Paleolimnological analysis of Bednesti Lake, B.C -- Final Report
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Fig. 2 Stratigraphic distribution of diatom taxa in the core from
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Appendix A: Summary of $^{210}$Pb and LOI data, and diatom analyses.
Appendix B: Summary of data used in calculating $^{210}$Pb dates and
$^{210}$Pb output.
Appendix C: Summary of relative abundances of diatom taxa in
Bednesti Lake.

BACKGROUND

Bednesti Lake was cored on October 5, 1999 by Rick Nordin
and Bruce Carmichael. The core was retrieved using a modified K-
B corer (internal diameter ~ 6.35 cm) from the deep basin. On
shore the core was sectioned into 0.5-cm intervals into 120-ml
plastic containers. Every other sample was shipped on ice to
Queen's University where they were stored in our coldroom at 4°C.
The containers were weighed to determine the total wet weight of
sediment prior to subsampling for $^{210}$Pb analyses. Twenty
intervals (every 2 cm) were subsampled for diatom and sixteen
intervals for $^{210}$Pb analysis. Prepared samples for $^{210}$Pb analysis
(see below) were sent to MYCORE Ltd.

METHODS

$^{210}$Pb Dating and Percent Organic Matter

The wet weight of the sediment was determined for all the
subsections of the core that were shipped to Queen’s. Sixteen
subsamples of wet sediment from each core were weighed and oven-
dried (24 hr at 105°C) and reweighed to determine percent water
and dry weight of the sediment. Samples that were submitted for
$^{210}$Pb analysis were ground to a fine dust by use of a pestle and
redried overnight at 105°C. The weight of this dried sediment
was recorded to four decimal places after it was put in a tared plastic digestion tube for determination of $^{210}\text{Pb}$ activity that was shipped to MYCORE Ltd.

Percent organic matter for each of the 16 $^{210}\text{Pb}$ samples was determined using standard loss-on-ignition methods (Dean, 1974). A known quantity of dried sediment (recorded to four decimal places) was heated to 550°C for 2 hours. The difference between the dry weight of the sediment and the weight of sediment remaining after ignition was used to estimate the percent of organic matter in each sediment sample.

$^{210}\text{Pb}$ activities were estimated from determination of 209-Po and a tracer of known activity by alpha spectroscopy. Unsupported $^{210}\text{Pb}$ is calculated by subtracting supported $^{210}\text{Pb}$ (the baseline activity determined from bottom samples of the core) from the total activity at each level. The sediment chronology and sedimentation rates were calculated using the constant rate of supply (CRS) model (Appleby and Oldfield, 1978) from the estimates of $^{210}\text{Pb}$ activities and estimates of cumulative dry mass (Binford, 1990). See Appendix B for summaries of $^{210}\text{Pb}$ analyses by MYCORE (B-1), summary of $^{210}\text{Pb}$ calculations (B-1,2), and output from the CRS model (B-3).

Diatom Preparation and Enumeration

Slides for diatom analysis were prepared using standard techniques (Cumming, Wilson, Smol and Hall, 1995). Briefly, a small amount of wet sediment was suspended in a 50:50 (molar) mixture of sulfuric and nitric acid in a 20-ml glass vial for 24 hr. prior to being submersed at 70°C in a hot water bath for 5 hr. The remaining sediment material was settled for a period of 24 hr, at which time the acid above the sample was removed. The sample was rinsed with distilled water and allowed to settle once again for 24 hrs. The procedure was repeated approx. 10 times until the sample was acid free (litmus test). The samples were settled onto coverslips in a series of four 100% dilutions, which when dry, were mounted onto glass slides using a high-resolution mounting media called Naphrax*. For each sample, at least 400 diatom taxa were enumerated with a Leica DMRB microscope equipped with DIC optics at 1000X magnification (Numerical Aperature of objective = 1.3). These analyses were based on the references of Krammer and Lange-Bertalot (1986, 1988, 1991a,b), Patrick and Reimer (1966, 1975) and Cumming et al. (1995).

Cluster Analysis

A depth-constrained cluster analysis was run on the diatom assemblages in the core to provide an unbiased assessment of changes in diatom assemblages through time. A squared chord distance as the similarity measure between samples in the cluster analysis. Zones based on this clustering algorithm were placed
on the diatom stratigraphy to represent zones of similar diatom assemblages (dashed lines on Fig. 2).

Diatom-based Reconstructions of Total Phosphorus

Inferences of total phosphorus from the diatom assemblages in the core are based on a phosphorus model developed from 111 freshwater lakes from the 219 lakes sampled by Wilson, Cumming & Smol (1996). This model is based on estimates of the optima of taxa from weighted-averaging regression on non-transformed relative percentage data. The coefficient of determination ($r^2$) of this model is 0.66, and the jackknifed $r^2$ is 0.47. This model is superior to the earlier models developed by Reavie, Hall & Smol (1995) for several reasons including its better predictive ability and the larger number of samples which provide more analogs for downcore reconstructions.

The total phosphorus inferences (Fig. 1E) were critically assessed to determine: 1) if they tracked the main direction of variation in the diatom species assemblages (Fig. 1D); and 2) to assess if the assemblages encountered in the core are well represented in the modern-day samples (Fig. 1F). If the diatom-based phosphorus reconstruction matches the main direction of variation in the diatom assemblages downcore, then we can be fairly confident that the diatoms are tracking changes that are mainly related to phosphorus. If the correlation between the main direction of variation and the diatom-inferred phosphorus values is weak or nonexistent, then other environmental variables (e.g. pH, conductivity, turbulence, etc), or interactions between environmental variables, are likely responsible for the observed changes in diatom assemblages.

