Cheslatta Lake Paleolimnological Assessment

Prepared for:

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Executive Summary

Paleolimnological from Cheslatta Lake sediments show significant changes in the physical and biological components of Cheslatta Lake following diversion of water through the Skin's Lake Spillway. Following diversion, productivity in the lake has been reduced. This is likely due to increased flushing rates that decrease nutrient levels in the lake as previous research has discussed. The paleolimnological data also suggest that the large amounts of inorganic material being deposited into the lake by high flows are also likely impacting the productivity of the lake by decreasing light available for photosynthesis.

Modification of the annual hydrograph along with increased flows and a faster flushing rate are all potential impacts of the Skin's Lake Spillway on Cheslatta Lake. However, limited data are available to assess the pre-diversion condition of the lake. Paleolimnology using the physical and biological remains in lake sediments was used to investigate the past conditions within Cheslatta Lake and note any changes that diversion of flow has had.

Large changes in the sediment composition are evident in the Cheslatta Lake sediment core. The core transitions from a long period of stable organic sediment to sediments strongly dominated by inorganic material. The most likely explanation for this change is the deposition of massive amounts of inorganic sediment from the Cheslatta River due to high flows after diversion and erosion of shoreline from variable water levels. Concomitant with the changes in sediment composition are changes in the biological remains found in the core. Both cladoceran invertebrates and diatom algae show large changes in species composition and abundance. In both groups species associated with more productive conditions disappear after diversion of water into Cheslatta Lake. Those species that persist are associated with lower productivity lakes and also occur at lower levels of abundance than were observed pre-diversion.

Introduction

Modification of flows, changes in water level, alteration of flushing rate, increased nutrient loss and loss of habitat are all documented impacts of altered hydrograhic cycles related to damming and flow diversion. However, the extent of these impacts can vary widely and are often dependent on local conditions. Previous research on Cheslatta and Murray lakes has documented many of the impacts of flow diversion in these systems (Stockner and Slaney 2006). The very fast flushing rates currently observed in these systems are likely resulting in large nutrient exports from these lakes along with other physical disturbances to the system as a result of water level changes. As a result, productivity is predicted to be considerably lower than what past conditions are believed to have been.

However, past data on the productivity of Cheslatta Lake is lacking. Descriptive and somewhat anecdotal accounts from a pre-dam lake survey of fish, plankton and littoral benthic fauna/flora by Lyons and Larkin (1952) provides only limited information. Generally, they reported a sense of 'mesotrophic richness' and elevated productive state.

Paleolimnology, which uses the remains of aquatic organisms along with physical and chemical markers preserved in lake sediments, can provide information on past physical and biological conditions within lakes. The paleolimnological approach is a useful tool because it provides a means of studying a lake's response to disturbance retrospectively, and can provide data relatively quickly (Smol 1992). Lake sediments act as archives of past lake conditions, and by using the chemical, physical and biological remains preserved in the lake sediments, past aquatic and terrestrial conditions can be inferred (Frey 1969). When pre-impact data are lacking, paleolimnology provides one of the few means of assessing historical conditions. The ability of paleolimnology to use a variety of chemical, physical and biological markers provides information on a wide variety of lake conditions. The use of multiple indicators also allows for corroboration from multiple ecosystem components when reconstructing past changes.

Cladoceran invertebrates and diatom algae are two groups of biological indicators that have been successfully used in a wide variety of paleolimnological studies (Frey 1969, Smol 1992). Both groups respond rapidly to changing environmental conditions, are found in a wide variety of lake habitats and preserve well in lake sediments. The cladocerans and diatoms also offer complementary data from different trophic levels and both groups may provide information on littoral and planktonic habitats. Elemental analysis of carbon and nitrogen content of sediments is useful to assess changes in lake productivity and sediment loading. High levels of organic sediment accompany productive conditions within lakes, or abundant organic matter being transported into the lake. Low levels of carbon and nitrogen are consistent with low productivity or large amounts of inorganic material being deposited in the lake. The ratio of the two elements provides information on the source of the organic matter. High values for the C/N ratio indicate a terrestrial source of the organic matter, while low values of C/N are associated with aquatic organic matter (Meyer and Terranes 2001). ^{210}Pb is a naturally occurring isotope with a short half-life of 22.2 years. Progressively less ^{210}Pb activity is found as sediments become older and models are available to date sediments based on the ^{210}Pb remaining (Appleby and Oldfield 1978).

