Paleolimnological analysis of Windermere Lake, B.C -- Final Report (March 1999).

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BACKGROUND

Windermere Lake was cored on July 23, 1998 by Rick Nordin and Les MacDonald. 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. These samples were shipped on ice to Queen's University where they were stored in our coldroom at 4°C. Each container was weighed to determine the total wet weight of sediment then subsampled for ^{210}Pb, diatom and pigment analyses. Twenty intervals (every 2 cm) were subsampled for diatom and pigment analyses, and sixteen intervals for ^{210}Pb analysis. Subsamples for analysis of pigments were sent to Prof. Leavitt at University of Regina. 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. 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}Pb activity that was shipped to MYCORE Ltd.

Percent organic matter for each of the 16 ^{210}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 original 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}Pb activities were estimated from determination of 209-Po and a tracer of known activity by alpha spectroscopy. Unsupported ^{210}Pb is calculated by subtracting supported ^{210}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}Pb activities and estimates of cumulative dry mass (Binford, 1990). See Appendix B for summaries of ^{210}Pb analyses by MYCORE (B-1), summary of ^{210}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 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 under oil immersion at 1000X magnification using an objective with a numerical aperture of 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

Cluster analysis, which groups similar diatom assemblages, was run on the taxa represented in Fig. 2. Cluster analysis on the diatom assemblage composition was constrained to the depth of the core samples to provide an unbiased assessment of changes in diatom assemblages through time. A squared chord was used to determine similarity between samples in the cluster analysis (Fig.2). Zones were placed based on these analyses to represent distinct groups in diatom assemblages through time (dashed line on Fig. 2).

Environmental Reconstructions from diatom assemblages

Inferences of total phosphorus downcore were based on a total phosphorus model based on the 111 freshwater lakes from the 219 lakes sampled by Wilson, Cumming & Smol (1996). This model is based on estimates of taxa optima 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 downcore 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 correlated to phosphorus. If the directions of variation do not match, then the diatom-inferred phosphorus reconstructions do not fully represent the changes, if any occurred, in diatom species composition downcore. Presumably, other environmental variables, or interactions between environmental variables, are contributing to the changes in diatom assemblages.

The main direction of variation in the diatom assemblages downcore in Windermere Lake was determined from the first axis scores from a principal components analysis (PCA) ordination using a co-variance matrix and non-transformed species abundance data. A PCA was chosen to represent the main direction of variation in this core since only minor changes in diatom assemblages occurred and thus a linear ordination technique would more effectively capture changes in this core then an approach based on unimodal techniques.

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 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 caution 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 Windermere Lake shows a slight flattening in activity in the top 2 cms of the core(Fig. 1A). The two most likely explanations for this pattern in the ^{210}Pb profile are: 1) an increase in sedimentation rate that could cause a dilution of the ^{210}Pb activity; or 2) slight sediment mixing. Small changes in the precent organic matter and diatom assemblages in the top few centimeters do not allow us to rule out slight mixing in the uppermost 2 cm of this core. Sedimentation rates in general are quite slow resulting in the short core representing a fairly long span of time, with estimated bottom dates of the early 1700s. The inferred increase in sedimentation rate from approximately 1920 to 1960(Fig. 1B) corresponds to a few percent increase in percent organic matter (Fig. 1C, * note the different time scales). 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 sediment to the lake. Historical information on the development of Windermere Lake may provide insight to these patterns.

Diatom Assemblage Changes and Analyses

Approximately 85 diatom taxa were encountered in the sediment core from Windermere Lake (Appendix C-1). The assemblages are dominated by a diversity of benthic taxa, such as *Fragilaria brevistriata*, *Fragilaria construens*, *Fragilaria pinnata*, *Navicula vitabunda*, and *Navicula* cf. *minuscula*. The latter two *Navicula* taxa only occur in the modern-day B.C. dataset at low abundances (6% or less) and thus not a lot is known about the ecological preferences of these taxa. The rest of the assemblage consist primarily of other benthic taxa in the genera *Amphora*, *Gomphonema*, *Navicula*, *Nitzschia*, and the ephiphytic taxa (live attached to macrophytes) in the genera *Achnanthes*. Planktonic taxa are very rare, with *Cyclotella gamma* being the only taxon to reach greater than 2%.

Cluster analysis suggests the changes in diatom assemblages through time can be divided into two primary zones (Fig. 2). The difference in zones A and B is the loss of *Nitzschia bacillum*, *Navicula diluviana*, and *Achnanthes rosenstockii* in Zone A, and the increase or appearance of other taxa such as *Navicula* cf. *minuscula, Cyclotella gamma*, *Navicula modica*, and *Navicula schaderi* in Zone A. The latter three taxa are not in the modern-day B.C. dataset, and thus little is known of their ecological requirements in this region.