Determination of the Main Direction of Variation

The main direction of variation in the diatom assemblages downcore was determined from the first axis scores from a principal components analysis (PCA) ordination using non-transformed species abundance data. A PCA was chosen to represent the main direction of variation of the diatom assemblages in this core based on the small gradient length (< 1.5 sd units) obtained in an initial detrended correspondence analysis (DCA) ordination.

Analog Analysis of Diatom Assemblages

The reliability of the downcore total phosphorus inferences assumes that the diatom assemblages encountered downcore are well represented in our modern diatom assemblages. To determine if appropriate analogs existed for the core samples, we determined which samples in our present-day dataset of 111 lakes most resembled each of the downcore samples. This determination was based on a squared chord dissimilarity coefficient between all species found in each of the core samples. The best match
between downcore and modern samples was compared with the
distribution of best match between modern samples. Any downcore
sample that was more dissimilar than 80% of the modern
distribution were deemed to be a 'poor analog'. Similarly, any
downcore sample that was more dissimilar than 95% of the modern
distribution were deemed to have 'no analog' in our present-day
dataset. If the downcore assemblages have good representation in
modern samples, more confidence can be placed in the
reconstruction. If modern analogs do not exist or are poor, then
cautions must be placed in reconstructions from these downcore
samples.

RESULTS AND DISCUSSION

$^{210}$Pb Profile, Sedimentation Rates and Organic Matter

The $^{210}$Pb profile from Bednesti Lake shows an exponential
decay with core depth, with the exception of the uppermost sample
(Fig. 1A). The impact of this anomalous top sample results in a
high inferred sedimentation rate in the uppermost interval. The
low activity of this top sample may be the result of increased
sedimentation rates or some disturbance in the uppermost
sediments. Given that there are marked changes in the diatom
stratigraphy in the uppermost two samples (e.g. 10 to 0% Aulacoseira ambiguа, 10% increase in Fragilaria crotonensis, Fig.
2) if any mixing occurred it was not sufficiently deep to affect
the sample at 2 cm depth. The time/depth chronology of this core
can be found in Appendix B-3. Interestingly, there is a
consistent increase from ~16% organic matter c. 1915 to ~19% c.
1950, at which time the % organic matter remains relatively
constant. This subtle increase in organic matter a unique change
when viewed in the context of the last ~200 years of sediment
accumulation in this lake (Fig. 1C). Increases in organic matter
can be attributed to several factors including increased in-lake
production of organic matter, increased inwash of organic matter,
or decreases in the load of inorganic matter of the lake.

Diatom Assemblage Changes and Analyses

Approximately ~150 diatom taxa were encountered in the
sediment core from Bednesti Lake (Appendix C-1). Cluster
analysis suggests the changes in diatom assemblages through time
can be divided into three primary zones (Fig. 2).

Prior to c. 1915 (Fig. 2, Zone C), the diatom assemblage is
dominated by taxa with TP optima in the range of 10-17 μg/L.
Circa 1915, there is an slight increase in the mean abundance of
the mesoeutrophic Aulacoseira ambiguа (Fig. 2, Zone B), as well
as small increases in Fragilaria brevistriata, and the planktonic
taxon Cyclotella kuetzingiana. At ~13 cm, Tabellaria flocculosa
str IIIP begins to increase. In the uppermost portion of the
core (Zone A, Fig. 2), F. crotonensis increases in relative abundance and A. ambiguus declines (Fig. 2). Changes in TP suggest that prior to c. 1915, TP concentrations exhibited low variance with a mean around 11 μg/L. However, after c. 1915, inferred TP increased slightly and became more variable (Fig. 1E).

PCA axis 1 scores (Fig. 1D) accounts for ~56% of the variation in diatom taxa in this core. The coefficient of determination between the PCA axis 1 scores (Fig. 1D) and the log TP inferences (Fig. 1E) is relatively weak but significant (r² = 0.37). Thus, the inferred changes in TP are only partially related to the main direction of variation in the diatom assemblages. The core diatom assemblages also appear to be adequately represented in the modern samples (Fig. 1F). The variation in the diatom assemblages that is not adequately explained by the TP inferences is the increase in Tabellaria in the uppermost portion of the core.

In summary, the changes in diatom assemblages in conjunction with the small increase in organic matter, suggest that this lake had pre-settlement TP values ~ 11 μg/L and it potentially became slightly more nutrient rich c. 1915.

REFERENCES


Fischer Verlag, Stuttgart/New York, 596 pp.


Figure Captions

Figure 1. Summary diagram for the sediment core from Bednesti Lake showing: A) total $^{210}$Pb activity from which the chronology of the core is based; B) the sediment accumulation rate; C) the change in the percent of organic matter in the core; D) the main direction of variation in the diatom assemblage data; E) diatom-based estimated late-summer total phosphorus; and F) analog analysis showing the dissimilarity between present-day and downcore samples (any sample that has a squared chord distance > 0.8 was determined to be a poor analog, whereas any sample with a squared chord distance greater than 1.1 was determined to have no analog in the modern dataset).

Figure 2. Stratigraphy of the most abundant diatom taxa found in the sediment core from Bednesti Lake, B.C. (see Appendix C for a complete list of taxa and the relative percentage data). The diatom taxa are arranged in order of increasing late-summer total phosphorus (TP) optima which is indicated in parentheses for those taxa with known optima. The dotted lines separate the stratigraphy into the zones that were identified by a cluster analysis on the diatom assemblage composition that was constrained to the depth of the core samples (see text for details).
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