Methods

Sediment Coring

A core was retrieved from Cheslatta Lake on March 27th, 2007 by Melanie Grubb with Calvin and Murray Creighton. A percussion corer was used to extract cores from the lake. Two cores were extracted and core 07Ches(01) was selected for analysis. This core was retrieved from the central deep basin of the lake. The water depth at the coring location was 65m and the coordinates were 53° 44' 33.4"N, 125° 21' 5.4"W.

^{210}Pb Dating of Sediments

Samples were prepared for ^{210}Pb analysis by drying a known weight of homogenized sediment. Samples were dried at 105° C for 24 hrs. After drying samples were re-weighed, ground to a uniform fine powder, placed in 50 mL plastic centrifuge tubes and shipped to Flett Research Ltd., Winnipeg, Manitoba, Canada for analysis. ^{210}Pb activity for each sample was measured using Alpha Spectroscopy and a ^{209}Po tracer of known activity. Supported ^{210}Pb was estimated following Binford (1990). Dates were calculated from unsupported ^{210}Pb using the constant rate of supply (CRS) model (Appleby and Oldfield 1978).

Carbon and Nitrogen Elemental Analysis

Elemental carbon and nitrogen composition of the sediment were analysed in the Central Equipment Lab at the University of Northern British Columbia using a Fisoms NA 1500 Series 2 elemental analyzer with a measuring range of 0.1 - 100 % for carbon and nitrogen with a detection limit of 10 ppm. Organic matter content of the sediment was determined by loss on ignition (LOI) on oven dry (105 °C) samples after 2 hours in a muffle furnace (550 °C). Inorganic content of the sediment was calculated as the residual from total sediment less water content and organic content.

Biological Microfossils

A limited number of cladoceran and diatom samples were enumerated to survey the broad biological changes in the lake. The scope of this component of the project was truncated due to damage and loss of samples during shipping. Additional samples were not prepared due to other inadequacies in the core, which were judged to make further commitment unprofitable. For each indicator group one sample was selected from a very recent section (2cm) of the core that is representative of current conditions. One sample was taken from the region of the core that most likely represents conditions immediately prior to diversion of water (14cm). A final set of samples was prepared for the region low in the core that likely represents conditions prior to any European impact (53cm).

Cladocera

Cladoceran samples were prepared by deflocculating a known mass of wet sediment (~ 2 g) in 200 mL of 10% KOH solution at 70° C for 1 hr. Samples were then sieved through a 34 μm Nytex® mesh. Material retained on the mesh was washed into a vial and the volume was adjusted to 5 mL. 200 mL of this solution was plated onto microscope slides/cover-slips with glycerin jelly as a mounting medium. Slides were enumerated at 400X magnification on a Leitz Laborlux microscope fitted with phase contrast optics. The entire sample under each cover slip was enumerated to avoid bias that could result from an uneven distribution of remains. Taxonomy follows that outlined in Bos (2001).

