	19.36667	43.575
0.078334	4.814172	1934	28.7	19.13333	43.05
0.080842	4.968319	1935	28.35	18.9	42.525
0.08343	5.127391	1936	28	18.66667	42
0.086101	5.291545	1937	27.65	18.43333	41.475
0.088857	5.460945	1938	27.3	18.2	40.95
0.091702	5.63576	1939	26.95	17.96667	40.425
0.094637	5.816163	1940	26.6	17.73333	39.9
0.097667	6.002335	1941	26.25	17.5	39.375
0.100793	6.194459	1942	25.9	17.26667	38.85
0.104019	6.392728	1943	25.55	17.03333	38.325
0.107348	6.597338	1944	25.2	16.8	37.8
0.110784	6.808492	1945	24.85	16.56667	37.275
0.11433	7.0264	1946	24.5	16.33333	36.75
0.117989	7.251279	1947	24.15	16.1	36.225
0.121765	7.483352	1948	23.8	15.86667	35.7
0.125662	7.72285	1949	23.45	15.63333	35.175
0.129684	7.97001	1950	23.1	15.4	34.65
0.133834	8.225077	1951	22.75	15.16667	34.125
0.138117	8.488305	1952	22.4	14.93333	33.6
0.142537	8.759956	1953	22.05	14.7	33.075
0.147099	9.040298	1954	21.7	14.46667	32.55
0.151806	9.329611	1955	21.35	14.23333	32.025
0.156664	9.628181	1956	21	14	31.5
0.161678	9.936304	1957	20.65	13.76667	30.975
0.166852	10.25429	1958	20.3	13.53333	30.45
0.172192	10.58245	1959	19.95	13.3	29.925
0.177702	10.9211	1960	19.6	13.06667	29.4
0.183389	11.2706	1961	19.25	12.83333	28.875
0.189258	11.63128	1962	18.9	12.6	28.35
0.195314	12.0035	1963	18.55	12.36667	27.825
0.201565	12.38763	1964	18.2	12.13333	27.3
0.208015	12.78406	1965	17.85	11.9	26.775
0.214672	13.19317	1966	17.5	11.66667	26.25

0.221542	13.61537	1967	17.15	11.43333	25.725
0.228631	14.05109	1968	16.8	11.2	25.2
0.235948	14.50074	1969	16.45	10.96667	24.675
0.243499	14.96479	1970	16.1	10.73333	24.15
0.251291	15.44368	1971	15.75	10.5	23.625
0.259333	15.93791	1972	15.4	10.26667	23.1
0.267632	16.44794	1973	15.05	10.03333	22.575
0.276196	16.9743	1974	14.7	9.8	22.05
0.285035	17.5175	1975	14.35	9.566667	21.525
0.294157	18.07809	1976	14	9.333333	21
0.30357	18.65661	1977	13.65	9.1	20.475
0.313285	19.25365	1978	13.3	8.866667	19.95
0.32331	19.86979	1979	12.95	8.633333	19.425
0.333657	20.50566	1980	12.6	8.4	18.9
0.344334	21.16187	1981	12.25	8.166667	18.375
0.355353	21.83908	1982	11.9	7.933333	17.85
0.366725	22.53796	1983	11.55	7.7	17.325
0.378461	23.2592	1984	11.2	7.466667	16.8
0.390572	24.00353	1985	10.85	7.233333	16.275
0.403071	24.77168	1986	10.5	7	15.75
0.41597	25.5644	1987	10.15	6.766667	15.225
0.429281	26.3825	1988	9.8	6.533333	14.7
0.443019	27.22678	1989	9.45	6.3	14.175
0.457196	28.09807	1990	9.1	6.066667	13.65
0.471827	28.99725	1991	8.75	5.833333	13.125
0.486926	29.9252	1992	8.4	5.6	12.6
0.502509	30.88285	1993	8.05	5.366667	12.075
0.518589	31.87114	1994	7.7	5.133333	11.55
0.535185	32.89106	1995	7.35	4.9	11.025
0.552312	33.94362	1996	7	4.666667	10.5
0.569986	35.02987	1997	6.65	4.433333	9.975
0.588227	36.15087	1998	6.3	4.2	9.45
0.607051	37.30775	1999	5.95	3.966667	8.925
0.626477	38.50165	2000	5.6	3.733333	8.4
0.646525	39.73375	2001	5.25	3.5	7.875
0.667215	41.00529	2002	4.9	3.266667	7.35
0.688567	42.31751	2003	4.55	3.033333	6.825
0.710602	43.67173	2004	4.2	2.8	6.3
0.733342	45.06929	2005	3.85	2.566667	5.775
0.75681	46.51157	2006	3.5	2.333333	5.25