The changes that have occurred in the diatom assemblages are quite minor and this is reflected in the small changes seen in the inferred total phosphorus (TP). TP has remained relatively stable since the 1700s, with a small increase in TP since approximately 1950 (Fig. 1E). However, these latter changes are being largely driven by the increases in *Navicula* cf. *minuscula*, which we have poor analogs (Fig. 1F), and thus the TP estimates must be viewed as preliminary at this time.

PCA axis 1 scores (Fig. 1D) accounts for 66% of the variation in diatom taxa in this core. The correlation between the reconstructed TP and the main direction of variation in taxa(represented by PCA axis 1 scores) is 0.75 when all 20 points are considered, which suggests that the changes seen in the diatom assemblages may be related to changes in total phosphorus.

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Figure Captions

Figure 1. Summary diagram for the sediment core from Windermere 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. Diatom stratigraphy of the diatom taxa that were present in at least ~2% relative abundance in the sediment core from Windermere 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. Those taxa without known optima are marked with an asterisk. The dotted line separates the stratigraphy into two zones that were identified by a cluster analysis on the diatom assemblage composition that was constrained to the depth of the core samples. ^{210}Pb dates with an asterisk are based on extrapolation of the sedimentation rates of the bottom two dates with unsupported ^{210}Pb activity.

