ASSESSMENT OF CHANGES IN TOTAL PHOSPHORUS IN EAGLET LAKE, B.C. : A PALEOLIMNOLOGICAL ASSESSMENT (March 2006)

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BACKGROUND

A 35-cm sediment core was retrieved from Eaglet Lake by James Jacklin and Greg Warren using a modified K-B corer (internal diameter 5.08 cm) on September 14, 2005 (54˚ 05' 39.3"N; 122˚ 19' 36.2" W). The core was sectioned into 0.5-cm intervals and all samples were sent to PEARL at Queen's University on September 15, 2005, where they were stored in our coldroom at 4 ºC. All the samples were weighed to determine the total wet weight of sediment prior to subsampling for ^{210}Pb, loss-on-ignition and diatom analyses. Twenty intervals were subsampled for diatoms and at least sixteen intervals were analyzed for ^{210}Pb analysis using gamma spectroscopy at PEARL, Queen's University.

METHODS

<u>^{210}Pb Dating and Percent Organic Matter</u>

Twenty samples for Eaglet Lake were dried in the freeze drier at PEARL (24 hr. cycle). Dry weight of the sediment and percent water was determined. Dry sediment was then precisely weighed into a plastic tube for gamma spectroscopy. The samples were then sealed with epoxy and allowed to sit for two weeks in order for ^{214}Bi to equalize for determination of supported ^{210}Pb used in estimating core chronology. Activities of ^{210}Pb, ^{137}Cs and supported ^{210}Pb (via ^{214}Bi) were determined for each sample. These activities were then used to estimate the chronology of the core.

The activities (in disintegrations per minute/gram) of ^{210}Pb, ^{137}Cs and ^{214}Bi were determined using the procedures outlined in Schelske et al. (1994). Unsupported ^{210}Pb was calculated by subtracting supported ^{210}Pb (average of all ^{214}Bi counts from all samples within each of the cores) from the total ^{210}Pb activity at each level.

Percent organic matter was determined for twenty samples, including the samples that were analysed for ^{210}Pb using standard loss-on-ignition (LOI) methods (Dean, 1974). Briefly, 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.

<u>Diatom Preparation and Enumeration</u>

Slides for diatom analysis were prepared using standard techniques (Cumming et al. 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 water bath for approximately 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 approximately 8 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 valves 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).

Absolute abundance of diatoms was determined for all samples analyzed for diatoms using methods outlined in Battarbee & Kneen (1982). Absolute abundances were determined by spiking each of the diatom samples, prior to settling on coverslips, with a known concentration of microspheres. The microspheres were enumerated along with the diatoms and used to calculate estimates of # diatoms per gram dry weight. Total diatom concentration (#/g dry weight x 10^7) provides a means of assessing whether there were any changes in diatom production during the time period analyzed.

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 268 freshwater lakes from across British Columbia. This dataset includes lakes from several regions within British Columbia. 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 0.62, and the bootstrapped r^2 is 0.51. This model is superior to the earlier models developed by Reavie et al. (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 (Figs. 1E) were critically assessed to determine if they tracked the main direction of variation in the diatom species assemblages (Figs. 1D). If the diatom-based phosphorus reconstructions match the main direction of variation in the diatom assemblages in the core, then we can be fairly confident that the diatoms are tracking changes that are related to phosphorus, or correlated variables. 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., water depth, 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 in the Eaglet Lake core was determined from the axis-1 scores from a principal components analysis (PCA) ordination using non-transformed species abundance data (Figs. 1D). A PCA was chosen to represent the main direction of variation of the diatom assemblages in these cores based on the small gradient length (< 1.5 standard deviation units) obtained in an initial detrended correspondence analysis (DCA) ordination.

Cluster Analysis

Cluster analysis provides a means of grouping those samples that are most similar to each other. The programs, TILIA and TGVIEW 2.02 (Grimm, unpublished), were used to provide a stratigraphic sequence (downcore) of the diatom assemblages and the cluster analyses (Fig. 2.). The cluster analyses were stratigraphical constrained in order to group the assemblages according to core depth (or core age) using square-rooted species data.

