CHIRONOMID-BASED PALEOSALINITY RECONSTRUCTION OF THREE LAKES IN THE SOUTH-CENTRAL INTERIOR OF BRITISH COLUMBIA, CANADA

by

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CHIRONOMID - BASED PALEOSALINITY RECONSTRUCTION OF THREE LAKES IN THE SOUTH - CENTRAL INTERIOR OF BRITISH COLUMBIA, CANADA

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Abstract

Salinity fluctuations in lakes of semi-arid regions have been recognised as indicators of paleoclimatic change, and have provided a valuable line of evidence in paleoclimatic reconstruction. In the present study, fossil remains of Chironomidae were used to reconstruct lake salinity changes from the early postglacial, through the early, mid and late Holocene.

In Mahoney Lake, a transition from head capsules typical of a freshwater community (*Protanypus, Sergentia, Heterotrissocladius, Cladopelma, Dicrotendipes*) during the early postglacial, to those indicative of saline environments (*Cricotopus/ Orthocladius*, *Tanypus*) occurred in the early Holocene. The chironomid-inferred salinity values reflected the shift from freshwater (0.031 g/l) immediately after deglaciation, to saline water (2.4 to 55.2 g/l) in subsequent periods. A less saline period was found to have occurred after about 1000 years ago, suggesting a cooler or wetter period.

Results from Kilpoola Lake indicate a similar early postglacial freshwater interval with an inferred salinity less than 0.03 g/l, followed by a prolonged period of higher salinities (1 to 3.5 g/l) during the Holocene. A community of chironomids including *Microtendipes*, *Sergentia*, and *Heterotrissocladius* (typical freshwater chironomids) were found in the basal sediments, and *Cricotopus/ Orthocladius* and *Tanypus* (saline environment chironomids) were found in subsequent intervals to the present. The peak Holocene salinity occurred during a period shortly after deposition of the Mazama ash.

The Big Lake chironomid stratigraphy did not indicate a freshwater to saline environment transition, as more moderate to saline environment chironomids (*Procladius,* Tanytarsina, *Chironomus*) dominated the sediments. There was little variation in the assemblage of chironomids and inferred salinity (0.5 to 3 g/l) throughout the Holocene. However, the non-continuous presence of some species (*Parakiefferiella cf. bathophila, Derotanypus, Glyptotendipes*) suggested that some climate induced lake changes may have occurred.

Reconstructions of the chironomid-inferred salinity records for Mahoney and Kilpoola Lakes compare favorably with the accepted climate trends and early Holocene warm period inferred from other paleoenvironmental evidence. Thus, chironomid-inferred paleosalinities appear to be a useful tool in reconstructing paleoclimates.

Dedication

To my parents.

Quotation

When it rains, it pours.

(author unknown)

Acknowledgments

I would like to acknowledge the support, encouragement, and patience of my co-supervisors, Drs. Ian R. Walker and Rolf W. Mathewes, who not only suggested the direction of study, but were readily available for consultation and advice, and tolerated my seemingly endless frivolity.

Additional recognition should go to Drs. John P. Smol, Susan E. Wilson, Brian F. Cumming, and Ken J. Hall for their input, assistance, and samples provided for this study.

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Final appreciation is due to the very many who have made my time here at SFU the best ever- Janice and all the rest- Cheers!

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I. Introduction

Late-Quaternary paleoclimates of the southern interior of British Columbia have been little studied relative to those of the coastal region. The existing studies indicate some controversy in terms of the details of timing and direction of climatic change (Hebda, 1995), thus, additional lines of evidence are required to adequately reconstruct the changes which have occurred in past climates. Not only will these be beneficial to assist in the prediction of the long term effects of future climate change, but they will also help to create a greater understanding of current problems associated with fisheries, eutrophication and other lake related issues. Similarly, there is almost no information on the postglacial development of lakes and their biota within this region.

Chironomids have not been used until recently as indicators of paleosalinity (Paterson and Walker, 1974; Mees et al., 1991; Verschuren, 1994), and never before as quantitative salinity indicators. As one component of the "Paleolimnological Investigation of Salinity, Climate and Environmental Shifts II" (PISCES II) programme, this study will make the first attempt to apply a quantitative method in reconstructing salinity from fossil Chironomidae.

Sediment from three lakes was analysed for the remains of chironomids. Inferred values of past salinity were calculated using the method recently developed by Walker et al. (1995). Combining these data with evidence from earlier paleoecological studies (Alley, 1976; Cawker, 1983; Hebda, 1982) and current diatom and algal studies (Cumming et al., 1995) should further illuminate our knowledge of the development of saline lake ecosystems, and past climate in the southern interior of British Columbia.

A. Literature Review

1. Climate Trends in British Columbia

Synopses of the accepted climatic trends of the Holocene in British Columbia have been compiled which indicate that the trends in the Pacific coast region, the interior, and the northern regions, were neither synchronous nor marked with the same directional change in temperature (Anderson et al., 1989; Matthews and Anderson, 1989; Hebda, 1995). In summarizing many paleoclimatic studies of the Holocene in British Columbia, Hebda (1995) and Anderson et al. (1989) suggest that the general trend is one of gradual warming from cool, moist conditions in the late glacial, approximately 12,000 to 10,000 yr BP, followed by a rapid increase in temperature by 9000 yr BP, when a xerothermic interval occurred. A period of gradual cooling and increased moisture occurred after the mid-Holocene, interrupted by some oscillations in direction, to generate the present climatic conditions.

Pollen analyses (Anderson et al., 1989) suggest that the coastal warm period occurred shortly after deglaciation, and is marked by a rapid rise in temperature between 10,500 and 10,000 yr BP, with the temperature maximum lasting until 7500 yr BP. Studies on the Queen Charlotte Islands suggest that a xerothermic interval occurred between about 9400 and 7400 yr BP (Warner et al.,1984; Mathewes, 1989). Pollen, plant macrofossil, and aquatic mollusc remains in the south-central interior suggest the xerothermic interval occurred between 8000 and 6600 yr BP (Mathewes and King, 1989). Neoglaciation (Porter and Denton, 1967) followed, beginning around 5800 yr BP in the Queen Charlotte Islands (Pellatt and Mathewes, 1994), and around 6600 yr BP for the southern coastal regions (Mathewes and Heusser, 1981; Mathewes, 1985). This cooling trend has continued to develop with various oscillations into what is now the present regional climate.

Stratigraphic analysis of lake cores in the south-central interior of British Columbia at Phair Lake, show the moister, cooler conditions beginning at 7000 yr BP by increased water levels. The Neoglaciation appears as a decrease in mudflat conditions, and deposition of marl sediment beginning around 5700 yr BP (Mathewes and King, 1989). Increasing water levels are suspected to have caused a change from marl to gyttja around 2000 yr BP.

Early studies on postglacial forest data in south-central British Columbia (Hansen, 1955) place the warmer, drier periods of the mid-Holocene between 7500 and 3500 yr BP, with a temperature maximum around 6600 yr BP. Investigation at Kelowna Bog suggests the warm interval occurred between 8400 and 6600 yr BP (Alley, 1976). Cooler and moister conditions prevailed from about 6000 yr BP to the present. Changes in grassland distribution and the presence of non-arboreal pollen suggests that the warm period was much earlier, between 10,000 and 8000 yr BP, followed by a moister trend until 4500 yr BP (Hebda, 1982; Hebda, 1995). Coincidental vegetational changes from shrubs to trees beginning around 7000 yr BP in south-eastern British Columbia, and forest expansion beginning around 5000 yr BP in northern Washington state (Mack et al., 1978; Hazell, 1979 in Hebda, 1995; Hebda, 1982) also suggest an early warm period followed by moister conditions.

A more recent comparison by Hebda (1995) of two studies in south-central British Columbia (Alley, 1976; Cawker, 1983) suggests that the driest period occurred in the early to mid Holocene, with a shift to a cooler and moister climate after the eruption of Mt. Mazama ca. 6800 yr BP (Bacon, 1983). Charcoal analysis was used to determine periods of maximum fire recurrence, and pollen analysis to determine maximum periods of bog growth, suggesting cooler and wetter periods. Hebda states that few studies have been done in this area to provide a clear understanding of trends, and that further investigations must be made in order to establish past climatic conditions.

2. Chironomids as Indicators of Paleoclimate

Chironomids were first used as indicators of paleoenvironmental change in 1927 (Gams, 1927). The technique developed slowly, however, as its major use in the 1940-60's was in the study of paleoproductivity, and during the 1970's it was applied to the study of anthropogenic lake eutrophication (Walker, 1987). Hofmann (1986) reviewed the application of chironomid analyses to environmental assessment and trophic status determination, and reiterated their importance in reconstructing past environments. It has only been in the 1980's and subsequently that chironomids were used to determine climatic variations.

Walker and Mathewes (1987a) examined chironomid remains at Marion Lake, British Columbia, finding variation in distributions which reflected a rapidly warming climate after the late-glacial. A discussion of climate, lake trophic status and chironomid distributions accompanied this study (Walker and Mathewes, 1987b). They followed this investigation with another at Hippa Lake, British Columbia (Walker and Mathewes, 1988). Chironomid assemblage changes were also observed with respect to depth in cores from Mike and Misty Lakes, British Columbia (Walker and Mathewes, 1989a).

An investigation of chironomid distributions over an altitudinal gradient (Walker and Mathewes, 1989b) provided data on the present climatic distribution of Chironomidae in British Columbia. Walker (1990) made further correlations between arctic and alpine chironomid distributions and those of the late-glacial and early postglacial communities. He also reported a reduction in number of taxa in waters with higher salinities, and indicated the potential for future study in this area.

The application of new statistical techniques has greatly advanced chironomid paleoecological studies. Statistical analysis of 21 chironomid taxa from Labrador (Walker et al., 1991a) demonstrated a close relationship between chironomid distributions and water temperature, and allowed a chironomid-temperature transfer function to be developed for the first time. Walker et al. (1991b) used this transfer function to identify lake temperature fluctuations in Atlantic Canada that followed a pattern of climatic change previously described in Europe, the Allerød-Younger Dryas fluctuations.