Diatoms

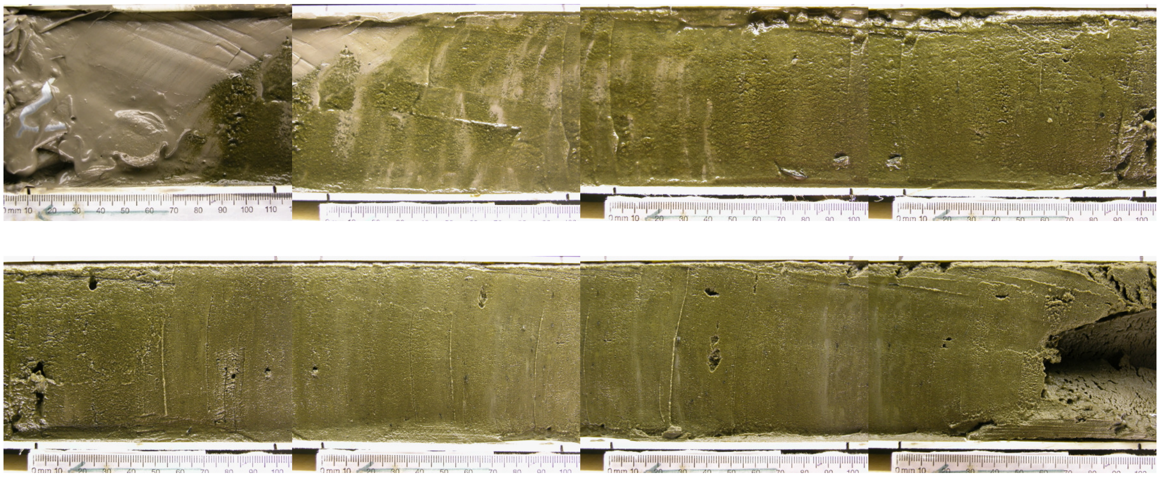
Identical intervals were sampled for diatom and cladoceran analyses. Diatom samples were prepared by treating a known mass of wet sediment (~ 1g) with concentrated nitric acid and sulfuric acid (1:1 by molecular mass). Samples were heated in an 80ºC water bath for 4 hrs to remove organic debris. Following acid digestion the samples were allowed to settle overnight, and the acid was then aspirated off the top of the samples. Subsequently, samples were rinsed with distilled water daily, allowing 24 hrs for diatoms to settle between aspirating. This was repeated 10 times until the sample pH became neutral. Loss of the diatom samples during shipping required that additional samples be prepared. Due to time constraints and complementary information that the core was not ideal, faster and less expensive diatom samples were prepared using an Utermohl chamber to provide a general semi-quantitative survey of the diatoms present. Slides were enumerated at 560X magnification using a Zeiss Inverted phase-contrast microscope. Taxonomy was based on Stockner and Costella (1980), Prescott (1981) and Canter-Lund and Lund (1995).

Results

Core Description

Core 07-Ches (01) consists of two facies. The lowermost is the organic gyttja (18-83 cm) dark greenish brown with a number of lighter laminae. The uppermost facie (18cm to core surface) consists of the reddish brown silty clay laminations. There is some smearing and disturbance in the core. From 9cm to 13cm some of the clay from the topmost section of the core has been dragged into lower segments. However, upwards of 9cm the core consists of fairly uniform clay and silt. The top 76cm of the core were sectioned, with sections below 76cm containing the core catcher.

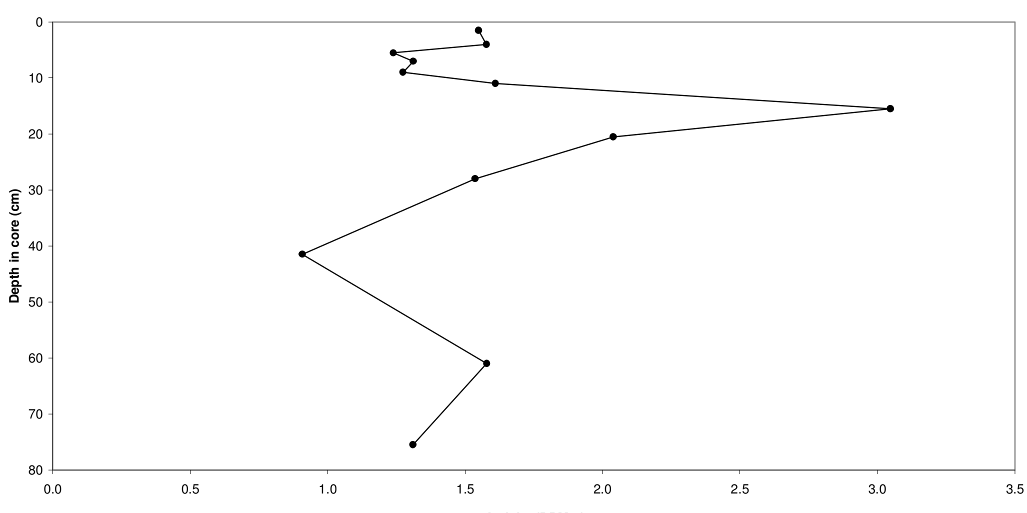
Fig. 1. Core Ches (01) retrieved from the deep basin at the western end of the lake. The core was photographed in sections with overlap between sections. The vertical black lines along the bottom of the core casing delimit each 10cm section. The top of the core is in the leftmost and top in the figure, the bottom of the core with the cut-out from the core catcher is shown in the lower right section of the figure.



^{210}Pb dating

^{210}Pb data for the core are unusual and do not decrease exponentially with depth, as would be predicted the constant rate of supply model (Fig. 2). The activity of the topmost samples and peak values in the core were both very low compared to other lakes in the region.