RESULTS AND DISCUSSION

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

The total ^{210}Pb activity of the Eaglet Lake core was low (Fig. 1A), and the background (supported ^{210}Pb was relatively high, average 3.6 ± 0.8 dpm/g; typically in the range of 0.5 to 1.5 dpm/g). As a consequence unsupported ^{210}Pb (total ^{210}Pb – supported ^{210}Pb) was extremely low and present only in the uppermost 11 cm. It is the decay of the unsupported ^{210}Pb that is used to estimate the core chronology. As expected, the log of the unsupported activity decreases linearly with the cumulative dry mass of sediment in the core ($r^2 = 0.76$, n = 8). Based on the limited number of samples with high amounts of unsupported ^{210}Pb, and the high background supported ^{210}Pb activity, we estimate the dates based on the half-life of ^{210}Pb (~22 years) and activities of ^{137}Cs. Peak concentrations of ^{137}Cs are expected in the intervals around 1963 (Fig. 1B), the peak of atmospheric testing of nuclear weapons. Based on the ^{210}Pb and ^{137}Cs activities, the year 1960 would likely fall between 5 and 7 cm in the core, likely closer to the 5-cm interval if we assume the ^{137}Cs peak hasn't undergone a significant migration in the core. This latter assumption is likely true given the relatively inorganic nature of this core. Based on estimates of accumulation of dry mass over the past 40 years, the c. 1900 AD sediment horizon would be around 10-11 cm in depth. Based on similar extrapolations of dry mass accumulation, the entire core likely represents 350 to 400 years of sediment accumulation.

The percent organic matter is relatively inorganic in nature and is generally less than 25% organic matter throughout the core (Fig. 1C). Prior to c. 1900, the percent organic matter was less than 15% with little variance. At c. 1900, percent organic matter increases to the highest values in the core, but is extremely variable. After 1960, the percent organic matter is lower, but not as low as the pre-1900 values.

Diatom Assemblage Changes and Analyses

Approximately 100 taxa were encountered in the core from Eaglet Lake. However, most of these taxa were rare. Throughout the recent history of the lake it has been dominated by mesotrophic to eutrophic planktonic taxa, such as *Tabellaria flocculosa* str. 3P, *Asterionella formosa*, *Fragilaria crotonensis*, *Aulacoseira ambigua, Stephanodiscus niagarae*, and *Aulacoseira granula* (Fig. 2). The absolute concentration of diatoms has also not changed appreciably over the last 400 years (Fig. 2).

Cluster analysis suggests two major periods of diatom assemblages in the recent history of the lake (Fig. 2). Below 200 mm in the sediment core (Zone B) the assemblage was comprised primarily of mesotrophic to eutrophic planktonic taxa, including *Fragilaria crotonensis*, *Stephanodiscus niagarae* and *Aulacoseira granulata* (Fig. 2). Above 200 mm in the sediment core (Zone A) planktonic taxa, *Tabellaria flocculosa* str. 3P, *Asterionella formosa* and *Aulacoseira ambigua*, increase in percent abundance. In Zone A the dominant planktonic taxa fluctuate in percent abundance. For example, *Aulacoseira granulata* reaches a higher percent abundance in zones A1 and A3, whereas *Aulacoseira ambigua* has higher abundance in Zone A2. *Asterionella formosa* reaches it highest percent occurrence in Zone A1.

Diatom-inferred total phosphorus (TP) estimates indicate mid-summer mesotrophic conditions (between ~24 to 30 μgL^{-1}; Fig. 1E) over the past 400 years, with the highest values occurring in pre-industrial times. The main direction of variation in the diatom assemblages, as defined by the PCA axis-1 scores (Fig. 1D), is not significantly correlated with the inferred TP inferences ($r^2 = 0.005$; $p > 0.05$). PCA axis-1 scores suggest that the diatom assemblages have undergone fluctuations in their composition over the past 200 years.