Wilson et al. (1993) used pollen, diatoms, and chironomids to examine climate changes in Atlantic Canada associated with the Younger Dryas event. They found that pollen evidence was not sufficiently sensitive to record this short climatic shift, however the limnological evidence provided by chironomids and diatoms suggested an abrupt cooling interval between 10 and 11 ka BP.

Levesque et al. (1993) utilised pollen, chironomids and sediment analyses to provide the first recorded evidence of a late-glacial, pre-Younger Dryas cooling event (the Killarney Oscillation) in North America. In a similar, multi-proxy investigation in New Brunswick, Canada (Levesque et al., 1994) they further illuminated the timing and severity of the Killarney Oscillation and the Younger Dryas event.

Most recently, Walker et al. (1995) have applied the same statistical techniques to assess the distributions of chironomids among British Columbia saline lakes. They provide a chironomid-salinity transfer function which should be useful in reconstructing past salinity and climatic changes. However, prior to the present study, the transfer function had never been applied or tested using fossil time series of chironomid data.

3. Saline Lakes as Archives of Paleoclimatic Data

Salinity is measured by the total dissolved concentration of inorganic ions including calcium, magnesium, sodium, potassium, carbonate, sulphate and chloride and can be expressed as g/l, mg/l, ppm (parts per million), $^{o}/_{oo}$ (parts per thousand), or as conductivity measured in Siemens/ cm. These ions originate primarily from weathering of rock and soil constituents in the surrounding drainage basin, but may also be enhanced by atmospheric precipitation (Wetzel, 1975). Ionic concentrations may fluctuate from biotic metabolism, but these may be insignificant when compared to changes due to water levels from climate. Lake salinity is also directly correlated to the amount of water present at a particular time (Ungar, 1978). Lakes of semi-arid regions are sensitive to the precipitation/evaporation balance; a warming trend should result in increased salinity from the increased evaporation and decreased input of water into the drainage basin. Cooling trends are likewise expected to result in increased lake levels by decreasing evaporation. Therefore, lake levels and salinities should be valuable indicators of climate (Hammer, 1990).

Fritz et al. (1991) reconstructed the paleosalinity of Devils Lake, North Dakota using a diatom-based transfer function. They suggest that changes in past salinity in closed basin lakes of arid and semi-arid regions accurately reflect changes in regional climate. Similar diatom models for reconstructing paleosalinity have been developed for the saline lakes of British Columbia's Cariboo and Chilcotin Plateaux (Cumming and Smol, 1993; Wilson et al., 1994). They submit that obtaining accurate climatic reconstructions provides climate modelers with the opportunity to compare climate change models with long term climatic records.

Chironomids were applied in a paleosalinity study of Lake Malha, Africa (Mees et al., 1991) and were found to provide an accurate indication of highly saline periods. Verschuren (1994) used the same chironomid technique at Lake Oloidien, Africa, to determine the paleolimnological record in terms of salinity and lake levels. He stated that a high resolution record of past climates can be produced from the fossil assemblages found in the sediments of climate-sensitive lakes.

Chironomids have been examined in several saline lakes in the central interior of British Columbia (Cannings and Scudder, 1978) in order to compare present salinity with associated biotic assemblages. The chironomid-inferred salinity transfer function developed by Walker et al. (1995) was derived from the study of chironomids among 65 saline lakes in the central interior of British Columbia. Their analysis indicates that late summer salinity, and concentrations of strontium and total phosphorus can explain much of the variation in chironomid taxonomic composition among lakes of different salinities.

B. Study Areas

Three lakes located in south-central British Columbia were selected for study. Two of the lakes, Mahoney and Kilpoola Lakes, are located in the Okanagan Valley , whereas Big Lake is located near 100 Mile House on the Cariboo Plateau.

The Okanagan Valley

The Okanagan Valley is situated in the south-central interior of British Columbia, Canada (Figure 1). Near the valley bottom, the climate is typically semi-arid with a maximum annual precipitation not exceeding 400 mm and summer daytime temperatures often exceeding 30° C (Energy, Mines, and Resources, Canada, 1992). The vegetation is typical of the Ponderosa Pine-Bunchgrass zone, the warmest and driest of British Columbia's biogeoclimatic zones (Meidinger and Pojar, 1991). The underlying rock formations are composed of undivided sedimentary and volcanic rocks of Cretaceous and Tertiary age (British Columbia Department of Mines and Petroleum Resources, 1976).

Mahoney Lake

Mahoney lake (Figure 2) is located 23 km south of Pentiction, British Columbia in the Okanagan Valley (49° 17' N, 119° 35'W) at an elevation of approximately 750 m above sea level. It is 19.8 ha in area, up to 18.3 m deep (Northcote and Hall, 1983) and its current salinity is in the range of 5- 35 g/l (Northcote and Hall, 1990). Mahoney Lake is presently meromictic, and often has complex stratification patterns at various times of the year (Northcote and Hall, 1990). In addition to its complex nature, it is also known to contain the world's greatest concentration of purple sulphur bacteria, *Amoebobacter purpurea* (Overmann, et al., 1991; Overmann and Pfennig, 1992). The surrounding hills which form the closed drainage basin rise up to a maximum of 800 m above sea level, and are covered with Ponderosa Pine and Douglas Fir. Mahoney Lake is associated with three bed rock types, a pre-Tertiary combination of metasedimentary and metavolcanic rocks, and a Tertiary rock formation; glacial deposits also surround the northern part of the lake (Northcote and Hall, 1983; Lowe et al., submitted). The lake has no outlet stream, and only short-lived inlet streams during extremely moist springs.

This site was chosen because of its closed basin, saline nature, and the semi-arid region in which it is located. It has also been previously well documented regarding its limnological characteristics of stratification and biota (Northcote and Halsey, 1969; Hall and Northcote, 1986; Hall and Northcote, 1990; Murphy, 1990), thus providing a basis for understanding lake history (Overmann et al., 1993; Lowe et al., submitted). The availability of a dated sediment core confirmed the choice of this lake for chironomid analysis.

Kilpoola Lake

Kilpoola lake (Figure 3) is located approximately 10 km west of Osoyoos, British Columbia, in the Okanagan Valley (49° 01' N, 119° 33' W) at an elevation of 815 m above sea level. It is a 21 ha saline lake with a maximum depth of 7.9 m, an average depth of 3.0 m, and a shoreline perimeter of 1920 m (surveyed by S. Hawthorne, May 29, 1969). The present salinity is approximately 9 g/l (August 17, 1993) (Cumming, pers. com.). It is located in a closed-drainage basin with the surrounding hills reaching elevations over 1000 m, including Mt. Kruger to the east, at an elevation of 1207 m. The valley in which Kilpoola Lake lies also contains Blue Lake (Figure 4), 2 km to the north at an elevation of 835 m above sea level. The surrounding vegetation is primarily bunchgrass (*Agropyron spicatum*), however Ponderosa Pine occur on the valley slopes. Kilpoola Lake had no visible inlet or outlet streams in April 1995, however the 1:50,000 topographical map (Canada Centre for Mapping (Ottawa), 1988) indicates Lone Pine Creek, an outlet stream at the south end of the lake, and two input streams, one from the north-west (towards Blue lake), and the other from the east (from Mt. Kruger).

This site was chosen for its moderate salinity (approximately 9 g/l) such that it would not be dominated by *Cricotopus/ Orthocladius*, and would reflect both increases and decreases in past salinity. Its location in a semi-arid region, closed-basin morphology, importance as a sport fishing lake, and the availability of a complete sediment core for chironomid analysis were also considerations in choosing this study site.

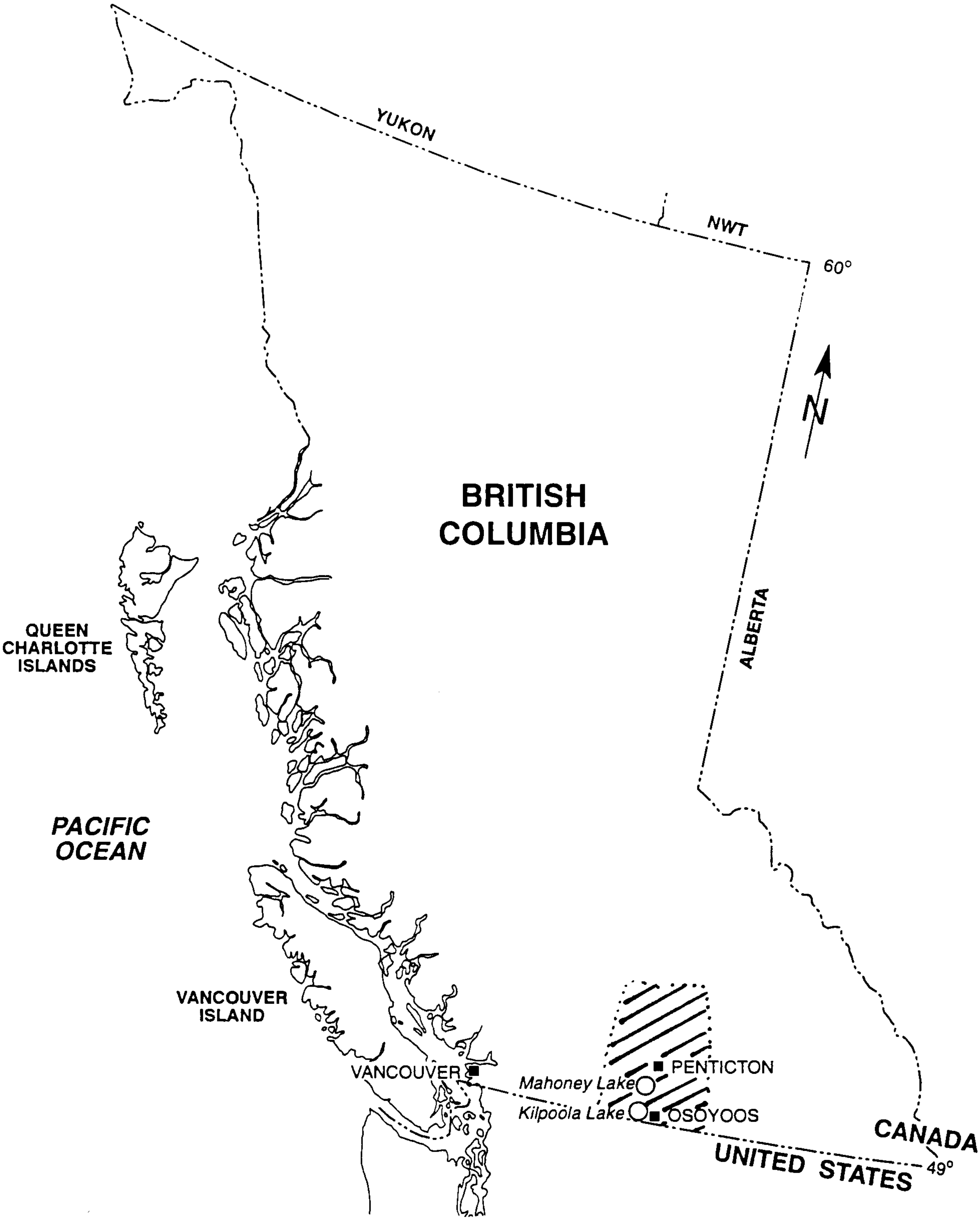


Figure 1.
Study site map, Okanagan Region
The Okanagan region of British Columbia, indicating the location of Mahoney and Kilpoola Lakes

Figure 2.
Mahoney Lake
A partial view of Mahoney Lake from the western shoreline, taken on April 14, 1995.