Fig. 2. ^{210}Pb activity data for the core. The vertical axis is aligned to represent the core with the youngest (topmost) sediments are plotted at the top of the diagram. The normal pattern for exponential decay should have the highest values found in the top-right corner of the figure with exponentially decreasing values reaching an asymptote in the lower sections of the core.



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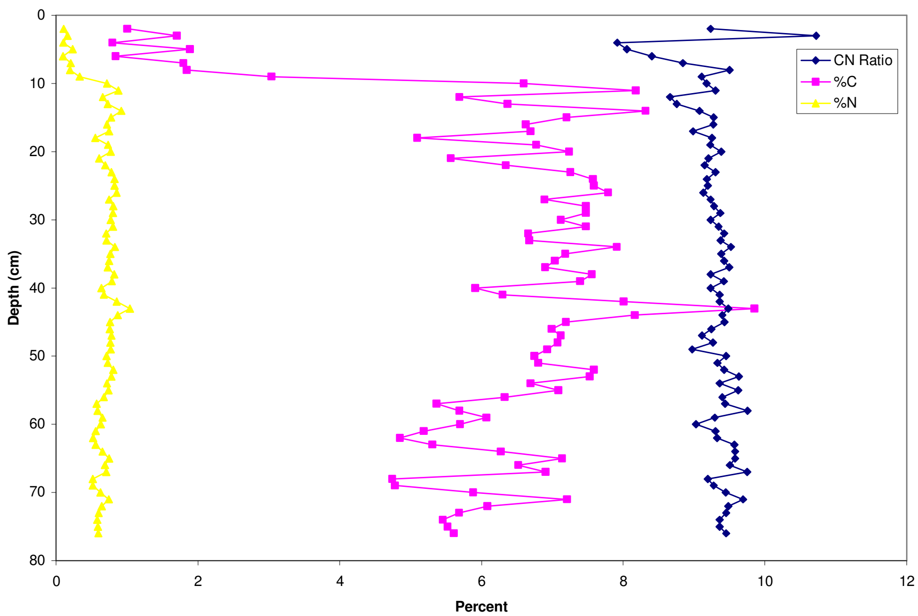
Carbon and Nitrogen Elemental Analysis

Carbon and nitrogen elemental analysis of the core both show similar trends. Both elements are present at higher levels throughout the lower section of the core until the 9cm interval, at which point the levels of both elements drop precipitously and remain low. While large changes are seen in the carbon and nitrogen content of the core, relatively little change was seen in the C/N ratio. The C/N ratio initially decreases slightly after the 9cm interval, then for one sample increases rapidly to levels slightly higher than had been previously observed in the core and finally finishes at the top of the core by returning to levels seen through most of the lower section of the core.

Fig. 3. Carbon and nitrogen elemental analyses show stable and high values in the lower sections of the core which drop sharply in the upper sections of the core where sediments transition from organic to inorganic sediments. In comparison the ratio of C/N is relatively stable and shows only small deviations of varying phase near the top of the core.