DISCUSSION

Changes in the relative abundance of diatoms suggest this lake has been mesotrophic over the last 400 years. The diatom concentration data also suggest that diatom productivity has changed little over this time frame. With few exceptions the dominant diatom taxa show as much variability in the past as they have shown since c. 1900. There is evidence for significant excursions and variability in the percent organic matter c. 1900, possibly reflecting a major watershed disturbance, but one that did not result in a change greater than the inherent natural variability of the diatoms in this lake. The swings in the dominant diatom taxa may be related to changes in climatic variability over the past 400 years. Accurate dating in the lower portions of this core will be necessary for us to compare to climate variation from other sources in the Prince George region (e.g., Enache and Cumming submitted and other references therein).

SUMMARY

In summary, the diatom-inferred TP level of Eaglet Lake indicates a relatively productive lake throughout the last ~400 years, with mesotrophic estimates ranging between ~24 to 30 μgL^{-1}. The impacts of any recent watershed disturbances around Eaglet Lake have been within the variance in natural variation in trophic conditions.

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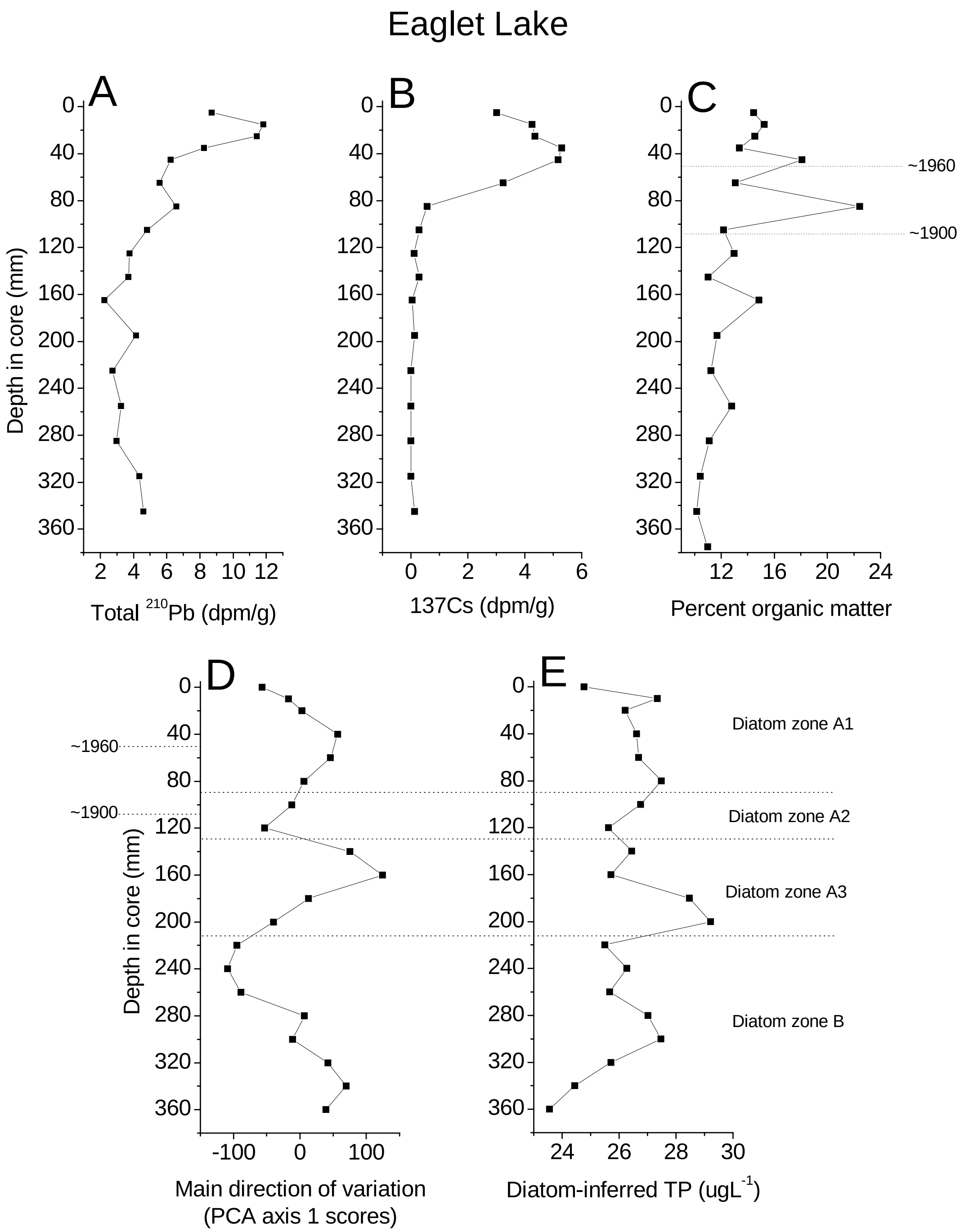