Figure 3.
Kilpoola Lake
Two views of Kilpoola lake from the north, taken on July 30, 1995.

Figure 4.
Blue Lake
A view of Blue Lake from the southern shoreline, taken on April 14, 1995.

The Cariboo-Chilcotin Plateau

The Cariboo region is located in the central interior of British Columbia, Canada (Figure 5). It is much wetter and cooler than the Okanagan Valley, having a maximum annual precipitation of 800 mm and summer daytime temperatures occasionally exceeding 30° C (Energy, Mines, and Resources, Canada, 1992). The vegetation is characteristic of the Interior Douglas Fir biogeoclimatic zone (Meidinger and Pojar, 1991). The surrounding forests are a mixture of Douglas Fir and Lodgepole Pine, with an understory of soapberry, bearberry and pinegrass. The underlying rock formations are composed of flat-lying plateau lavas and undeformed volcanic piles of Miocene age (British Columbia Department of Mines and Petroleum Resources, 1976).

Big Lake

Big lake (Figure 6) is an approximately 110 ha lake located 9 km west of 100 Mile House in a closed-drainage basin of the Cariboo region (51° 40' N, 121° 27' W) at an elevation of about 1030 m above sea level. It has an average depth of 3.8 m, a maximum depth of 10 m, and a perimeter of 8.4 km. Its current salinity is less than 1 g/l (Cumming, pers. com.). The gently sloping valley in which it is situated runs in a northwest- southeasterly direction, with the highest hill to the northeast, rising to 1160 m. It has a single, unnamed input stream from the southeast with no recorded outlets (Surveys and Mapping Branch, 1978).

This site was chosen as part of the PISCES-II project, to infer past environmental shifts in high conductivity B.C. lakes that are currently undergoing fish survival problems. This lake was chosen because it experienced substantial water drawdowns and fisheries problems during the extended drought in the 1980's. It was cored in the spring of 1993, and the length of the core (10.4 m) was such that it allowed for a high resolution study. The complete core was made available for paleoecological study.

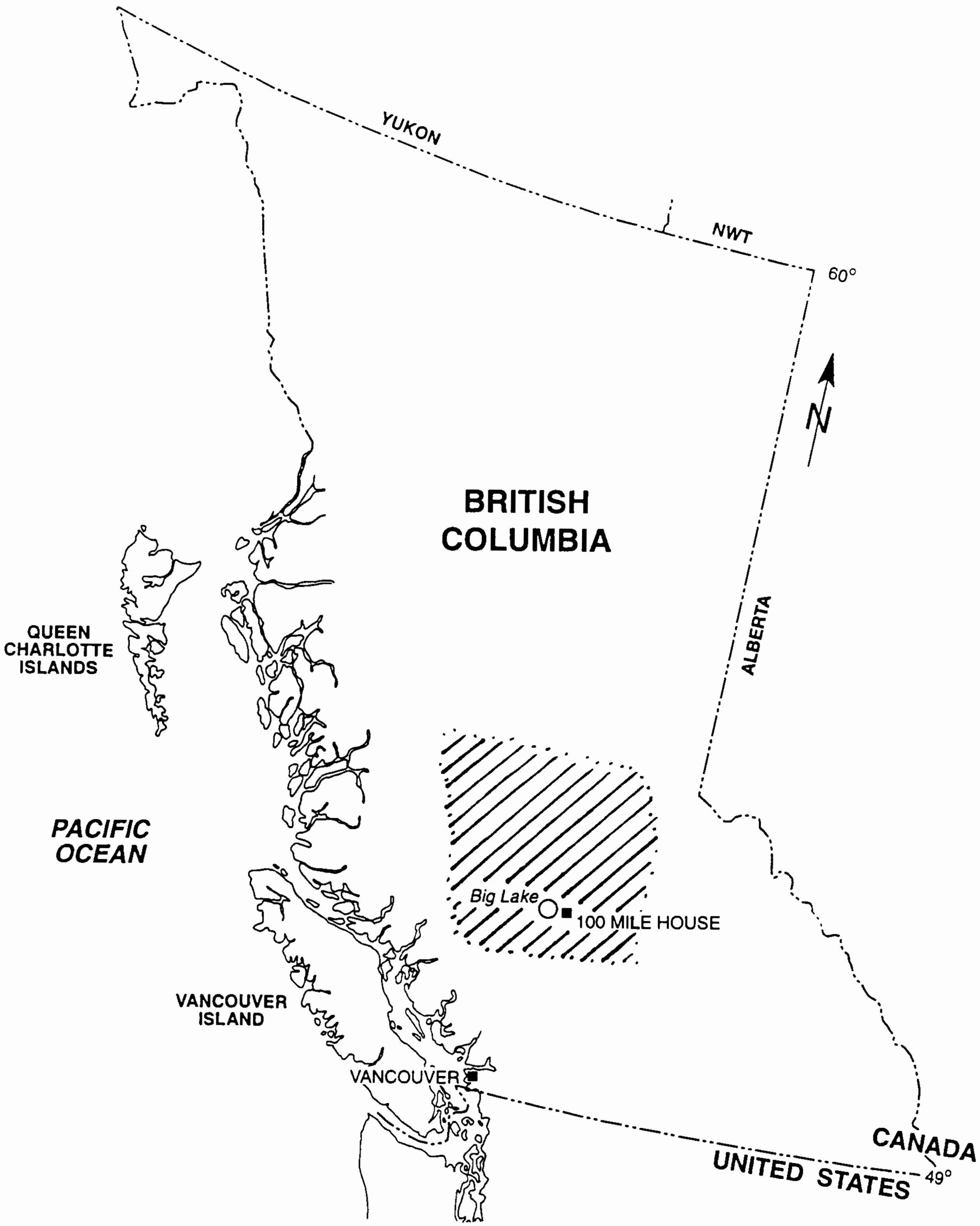


Figure 5.
Study site map, Cariboo Region
The Cariboo region of British Columbia, indicating the location of Big Lake.

Figure 6.
Big Lake
A partial view of Big Lake from the northern shoreline, looking southeastward, taken on August 15, 1995.

II. Methods

Field Methods

Mahoney Lake

Mahoney Lake was sampled during May, 1985 by Drs. Ken Hall and Tom Northcote, at which time a 5.45 m long core was taken from the deepest part of the lake using a McKean percussion corer (McKean and Nordin, 1986) with a 5 cm internal diameter. The core was stored in a freezer at the Westwater Research Centre at the University of British Columbia, Vancouver, Canada, until October, 1993 at which time it was subsampled for chironomid analysis. The core had been previously subsampled for various other analyses; thus, several large intervals were no longer available for sampling. Fifteen intervals were removed with the aid of spatulas, and placed in Whirl-pak© sampling bags. These subsamples were transported to the cold rooms of Simon Fraser University and Okanagan University College, and thereafter kept at 4° C until analysis was completed.

Kilpoola and Big Lakes

Kilpoola Lake was cored by Dr. Brian Cumming and Mr. John Glew in the early spring of 1993, at which time complete cores were removed from the deepest part of the lakes using a modified Livingstone piston corer with an internal diameter of 2.5 cm. The Big Lake core was 10.5 m in length, and the Kilpoola Lake core was 4.9 m in length. The cores were taken to the Paleoecological Environmental Assessment and Research Laboratory (PEARL) at Queen's University, Kingston, Canada where they were photographed, sectioned into 1 cm intervals, and stored using Whirl-pak© sampling bags. The intervals were maintained at 4° C.

Laboratory Methods

Chironomid analysis

Chironomid head capsules were extracted from the lake sediment using the method described by Walker et al. (1995). Sediment was treated with hot 10% potassium hydroxide solution to defloculate, followed by a water rinse, and then treated with 5% hydrochloric acid to remove any carbonates. The sediment was sieved on a 95 μm Nitex© mesh and the residue retained on the sieve was backwashed into a 100 ml beaker. The residue was later hand sorted for head capsules in a Borgorov counting tray under a Wild M5 dissecting microscope. 12- 25x magnification was used for head capsules floating on the surface and 25- 50x magnification was used when removing head capsules from the bottom. Individual, complete and partial remains were extracted with #4 forceps and placed onto coverslips, which were dried and mounted with Permount© medium.

Chironomids were identified with the aid of a Zeiss Universal compound microscope with Plan Neofluar objectives and 1.25X condenser, or an Olympus model BH S/2 compound microscope with 1.25X condenser. Identifications were made at 200 to 500X according to keys and descriptions prepared by Walker (1988), Wiederholm (1983), and Oliver and Roussel (1983). A photograph reference collection was prepared to promote consistency in identification, and to provide records of unidentified chironomids for possible future identification.