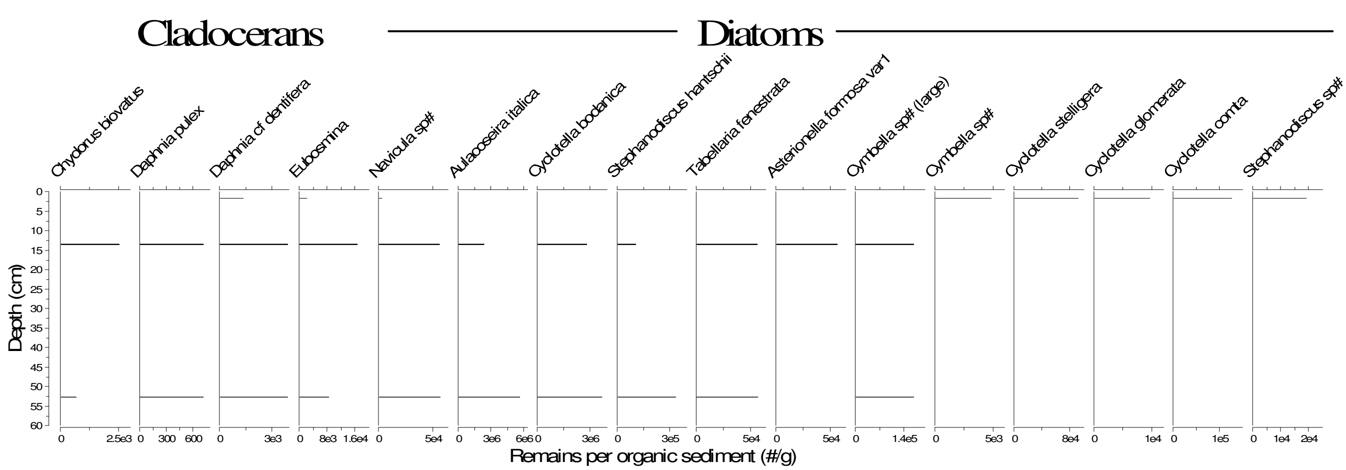


Biological Remains

Even with a limited number of samples, the trends in the biological data are very clear. Pre-diversion and post-diversion assemblages are very different. For the cladoceran invertebrates, four species are commonly encountered in the sediments. Two species, *Chydorus biovatus* and *Daphnia pulex,* which are associated with more productive lakes in British Columbia (Bos and Cumming 2003), disappear entirely after the diversion of water into Cheslatta Lake (Fig. 4). Two other species that are common in oligo-mesotrophic conditions, *Daphnia* cf *dentifera* and *Eubosmina* spp., were observed throughout the core albeit with reduced abundance in the upper sections of the core.

The diatom data show similar trends to the cladocerans, but with an even more pronounced modification of the species assemblages. Only one group of diatoms, *Navicula* sp. was found in abundance throughout the core and even it showed much reduced levels in the uppermost section of the core (Fig. 4). For all other common species there was an almost complete changeover in the diatom community following diversion of water from the Skin's Lake Spillway. Before diversion, *Aulacoseira italica, Cyclotella bodanica, Stephanodiscus hantschii, Tabellaria fenestrate, Asterionella formosa* and *Cymbella* sp. were all common (Fig. 4). The first seven of these species are all associated with more productive waters in BC (Cumming et al. 1995) ranging from mesotrophic to eutrophic. Cymbella sp. does not have defined TP optima because it could be one of many species. After diversion of water from the Skin's Lake Spillway, the diatom assemblage is dominated by *Cymbella* sp., *Cyclotella stelligera, Cyclotella glomerata, Cyclotella compta* and *Stephanodiscus* sp. All four of the *Cyclotella* species are typical of less productive waters ranging from ultraoligotrophic to the lower end of mesotrophic (Cumming et al.1995, Gregory-Eaves et al. 1999). *Cymbella sp.* and *Stephanodiscus* sp. do not have defined optima because they could be one of several species. Diatom remains also become much less abundant in the sediments after diversion.

Fig. 4. Algal and invertebrate remains show large changes in species composition and abundance between the inorganic and organic dominated sections of the core. Note that species found only at the top of the core have abundances that are one or two orders of magnitude lower than species found in the bottom of the core.



Discussion

The very low levels of ^{210}Pb activity seen in the core and the absence of a normal exponential decrease with depth make ^{210}Pb unreliable for dating the core. Several explanations exist for the observed data. The type of corer used to extract the core can result in disturbance of the surface sediment layers. These are the levels where ^{210}Pb activity is highest and loss of these sediments can result in flat ^{210}Pb profiles where the area of exponential decrease is simply missing. In lakes with low sedimentation rates, relatively little sediment needs to be lost from the top of the core to prohibit ^{210}Pb dating. The large amounts of inorganic sediment that is entering the lake in more recent times also likely contributes to low ^{210}Pb levels observed in the top of the core. Old reworked sediments such as eroded riverbanks are likely to have very low ^{210}Pb levels. Although it is possible for the CRS model to account for changes in sedimentation rate, the very low levels of activity seen at the top of the core are similar to background levels seen at the bottom of the core and would exceed even the flexible CRS model. Disturbance to the core during transport from the lake may also have played a role in the disturbance of the upper sections of the core. Combined these features make interpretation of ^{210}Pb data and dating of the core untenable.

Despite some apparent mixing of the upper portion of the core, visible in the core photos, large changes in the organic and inorganic composition of the core are clearly evident. Both carbon and nitrogen levels drop precipitously starting at nine centimetres in the core. Decreases in the organic content of a core may be caused by decreases in lake productivity or increases in the inputs of inorganic material into a lake. Although both processes are likely at work in Cheslatta Lake, the large volumes of inorganic material in the top of the core suggests that increases in the delivery of inorganic matter to the lake are likely driving the observed changes.