Greenwood Lake Pb-210 Mass Plot



Greenwood Lake – ln xs Pb-210 Plot



Greenwood Lake Pb-210 CRS model

CRS ΔT (years)	1σ pos	1σ neg	mean yrs/section	CRS Date (at bottom)	1σ pos	1σ neg	CRS ave date	1σ pos	1σ neg	Ave depth (cm)	Ave rate (cm/y)
0.27	0.02	0.02	0.27	2006.7	2006.7	2006.8	2006.9	2006.9	2006.9	0.25	1.82
1.45	0.11	0.11	1.17	2005.6	2005.4	2005.7	2006.1	2006.1	2006.2	1	0.85
6.52	0.51	0.50	5.07	2000.5	2000.0	2001.0	2003.0	2002.7	2003.3	2.375	0.34
11.89	0.84	0.82	5.36	1995.1	1994.3	1995.9	1997.8	1997.1	1998.5	4	0.28
16.53	1.16	1.12	4.64	1990.5	1989.3	1991.6	1992.8	1991.8	1993.8	5.25	0.22
24.77	1.95	1.84	8.24	1982.2	1980.3	1984.1	1986.4	1984.8	1987.8	6.75	0.24
37.43	3.70	3.32	12.66	1969.6	1965.9	1972.9	1975.9	1973.1	1978.5	8.5	0.12
60.93	10.23	7.75	23.50	1946.1	1935.8	1953.8	1957.8	1950.9	1963.4	10.875	0.14
91.45	51.06	18.81	30.53	1915.5	1864.5	1934.4	1930.8	1900.2	1944.1	15	0.16
113.17	#NUM!	31.22	21.71	1893.8	#NUM!	1925.1	1904.7	#NUM!	1929.7	20.25	0.25
202.03	#NUM!	107.64	88.87	1805.0	#NUM!	1912.6	1849.4	#NUM!	1918.8	26.5	0.08