Dating and Ash Layers

Mahoney Lake

Radiocarbon dating by benzene synthesis and liquid scintillation counting was carried out on the Mahoney Lake core samples, providing old (Libby) half life radiocarbon ages (Lowe et al., submitted). The ash layer found between 2.82 and 3.45 m in the core was identified as the Mazama ash derived from Mount Mazama, now Crater Lake, Oregon, and the reported ages are corrected for the "hard water" effect and chronologically corrected to Mazama ash (Lowe et al., submitted). Mt. Mazama is recognised to have erupted ca. 6800 yr B.P. (Bacon, 1983).

Kilpoola Lake

Radiocarbon dating has not yet been performed on the Kilpoola Lake core. It is likely that the ash layer located between 294 and 303 cm is the Mazama ash, based on relative depth and colour.

Big Lake

Radiocarbon dating has not yet been performed on the Big Lake core. Clague (1981) places the Mazama ash plume as far north as Quesnel, B.C., therefore it is likely that the ash layer located between 566 and 569 cm is the Mazama ash, based on relative depth and colour.

Data Analysis

Data was compiled and analysed using Tilia version 2.0, written by Eric C. Grimm of Illinois State University Research and Collection Center (copyright 1991-1993). The chironomid stratigraphy diagrams were produced using Tilia Graph version 1.25 (Grimm, 1991). Chironomids are arranged in the figures in order of increasing salinity optima from left to right, with the exception of *Nilotanypus*. *Monopsectrocladius*, and *Xenochironomus*, for which no salinity optima are available (Walker et al., 1995). Constrained sum-of-squares cluster analysis (CONISS) was applied to the percentages of identified chironomids of Mahoney and Kilpoola Lakes. Intervals were stratigraphically constrained and zonations were based upon the examination of major differences in CONISS groupings.

Intervals were included in this study if they contained a minimum of 30 identified chironomid head capsules. Those intervals with less than 50 identifiable Chironomidae are included, but percentages are considered potentially suspect due to small sample size. Intervals with greater than 50 identifiable Chironomidae were considered to be representative of the chironomid community present at the time of deposition. Tables 1, 2, and 3 provide the totals of identified chironomids at each interval for Mahoney, Kilpoola and Big Lakes, respectively.

Chironomid inferred salinity was determined using the transfer function developed by Walker et al. (1995). They developed a weighted-averaging model based on 86 saline lakes of the central-interior plateau of British Columbia, incorporating tolerance downweighting and inverse deshrinking to provide an equation to infer salinity values from past chironomid communities. Appendix 2 contains a brief description of the transfer function, and the tolerance and optima data of the chironomids found in this study. Inferred salinity computations and graphs were prepared using Microsoft Excel 5.0.

Table 1. Chironomid Data for Mahoney Lake

Depth (cm)	Number of head capsules	Inferred salinity (g/l)
3	73.5	36.007
25	114	6.963
50	36.5	9.332
72	143	44.763
113	133	48.701
150	51.5	24.354
203	173.5	55.187
246	36.5	10.04
330	61.5	37.062
365	94.5	20.3
400	102.5	32.551
420	266.5	2.42
445	88.5	2.857
482	49	0.039
501	66	0.031

Table 2. Chironomid Data for Kilpoola Lake

Depth (cm)	Number of capsules	Salinity (g/l)	Sediment vol (ml)	Depth (cm)	Number of capsules	Salinity (g/l)	Sediment vol (ml)
2	50.5	1.855		210	78	1.789	2.3
12	51.5	2.033	4.3	222	105	1.714	5.5
19	10		5.4	235	96	2.111	3.1
21	4			241	48.5	2.543	3.2
25	35	2.204	5.1	251	121	4.942	3
31	6		3	257	107	7.722	2.9
32	1.5		5.6	267	45	7.357	3
40	42.5	3.541	3.6	277	25.5		3.5
41	1		0.8	287	76.5	1.576	3
47	20.5		5.9	297	2		4.2
54	77	1.522	2.1	307	124	1.826	3
63	46.5	1.746	2.7	308	98	1.832	2
72	77	1.418	2.6	317	121	1.566	3
75	22.5		3.3	327	132	1.834	3
83	51	2.535	3	337	75	1.579	3
85	46.5	0.713	6.7	347	122	1.591	3
92	13.5		3.4	357	102	1.531	3
98	87.5	1.363	3.4	367	91	1.951	3
103	56.5	1.565	2.6	377	77.5	1.757	3
110	138	1.731	4.4	387	67	1.916	3.3
118	123	1.959	4.4	397	62	1.972	3
129	118	1.873	5.7	407	22		3
136	137	1.862	5	417	13		3
149	96	1.52	3.2	427	13		3
150	134	1.6	2	437	61.5	0.037	3
160	133	1.132	3.8	443	43	2.06	1.3
171	206	1.304	3.2	453	21.5		3
182	274	1.665	6.1	463	97	1.172	3
190	169	1.61	3.1	473	65	0.035	3
200	53	2.733	2.6				

Table 3. Chironomid Data for Big Lake

Depth (cm)	Number of Capsules	Inferred Salinity (g/l)	Sediment vol. (ml)	Depth (cm)	Number of Capsules	Inferred Salinity (g/l)	Sediment vol. (ml)
0	9		1.1	295	8.5		1.4
10	5.5		2.3	311	27		1.5
20	43.5	1.15	1.9	409	114	1.24	2
30	28		2.1	414	223	1.355	2
40	9		1.7	434	179	0.839	2
50	164.5	1.199	3.2	454	295	1.369	1.9
60	81.5	1.208	2.7	474	626	1.605	2.5
70	9		1.7	494	264	1.195	2
80	3.5		2.5	510	220	3.236	1
90	149	1.377	2.6	618	5		1.9
100	41	1.43	2	716			2
101	5.5		1.6	725	486	1.587	2.7
111	5		3.4	744	254	3.097	1.6
121	14		3	764	120	1.461	2.1
131	3.5		3.3	784	98.5	3.13	2
141	15		1.9	804	100	1.776	1
151	8.5		1.7	824	133	1.259	1
161	13.5		1.9	831	239	1.44	2.1
171	53	1.413	3	849	180	1.381	*
181	8.5		2.2	889	26		1
191	13		2	909	40.5	1.393	1
205	20.5		1.5	928	4		1.2
215	11.5		0.7	948	207	1.123	*
225	37.5	1.196	0.8	968	10.5		*
235	102	3.115	1.5	988	19		*
245	12		*	1008	1		*
255	20		1.1	1047	0		*
265	7		*	1056	3		3.2
275	5		0.9	1067	0		*
285	7.5		*				

*volume not recorded

III. Results and Discussion

Mahoney Lake

Figures 7 and 8.

Zone Ia 500 cm to 462 cm

The basal sediments of Zone I are characterised by an abundance of Tanytarsina and a diverse assemblage of chironomids. There are significant freshwater indicators present such as *Heterotrissocladius*, *Sergentia*, and *Protanypus*. These genera are also considered to be cold-stenothermous taxa (Walker 1990; Walker et al., 1991a).

Zone Ia represents the only freshwater interval in the lake record with chironomid-inferred salinity values of less than 0.01 g/l. The freshwater probably originated primarily from precipitation and glacial meltwater, and did not yet have time to concentrate solutes by evaporation.

Analysis of diatoms (Wilson, pers. com.) also indicates a major change from freshwater to subsaline conditions occurring at 455 cm, corresponding to approximately 9800 yr BP.

Zone Ib 462 cm to 410 cm

The percentages of chironomids shift in Zone Ib; *Heterotrissocladius*, *Protanypus*, and Tanytarsina decrease as *Polypedilum*, *Cladopelma*, Pentaneurini, *Psectrocladius, Chironomus*, and the saline indicators *Tanypus* and *Cricotopus/ Orthocladius* increase.

The chironomid-inferred salinity in the sediments increases with the increased proportion of *Cricotopus/ Orthocladius*, indicating a shift to subsaline conditions. The timing of this increase corresponds to approximately 9000 yr BP. It is believed that the increase in salinity is due to a shift towards an evaporation-dominated water balance, suggesting a warmer and/ or drier period beginning in the early postglacial.

Zone II 410 cm to 60 cm

Zone II is characterised by a marked increase in *Cricotopus/ Orthocladius* (approximately 75 to 95%) and *Tanypus*, both recognised saline indicators (Walker et al., 1995). The disappearance and/ or decline of all other fresh or moderately saline chironomids is also seen in this transition. *Procladius* appears on three occasions in Zone II, only as the percentage of *Cricotopus/ Orthocladius* declines and Tanytarsina and *Chironomus* increase. *Psectrocladius* declines with the increase in *Cricotopus/ Orthocladius*, and does not vary significantly in this zone. The latter section of Zone II shows an oscillation in the *Cricotopus/ Orthocladius* percentage, with corresponding changes in *Chironomus*, Tanytarsina, *Tanypus*, and *Procladius* percentages.

The increase in chironomid-inferred salinity from subsaline conditions in Zone Ib to 30 g/l occurs rapidly, and during the remainder of Zone II increases to over 50 g/l.

The latter part of Zone II shows a reduction in chironomid-inferred salinity to less than 25 g/l, followed by an increase to nearly 50 g/l.

Higher salinities are seen until approximately 1870 yr BP (110 cm), when salinities are at their lowest since the early Holocene. The reduced salinity observed shortly after 5480 yr BP (249 cm) is suspect, as dense algal material in the sample may have interfered with unbiased picking of chironomid head capsules.

The highest salinities were observed during the mid to late Holocene when paleobotanical evidence (Hebda, 1995) suggests that precipitation was the greatest. Higher temperatures than present may have maintained an evaporation/ precipitation balance in favour of evaporation.

Zone III 60 cm to 0 cm

Zone III is characterised by a return to chironomid conditions similar to those seen in Zone Ib. Tanytarsina and *Psectrocladius* make up significant portions of the chironomid community, and the percentage of *Cricotopus/ Orthocladius* is reduced. *Procladius* and *Psectrocladius* return in significant numbers, however, an absence of all freshwater or moderately saline chironomids is noted.

This zone is marked by a sharp decline in chironomid-inferred salinity, to less than 10 g/l, at approximately 1000 yr BP. Declining temperatures thought to have occurred since 4000 yr BP (approximately 180 cm) may have shifted the evaporation/ precipitation balance towards decreased evaporation, resulting in higher lake levels and lower salinities. The decrease in salinity may in fact be evidence for a neoglaciation such as the Little Ice Age (Grove, 1988).