The low ratios of C/N observed in the core are consistent with algal production being the primary source of organic sediment for the lake. C/N levels less than 15 are commonly associated with in-lake production of organic sediment, while higher values are associated with terrestrial organic materials (Meyer and Terranes 2001). Thus, the small changes in the C/N ratio suggests that although productivity has likely decreased in the lake, aquatic production still dominates the organic component of the sediment. The initial decrease in the C/N ratio at nine centimetres suggests that N-limitation may have developed within the lake after diversion and is consistent with low nutrient water being diverted to the lake from the Nechako Reservoir, which is known to be oligotrophic or unproductive. However, the changes in C/N are relatively small and thus the interpretation of potential nitrogen limitation is speculative.

Sedimentary invertebrate and algal remains both show clear changes associated with diversion of water into Cheslatta Lake. For both groups, species associated with more productive lakes disappear in the upper section of the core. Species found at the top of the core are consistent with less productive conditions and those species that persists throughout the core occur at much lower densities after the transition to inorganic sediments. For both groups the density of remains was expressed as the number or remains per gram organic sediment. The C/N data show that the organic component of the lake sediment is dominated by in-lake production and thus this component has seen relatively little change even after diversion of water through the lake. In this manner, remains expressed per organic sediment avoid bias that might otherwise been encountered due to changes in sedimentation rate accompanying water diversion. Thus, the reduced density of remains seen in the upper sections of the core represents a genuine decrease in the productivity and not simply dilution from inorganic matter transported to the lake from the Cheslatta River.

The rapid transition to inorganic sediments seen in the core shows the dramatic change that diversion of the spillway had on the physical environment of the lake. The much larger flows through the upper Cheslatta River appear to have resulted in a radical increase in the deposition of fine inorganic material into the lake. This has likely had a significant impact on the photic environment of the lake and would further decrease primary productivity. As described in Stockner and Slaney (2006) rehabilitation of the upper Cheslatta River will be important in rehabilitating Cheslatta Lake. The large amounts of inorganic material found in the lake are being deposited from erosion along the Cheslatta River as well as erosion of the lake banks during water level changes. The suspended inorganic sediments likely have a significant effect on the photic environment of the lake. Decreased light penetration associated with this fine suspended inorganic sediment will decrease the depth in which algal photosynthesis can take place and decrease algal productivity. Consistent with requirements for fisheries rehabilitation in the river, large woody debris and decreased flows should not only help fisheries recovery, but also decrease the export of inorganic sediment from the river into the lake.

Paleolimnological data are consistent with previous work that suggested that the high flows in the Cheslatta River have impacted the productivity of the lake. Biological microfossils clearly show changes associated with less productive conditions and lower nutrient levels. The high levels of inorganic sediments found in the lake also suggests that the high flows in the Cheslatta River are also directly impacting the physical environment of the lake through increases in suspended inorganic matter and decreased light transmission. Decreased flows through the Skin's Lake Spillway would have the potential to remediate both these problems.

Further Work

Although the current project has demonstrated that increased flows though Cheslatta Lake have resulted in biological and physical changes within the lake, inadequacies in the core and loss of samples during shipping have limited some of the potential data available using paleolimnological techniques. Detailed analysis of diatom species would allow for quantitative predictions of past phosphorus levels in the lake. BC is fortunate to have one of the best diatom-phosphorus transfer functions in the world (Reavie et al. 1995). Although somewhat more demanding in terms of the level of diatom taxonomy required, utilization of the transfer function would allow for quantitative reconstruction of past phosphorus levels in the lake and could provide a target for remediation efforts. Detailed microfossil analysis with increased counts for cladoceran and diatom species could also better reveal previous littoral conditions as the current data are dominated by the more abundant planktonic species. Retrieving an undisturbed core from the lake would provide an opportunity for improved ^{210}Pb dating. Use of a corer less likely to disturb the surface sediments and vertical sectioning of the core on site could provide accurate dating for the core.

Additional biological samples could be prepared for either of the two existing cores from the lake and would provide a cost-effect way of gaining valuable quantitative information on the past productivity of the lake. Retrieving a new core from the lake would require a greater financial commitment, but would improve confidence in the timing of changes.

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