Union Lake Pb-210 Dating

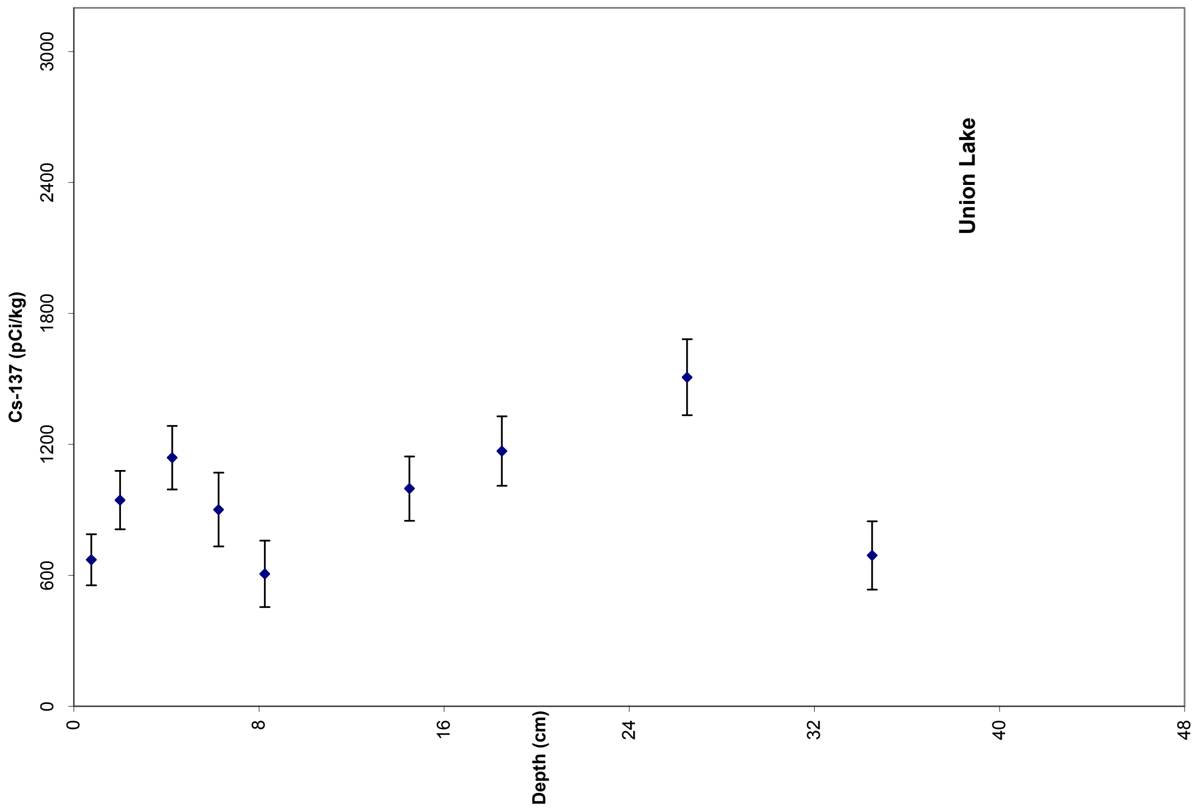
Summary

1) The supported Pb-210 activities are very high - a few tens of dpm/g compared to the more typical 1-4 dpm/g in the GWL and Coss cores. This reflects the high natural radioactivity associated with the local geology. Southern NJ is well-known for this, at least to me, as I have similar values of supported Pb-210 in several lakes from this general area. This results in higher absolute errors in the calculated xs-Pb-210 activities.
2) Excess Pb-210 values are not particularly high - a maximum of ca. 14 dpm/g compared to ~ 50 in GWL C2 ans 30 in Cossayuna. This is likely related to a higher particle flux in Union relative to the other two lakes that "dilutes" the xsPb-210 signal. The detection of significant Cs-137 activity in the deepest section, the strong Be-7 signal in the upper 1.5 cm, and the relatively low weight % water values are all consistent with a higher particle flux in the Union L core compared to GWL C2 or Cossayuna.
3) For some lakes in southern NJ with high supported Pb-210, I have been able to provide fairly detailed dating interpretations based on "near ideal" xsPb-210 and Cs-137 profiles. In the case of this core, both profiles defy any simple interpretation suggesting a complex sedimentation/ mixing history at the site (see Cs and Pb plots).
4) The most I'd be willing to say about the Union Lake core is that the top section represents very recent accumulation - likely within a year prior to coring (based on Be-7); and that the deepest section contains particles that accumulated some time after the early 1950s (based on Cs-137).

Union Lake Radionuclide Data

	Upper (cm)	Lower (cm)	Be-7 (pCi/g)	1σ	Cs-137 (pCi/kg)	1σ	Pb-210$_{supp}$ (dpm/g)	1σ	Pb-210$_{xs}$ (dpm/g)	1σ
R1607ABC*	0	1.5	3.79	1.34	671	117	***35.52***	***1.20***	6.26	3.04
R1607DE*	1.5	2.5	2.02	1.46	945	133	***35.52***	***1.20***	9.71	3.27
R1607I	4	4.5			1139	145	35.52	1.20	14.45	3.51
R1607M	6	6.5			901	169	31.75	1.20	6.93	3.41
R1607Q	8	8.5			607	152	27.08	1.05	3.67	2.99
R1607Y	14	15			997	147	25.92	0.97	5.86	2.84
R1607AC	18	19			1169	159	24.64	0.97	2.63	2.72
R1607AK	26	27			1508	174	19.34	0.84	5.97	2.62
R1607AS	34	35			691	157	14.47	0.74	-4.38	2.28

Union Lake Cs-137 Plot



Union Lake Pb-210 Plot