The most recent sediments of Zone III records a shift in the chironomid community towards one similar to that seen in Zone II. The *Cricotopus/ Orthocladius* proportion increases with a corresponding decrease in Tanytarsina and *Psectrocladius* percentages. The chironomid-inferred salinity values increased to over 35 g/l, and may be evidence for a recent warming trend of this century (reference, year)

Figure 7.
Mahoney Lake Chironomid Stratigraphy

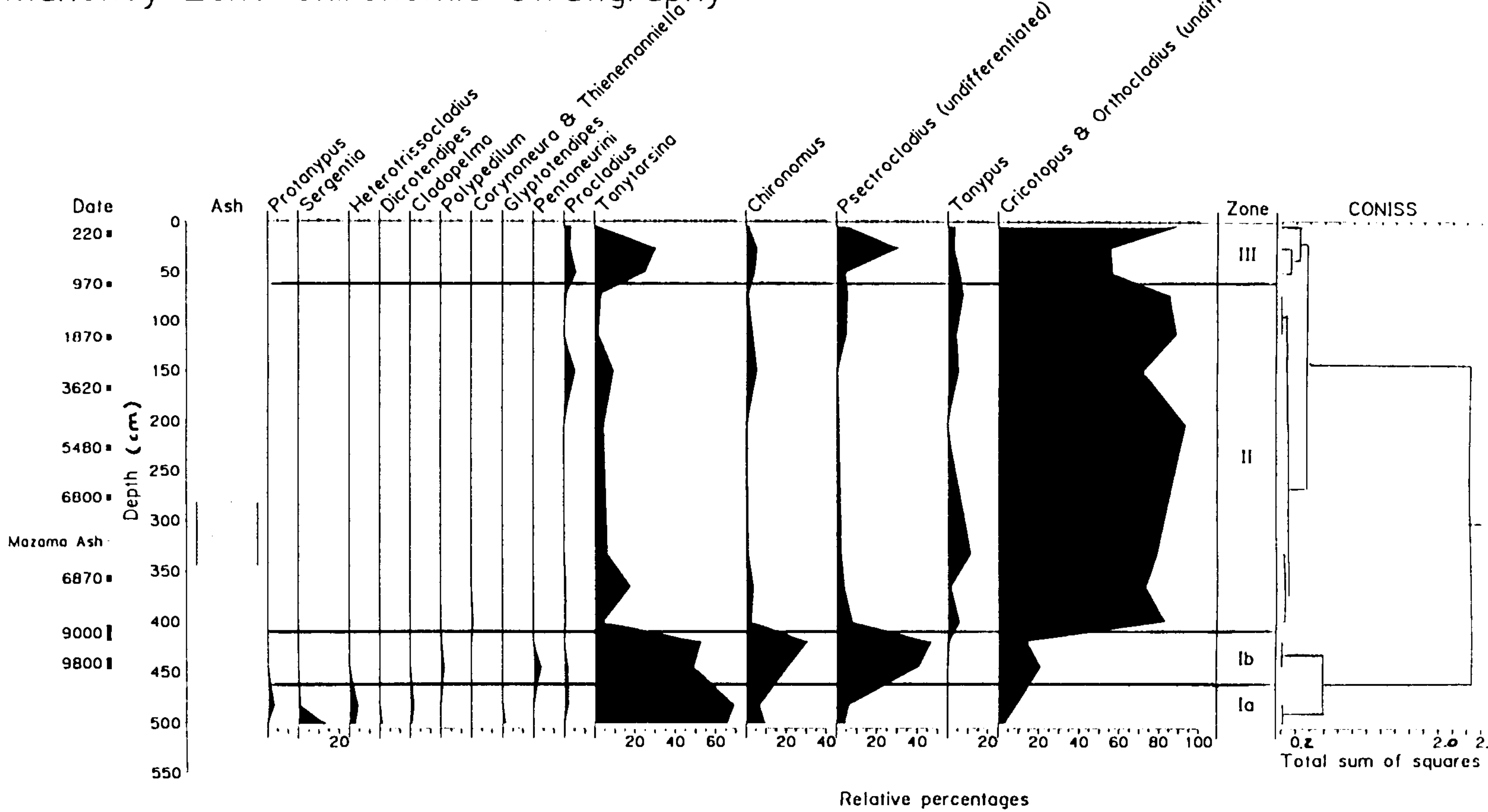
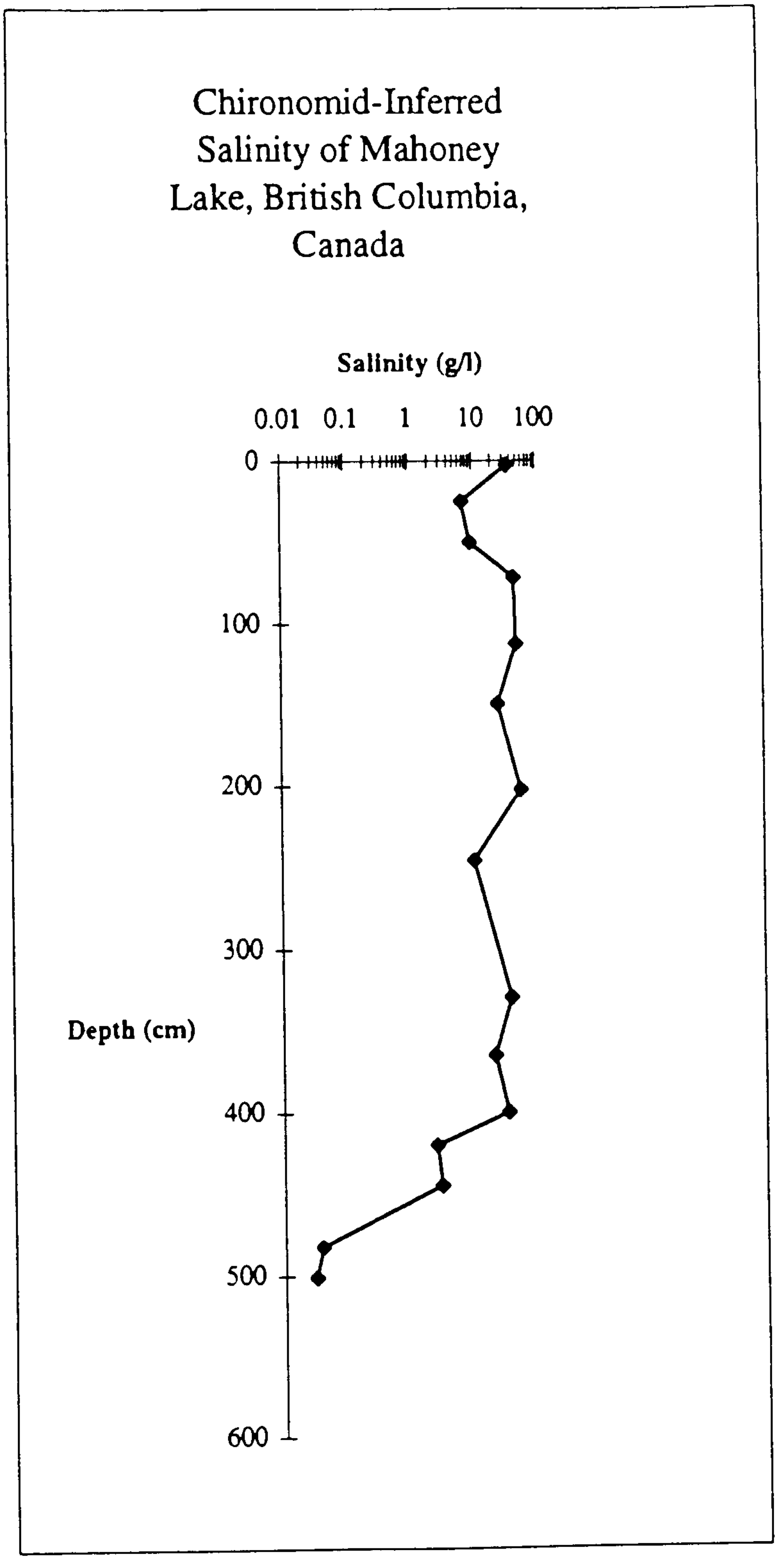


Figure 8.
Chironomid-inferred Salinity of Mahoney Lake



Kilpoola Lake

Figures 9 and 10.

Zone Ia 473 cm to 453 cm

Zone Ia is identified by the presence of freshwater indicator taxa including *Microtendipes, and Heterotrissocladius*. In the next interval, there are no remains of *Heterotrissocladius*, but a sharp increase in *Chironomus* is recorded coincidentally with a decrease in Tanytarsina. Subsaline-to-saline condition chironomids such as *Dicrotendipes, Glyptotendipes, Procladius* and *Psectrocladius* are indicated, however, species richness is low.

The chironomid-inferred salinity reflects the distribution of freshwater indicator species, as the basal inferred salinity is less than 0.05 g/l, suggesting high lake levels, perhaps due to glacial meltwater.

Zone Ib 453 cm to 412 cm

The subsequent interval has a salinity greater than 1 g/l suggesting warmer or drier conditions with high rates of evaporation. However, the appearance of *Sergentia* and Tanytarsina and a decrease in *Chironomus* was noted in the uppermost sample from this zone, yielding a chironomid-inferred salinity less than 0.05 g/l. The return to freshwater conditions suggests higher lake levels, probably due to a cooler, moister climate.

The apparent shift in Zones Ia and Ib to subsaline conditions, and return to freshwater conditions is intriguing, as it suggests a climatic oscillation. However, this possibility requires further evaluation since the chironomid sample sizes are low, and the inferred salinities are very sensitive to the presence/ absence of a few uncommon, but important indicator taxa. Larger sample sizes, closer interval sampling, and independent evidence from forthcoming analyses should help to resolve this possibility.