Figure 1. Summary diagram for Eaglet Lake showing: A) total ^{210}Pb activity; B) the ^{137}Cs activity; C) the change in the percent of organic matter in the core; D) the main direction of variation in the diatom assemblage data; and E) diatom-based estimates of late-summer total phosphorus.

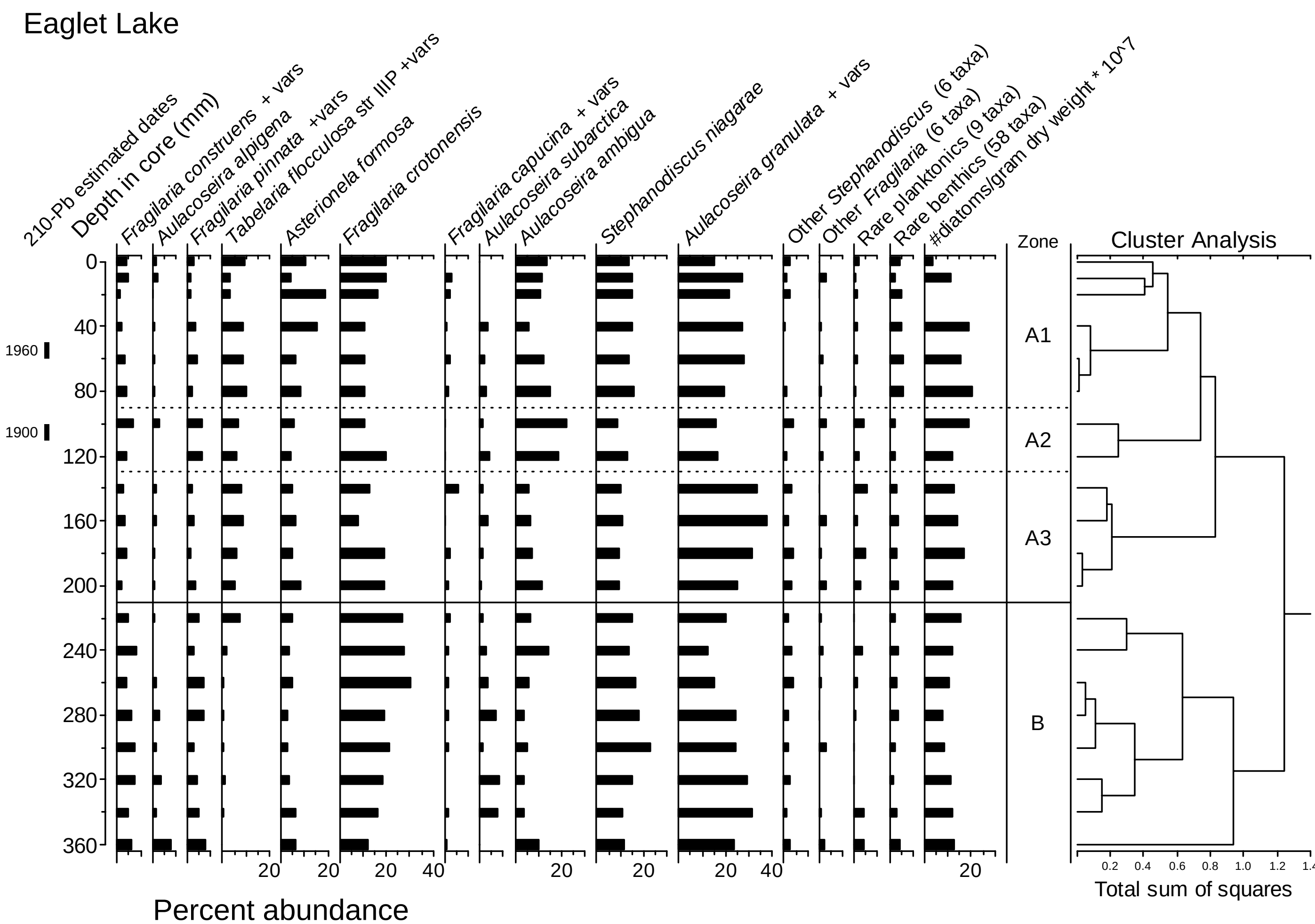
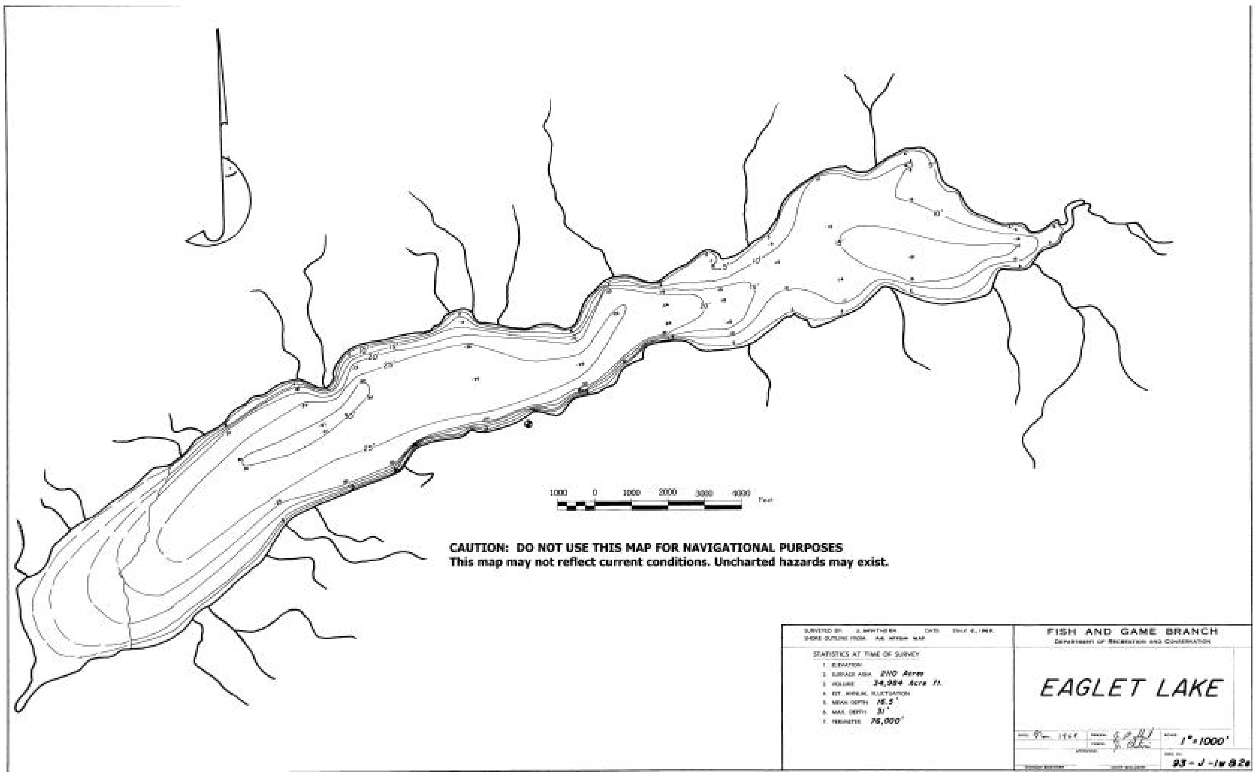
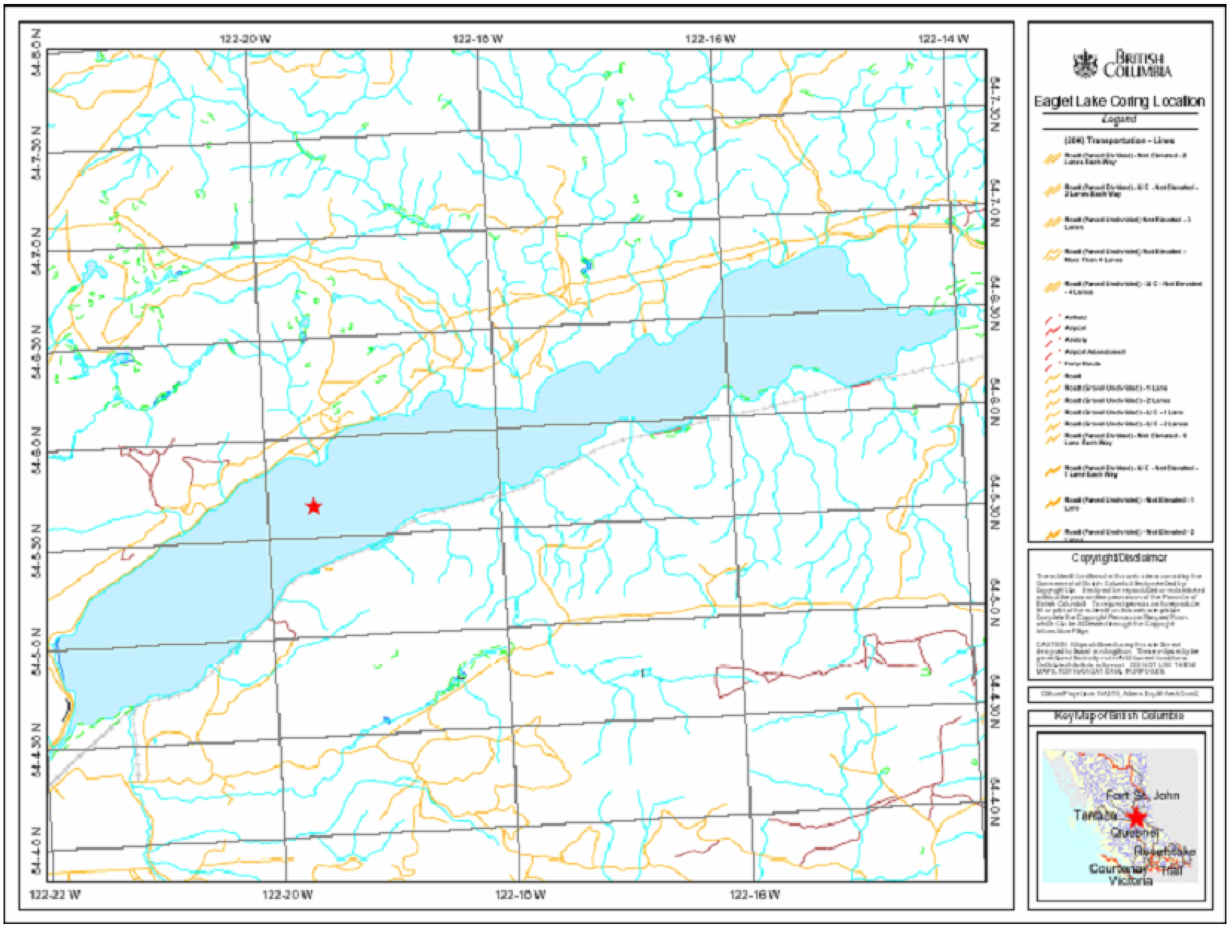


Figure 2. Stratigraphy of the most abundant diatom taxa found in the sediment core from Eaglet Lake. The diatom taxa are arranged in order of increasing late-summer total phosphorus (TP) optima.



Appendix 1 – Bathymetric Map of Eaglet Lake

Eaglet Lake Coring Location, September 14th, 2005. 54° 05' 39.3"N; 122° 19' 36.2"W



Appendix 2 – Map showing location of the sediment core