Zone II 412 cm to 277 cm

Zone II is relatively complex in its chironomid assemblages. Large shifts in percentages of Tanytarsina and *Chironomus*, intermittent appearances of *Cryptochironomus*, *Cladopelma, Psectrocladius, Cricotopus/ Orthocladius* and *Glyptotendipes* occur in this zone. The presence of *Procladius* throughout this zone suggests moderate salinities, however at the point where *Procladius* decreases (at 367 cm) an increase in *Cricotopus/ Orthocladius*, *Tanypus* and *Monopsectrocladius* may be observed. The appearance of *Labrundinia, Derotanypus*, and Pentaneurini also occurs in this zone.

Zone II has a near constant salinity, ranging between 1 and 2 g/l. This zone has slightly less chironomid richness than the previous zone. Zone II ends with deposition of Mazama ash.

Zone IIIa 277 cm to 246 cm

The chironomid fauna changes abruptly after the eruption of Mt. Mazama, as seen by a rapid increase in *Cricotopus/ Orthocladius* and *Tanypus*, and a slower increase of *Monopsectrocladius* and *Psectrocladius*. Corresponding decreases in *Chironomus, Cladopelma* and *Glyptotendipes* are also observed.

The chironomid-inferred salinity during this period reflects the drastic change in assemblage, increasing from 1 g/l to approximately 8 g/l, followed by a decrease to approximately 2 g/l.

The deposition of Mazama ash had an apparent affect in increasing the salinity of Kilpoola Lake. Hebda (pers. com.) reports that volcanic tephras have apparently changed the nature of bogs on Vancouver Island, and Wigand (pers. com.) also indicates that volcanic ash deposits alter lake environments in the American south west.

Unpublished data from Hall (Appendix 1) shows a marked increase in concentrations of calcium, magnesium, iron and phosphorus ions in Mahoney Lake sediments deposited immediately after the ash layer. Soluble constituents from Mazama ash may be responsible for the apparent increase in salinity instead of a rapid increase in temperature or decrease in precipitation.

Zone IIIb 246 cm to 143 cm

The return to salinities similar to those prior to the eruption of Mt. Mazama indicates a stable climate, similar to that seen in Zone II.

The percentage of *Cricotopus/ Orthocladius* decreases around 246 cm, with corresponding increases in both *Chironomus* and Tanytarsina. Tanytarsina appear to be relatively unaffected by any changes in lake environment. Overall density increases, with *Nilotanypus, Corynoneura/ Thienemaniella, Xenochironomus* and *Parakiefferiella* cf. *bathophila* appearing for the first time, and the return of

Dicrotendipes, Labrundinia, Cryptochironomus, Cladopelma, Glyptotendipes, Pentaneurini, and *Procladius*. The assemblage appears to remain relatively consistent until the end of this zone.

The chironomid-inferred salinity for the latter part of this subzone does not reflect the stability in assemblage, but rather the increase in diversity, as a range in salinities from approximately 1 to 3 g/l are observed.

Zone IIIc   143 cm to 0 cm

Subzone IIIc is characterised by large oscillations in Tanytarsina and *Chironomus* percentages, and species diversity fluctuations are greatest during these periods. *Cryptochironomus* and Pentaneurini are not seen in this subzone. A small increase in *Cricotopus/ Orthocladius* and *Psectrocladius* is apparent at approximately 50 cm, and *Tanypus* is observed in the most recent sediments.

The chironomid-inferred salinity shows similar oscillations, decreasing to 0.7 g/l at 85 cm, and immediately increasing to 2.5 g/l at 83 cm. Further increases raise the salinity to 3.5 g/l at 40 cm, however towards 0 cm, the salinity returns to approximately 2 g/l. These apparent salinity changes are probably well within the errors inherent to chironomid-salinity inferences, and probably do not reflect real salinity changes (Walker, pers. com.).

The major setback to comparing salinity changes and climatic inferences from the Kilpoola data with other evidence of regional climatic change originates from the lack of radiometric dating evidence. Other than the date from Mazama ash, no measure of sedimentation rate or timing of events is possible. Future research will provide dates from pollen and/ or macrofossils.

At this time, it seems likely that the early freshwater intervals of Zone I represent late-glacial conditions at Kilpoola Lake, followed by a rapid warming at the onset of the Holocene (beginning of Zone II), but radiocarbon dates are necessary to confirm this interpretation.

Figure 9.
Kilpoola Lake Chironomid Stratigraphy

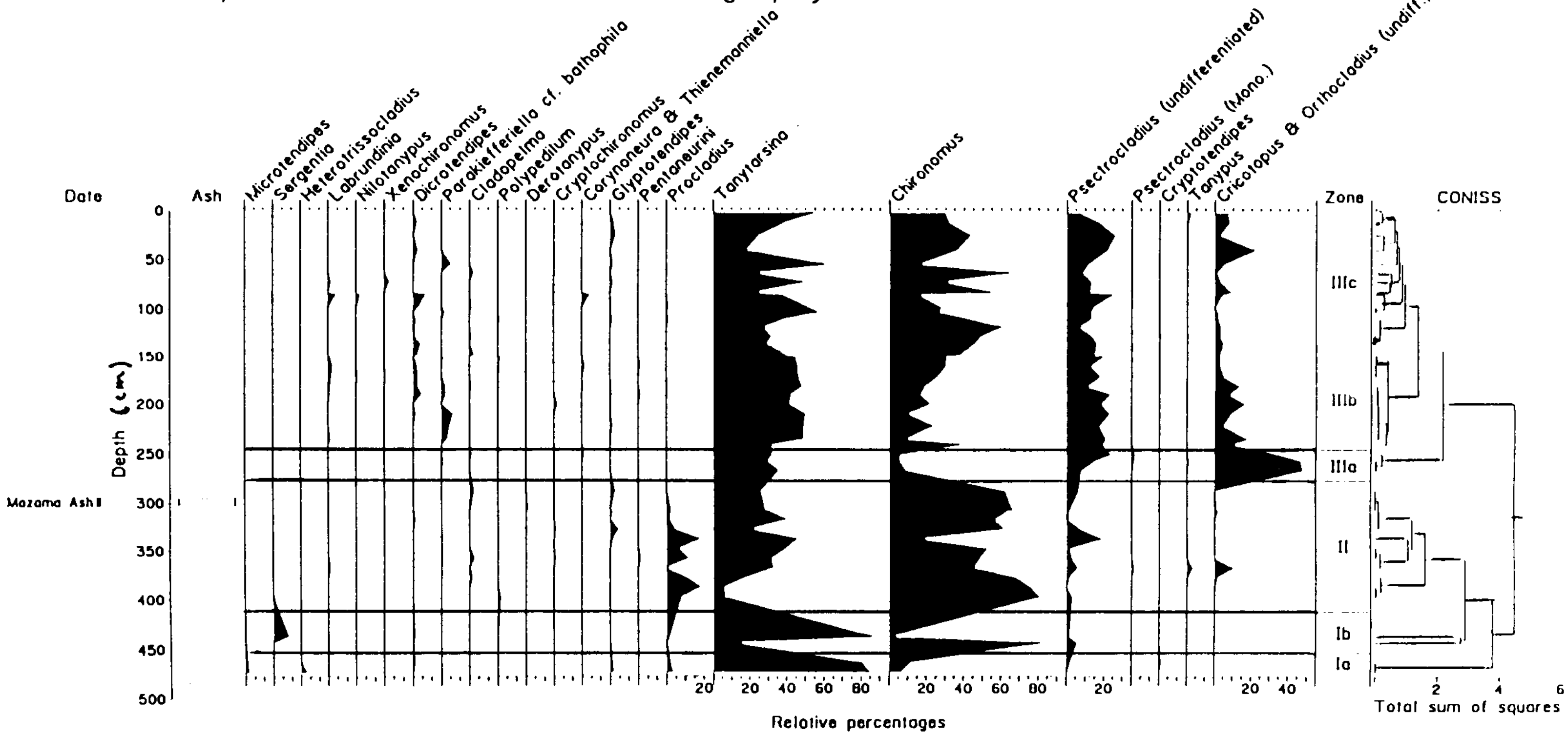
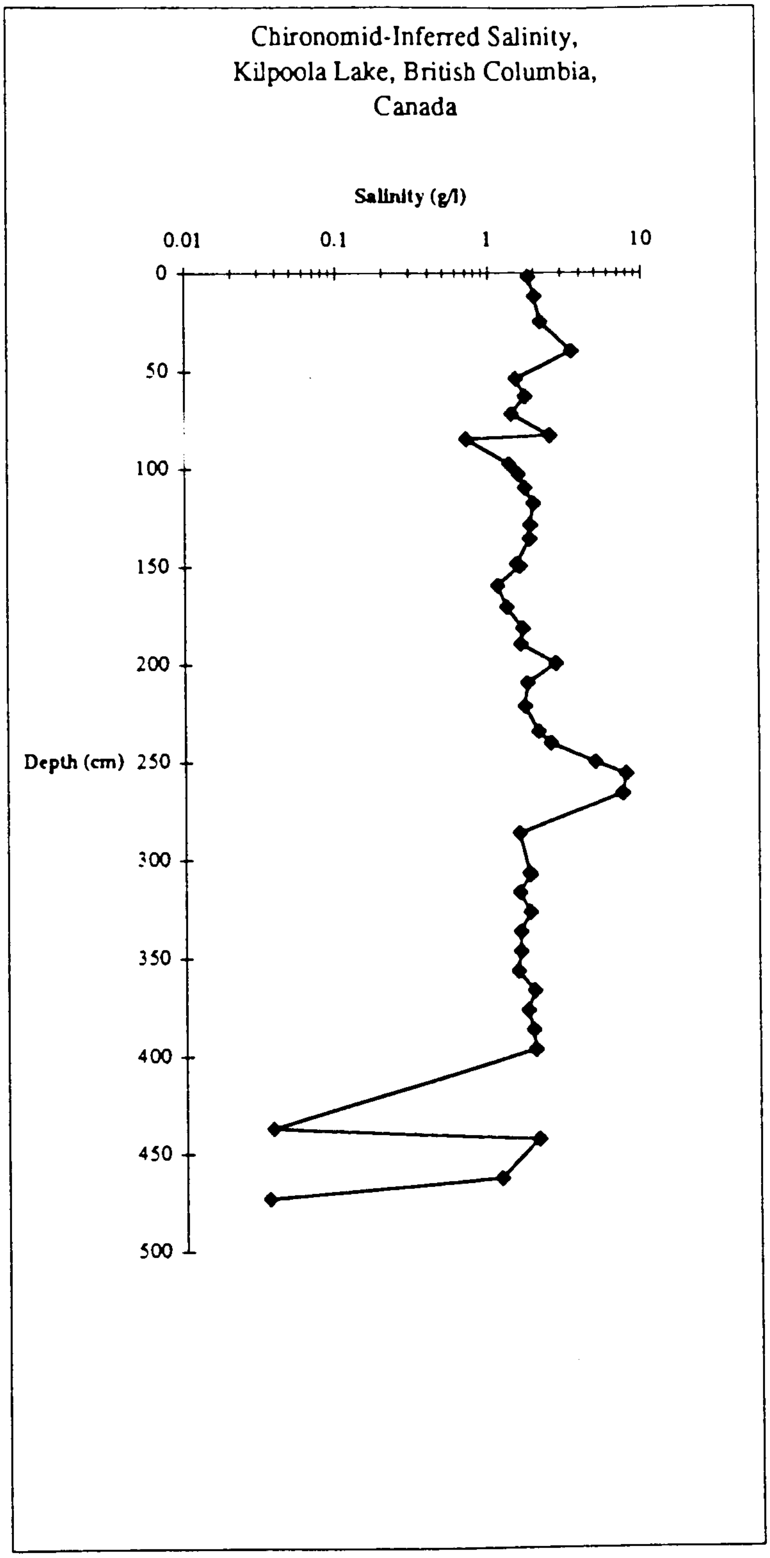


Figure 10.
Chironomid-inferred Salinity of Kilpoola Lake



Big Lake

Figures 11 and 12.

The basal sediments of Big Lake contained few chironomid remains (Table 4), and those intervals which did have enough chironomids to be statistically significant contained no freshwater indicator species, such as *Heterotrissocladius, Microtendipes* or *Sergentia.* The assemblage present consists primarily of Tanytarsina, *Chironomus, Procladius, Parakiefferiella cf. bathophila,* and *Psectrocladius,* which are all tolerant of moderate salinities. *Cricotopus/ Orthocladius,* a saline indicator, is found in small numbers throughout the core. The initial chironomid-inferred salinity is 1 g/l, at the basal interval, and only increases to a maximum of 3 g/l during the entire Holocene record.

The overall impression is one of stability. There is little indication of faunal changes throughout the record. The apparent salinity changes are probably within the errors inherent in the chironomid-salinity inference model.

It is possible that the location of Big Lake, which is not in a semi-arid region but in one that is more moderate, contributes to the lack of sensitivity to climate change. The low-resolution reconstruction makes any detailed inferences regarding regional climate change difficult, and the lack of radiometric dating make correlation of events nearly impossible. Chironomid head capsules were present in low concentrations throughout most of the core; thus relatively few samples contained greater than 50 head capsules. Until radiocarbon dates are obtained, it will not be possible to determine whether the core penetrated late-glacial sediments (>10,000 yr BP) or whether the stable environment reflects only the relatively stable climatic conditions of the Holocene (after 10,000 yr BP).

Figure 11.
Big Lake Chironomid Stratigraphy

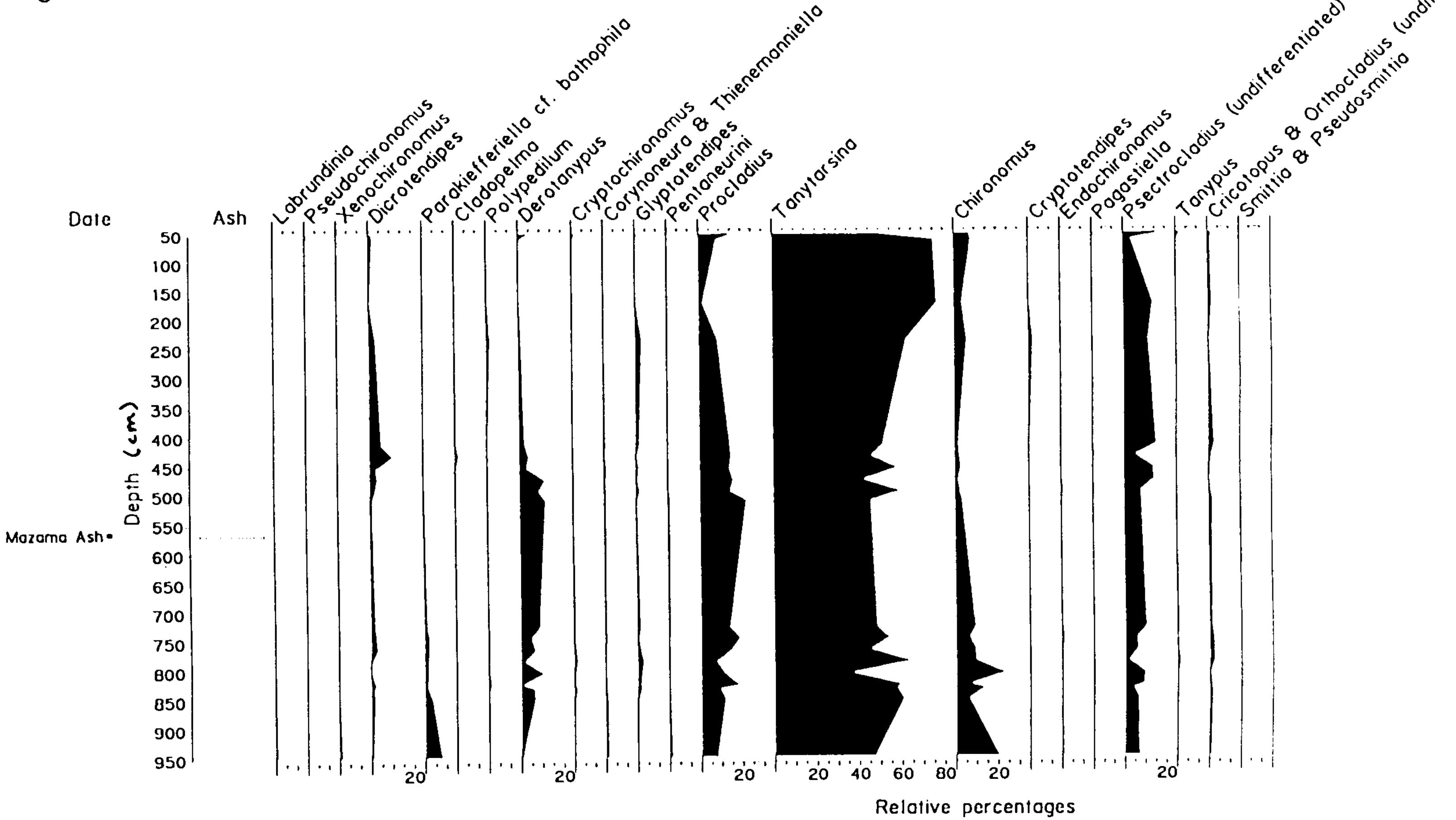
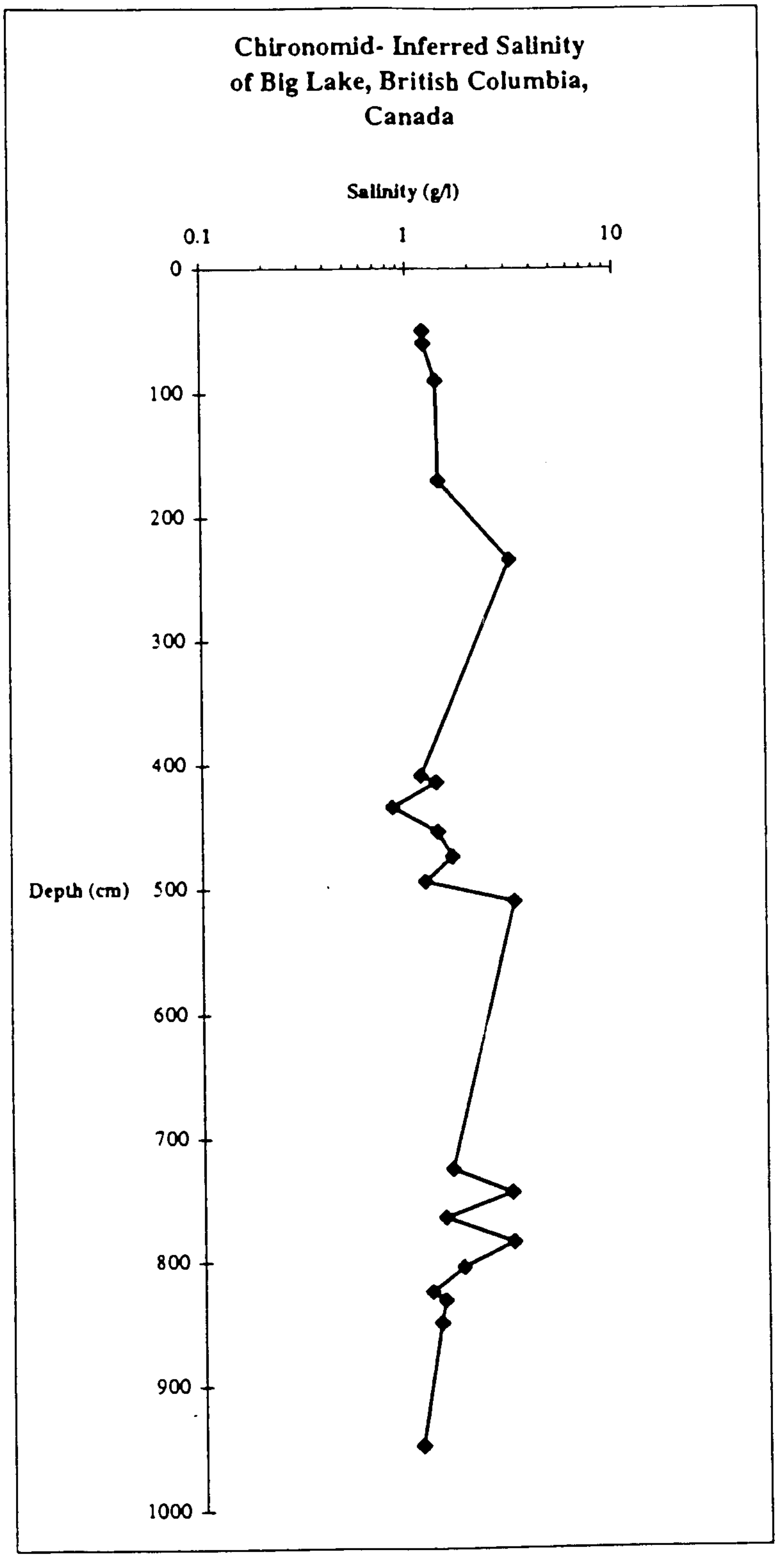


Figure 12.
Chironomid-inferred Salinity of Big Lake



Implications for Regional Limnology and Climate Change

The late-glacial is generally considered to have been cool and moist in the south-central interior of British Columbia (Hebda, 1995), changing rapidly in the early Holocene such that the climate was much warmer and drier than present, from 9000 until approximately 7000 yr BP, when precipitation increased. Temperatures remained higher until approximately 4000 yr BP, when a modern climate was established with the reduction in temperature and an increase in precipitation.

Paleosalinity reconstructions from Mahoney and Kilpoola Lakes show a transition from freshwater to saline environments early in their history. This suggests a trend toward warmer or drier climate early in the Holocene. It may also be coincident with decreased lake levels. Salinities reach a maximum at Mahoney Lake at 9000 yr BP, suggesting that for this region, the xerothermic interval began at this time. The pre-Mazama Holocene record of Mahoney Lake indicates mesosaline conditions, suggesting a warm and dry climate. Mesosaline conditions persisted at Mahoney Lake until 1000 yr BP. The subsequent decrease may reflect declining temperatures and a shift in the evaporation / precipitation water balance, resulting in higher lake levels, perhaps evidence of the Little Ice Age. The most recent sample indicates a return to higher salinity, suggesting the presence of a current warming trend.

Apart from the initial salinity changes in the basal 50 cm of the Kilpoola Lake core, and those changes associated with the Mazama ash, Kilpoola Lake has remained relatively stable; thus Kilpoola Lake's record does not appear to provide a sensitive record of Holocene climate. Similarly, the fauna and inferred salinities at Big Lake appear to have remained stable and do not appear to provide a sensitive climatic record.

The pattern apparent in the development of saline lakes in the south-central interior of British Columbia suggests a marked increase in temperature after the late-glacial or in the early Holocene, resulting in a transition from freshwater to saline conditions.

IV. Conclusions

Sediments from Mahoney, Kilpoola, and Big Lakes in the south-central interior of British Columbia were analysed for chironomid remains, and a postglacial paleosalinity record was inferred for this region. This study is the first to use chironomids as quantitative indicators of paleosalinity, making use of the transfer function developed by Walker et al. (1995). From the inferred paleosalinity of these lakes, a reconstruction of postglacial climate was developed and compared with accepted climate trends. The synchronous occurrence of climate shifts suggested by chironomid-inferred salinity cannot be accurately compared with accepted trends of the decrease of precipitation at 8000 yr BP and temperature at 4000 yr BP, due to the lack of radiometric dating of Kilpoola Lake. However, there does appear to be a general correlation between the Mahoney and Kilpoola Lakes and the accepted climate trends of the late-glacial or early Holocene period. Mahoney and Kilpoola Lakes indicate a shift from freshwater to saline conditions early in the Holocene, suggesting an increase in temperature. Both these lakes have relatively stable chironomid-inferred salinities through the mid Holocene, but they both have a decrease in salinity late in the Holocene which may correspond to the Little Ice Age.

Further research to obtain accurate radiometric dating of Big and Kilpoola Lakes and to develop a higher resolution analysis of Big Lake is planned. Combining this study with diatom and chrysophyte data in order to reconstruct climate as part of the PISCES II programme lakes is also anticipated, and will provide an independent assessment of the salinity changes and climatic implications suggested by the present study.

The application of chironomids in paleosalinity reconstructions appears to be a valuable and useful technique in examining climate change. However, caution must be employed when choosing study sites, as a closed-basin, non-ephemeral nature, sensitivity in the precipitation/ evaporation water balance, an absence of groundwater input, and a current subsaline to hyposaline condition are all characteristics which aid in the lake's ability to maintain a complete and sensitive climatic record. It is hoped that future paleosalinity reconstructions will provide a clearer and more accurate interpretation of paleoclimates not only in the south-central interior of British Columbia, but in semi-arid regions worldwide.

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VI. Appendix 1. Unpublished Data from Mahoney Lake, courtesy Dr. Ken J. Hall

Depth (cm)	Ca (mg/kg)	Mg (mg/kg)	Fe (mg/kg)	Total P %
0	51300	41200	3510	0.048
5	73300	38600	1630	0.046
15	82600	32200	2240	0.04
25	82200	37500	3680	0.05
35	79300	28100	3240	0.042
45	73800	54100	2150	0.049
55	58800	41100	1640	0.044
65	74100	37000	1990	0.053
75	101000	29600	1840	0.049
85	95300	41600	1500	0.049
95	56900	22200	2710	0.052
105	63400	20100	2850	0.048
115	51000	21800	2490	0.058
125	48300	20000	3080	0.047
135	58600	26700	2320	0.043
145	78400	21600	2700	0.043
155	63100	18400	2630	0.041
165	51100	18400	2470	0.04
175	23500	31500	2590	0.043
185	59400	20900	2490	0.047
195	56300	65900	2830	0.044
205				0.057
215	121000	79700	2520	0.096
225	70900	64200	5800	0.053
235	119000	70400	3940	0.067
245	91500	48100	4710	0.063
255	14400	20300	34500	0.081
265	110000	70300	2110	0.06
275	11600	15800	16100	0.047
285	14900	10700	6970	0.032
295				*
305				*
315				*
325	12500	8440	10700	Mazama
335				ash layer
345				*
355				*
360	100000	55900	8490	0.07
365	58700	28000	7260	0.066
375	23800	24000	8810	0.057
385	7280	15100	12000	0.061
395	73600	49600	8300	0.067
405	53000	37900	10900	0.072
415	10300	14600	12700	0.071

continued on next page

Depth (cm)	Ca (mg/kg)	Mg (mg/kg)	Fe (mg/kg)	Total P %
425	63200	46100	11600	0.081
435	116000	73400	8680	0.088
445	123000	81100	9050	0.088
455	16200	20700	18400	0.086
465	5800	14800	35100	0.113
485	23900	23600	34100	0.118
505	5100	10000	23100	0.13
525	6640	10100	25400	0.159
545	5190	9850	25800	0.034
555	7050	6480	17400	0.101

VII. Appendix 2.

Chironomid-Inferred Salinity Transfer Function, and Salinity Optima and Tolerances for Chironomids Found in this Study

Portions of Appendix 2 were taken from the following paper, which describes the transfer function in detail:

Chironomidae (Diptera): Quantitative Paleosalinity Indicators for Lakes of Western Canada
Ian R. Walker, S.E. Wilson, and J.P. Smol, 1995, *Canadian Journal of Fisheries and Aquatic Sciences* (1995).

Abstract

A survey of chironomid remains preserved in the surficial sediments of 86 British Columbia lakes was conducted to assess the feasibility of reconstructing palaeosalinities from assemblages of fossil chironomid head capsules. Many taxa common in freshwater lakes were rare or absent at higher salinities. Lakes having salinities greater than about 10.0 g/l were distinguished by the overwhelming relative abundance of *Cricotopus/ Orthocladius*. In less saline waters, common taxa included *Chironomus, Procladius, Psectrocladius* and the subtribe Tanytarsina. *Heterotrissocladius, Lauterborniella/ Zavreliella, Pagastiella* and *Sergentia* were only collected in freshwater habitats.

Canonical correspondence analysis revealed that three environmental variables (late summer lakewater salinity, and concentrations of Sr and Total P) explained significant variation in the weighted averages of taxa. Tanytarsina and *Dicrotendipes* were common at low [Sr] in carbonate lakes. A weighted-averaging calibration function was developed to infer salinity on the basis of fossil fauna. This model will allow palaeolimnologists to detect transitions between freshwater and moderately saline states, and can be used to assist palaeoclimatic reconstructions for athalassic lake sites.

Table of optima and tolerance of chironomids used in the weighted averaging model of this study to generate chironomid-inferred salinities. Inferred salinities (mg/l) may be calculated as :

$$x_i = a + b\left[\left(\sum_{k=1}^{m}\left(y_{ik}u_k / t_k^2\right)\right) / \sum_{k=1}^{m}\left(y_{ik} / t_k^2\right)\right]$$

where x_i = the inferred salinity for sample i, a and b are the intercept (-1.341) and slope (1.447) of the deshrinking equation, y_{ik} is the relative abundance of taxon k in sample i, u_k is the optimum (as $\log_{10}$ (mg/l)) of species k, and t_k is the tolerance of species k (Fritz et al., 1991; ter Braak, 1987).

Taxa	Optimum (u_k)		Tolerance (t_k)
	mg/l	$\log_{10}$ (mg/l)	$\log_{10}$ (mg/l)
Cricotopus/ Orthocladius	21135	4.325	0.798
Tanypus	5070	3.705	1.330
Cryptotendipes	3451	3.538	0.534
Derotanypus	2249	3.352	0.438
Psectrocladius	2234	3.349	0.638
Chironomus	1738	3.240	0.747
Procladius	1211	3.083	0.713
Cryptochironomus	1079	3.033	0.770
Glyptotendipes	1072	3.030	0.729
Tanytarsina	1064	3.027	0.680
Pentaneurini	995	2.998	0.701
Corynoneura/ Thienemanniella	634	2.802	0.685
Polypedilum	573	2.758	0.601
Dicrotendipes	422	2.625	0.495
Parakiefferiella cf *bathophila*	378	2.577	0.672
Cladopelma	226	2.355	0.499
Labrundinia	188	2.274	0.286
Microtendipes	104	2.019	0.925
Heterotrissocladius	85	1.930	0.031
Sergentia	83	1.921	0.061