FIGURE 1

Windermere Lake , British Columbia

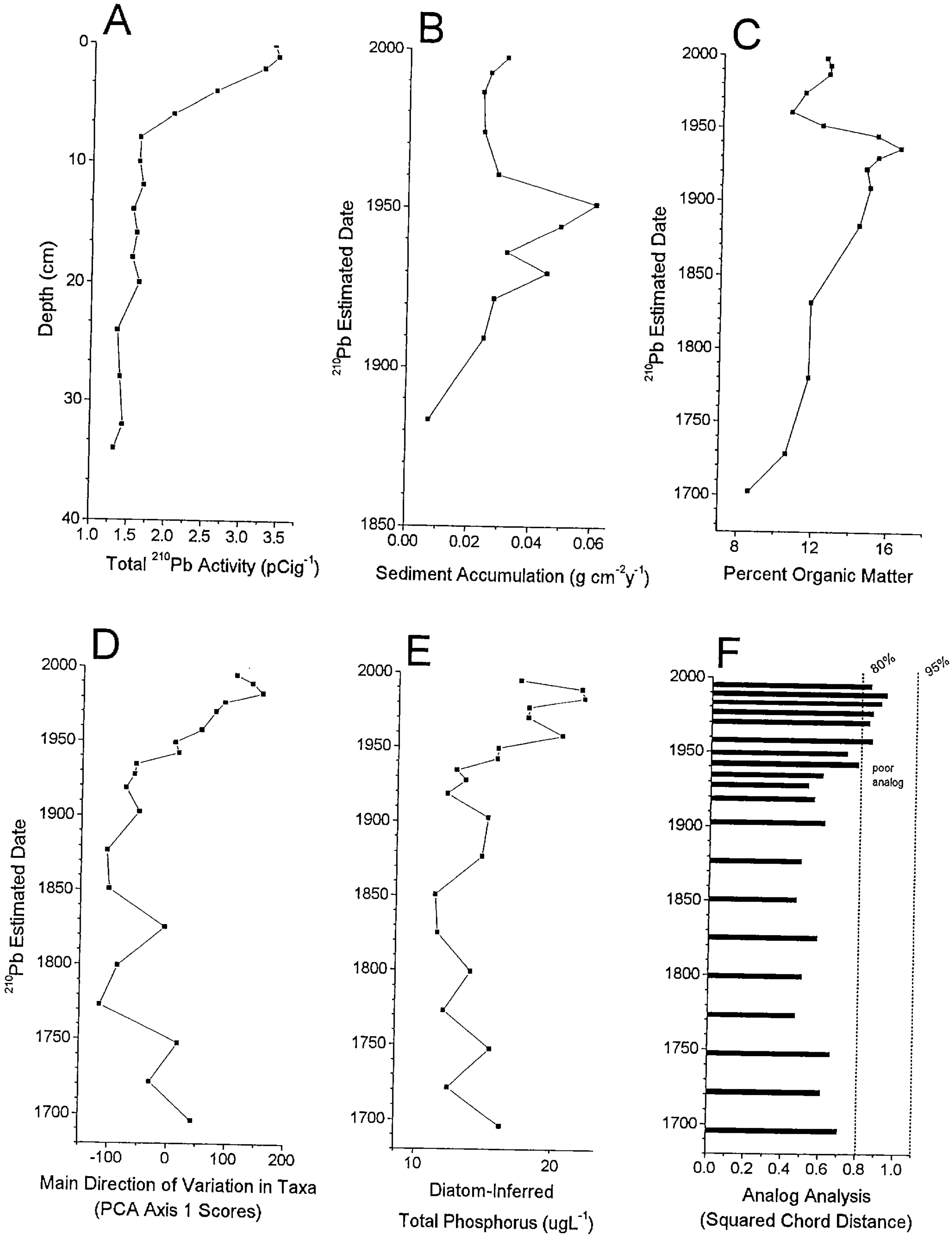
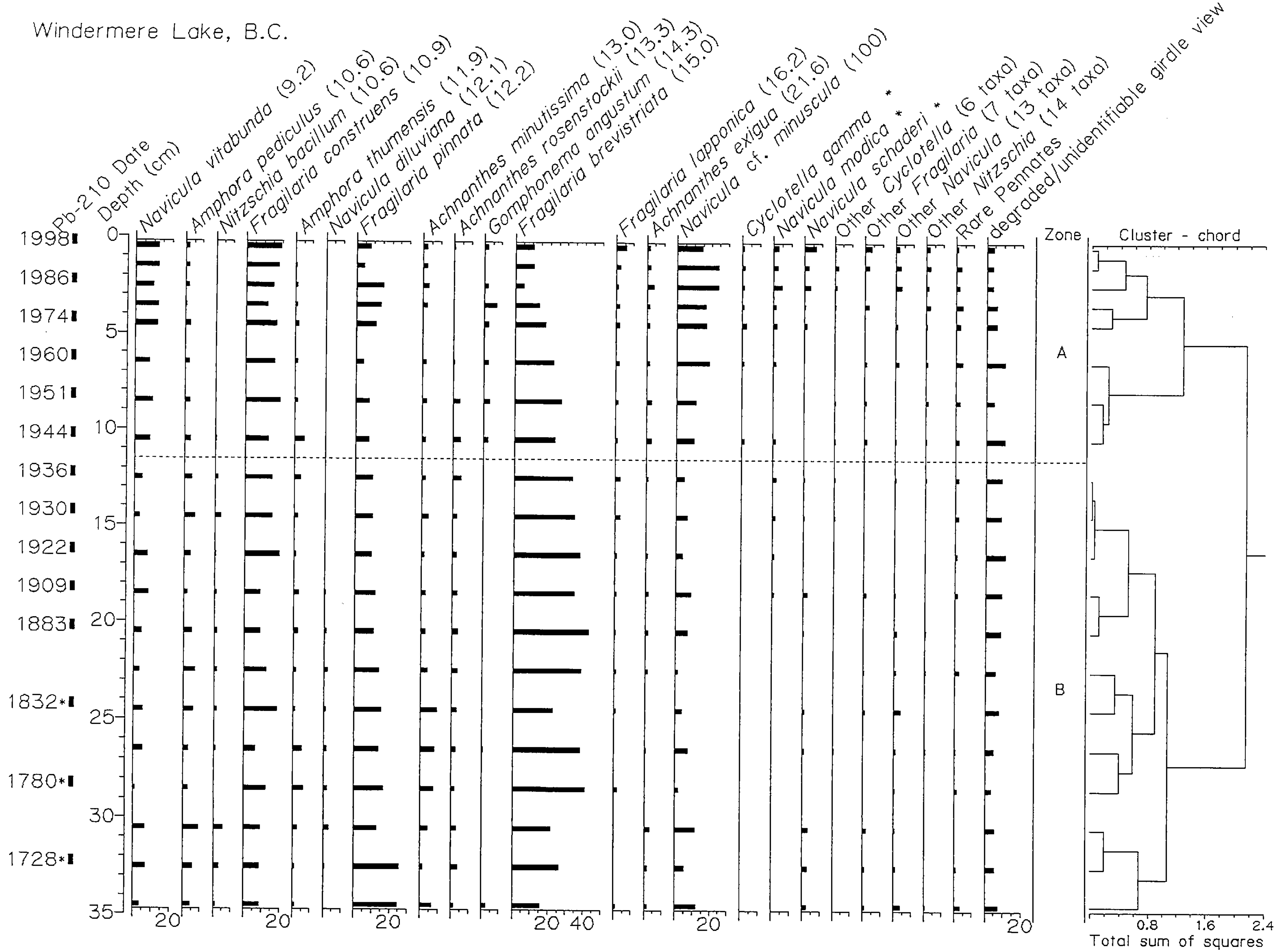


FIGURE 2



Windermere Lake, B.C.
Pb-210 Date
Depth (cm)
Navicula vitabunda (9.2)
Amphora pediculus (10.6)
Nitzschia bacillum (10.6)
Fragilaria construens (10.9)
Amphora thumensis (11.9)
Navicula diluviana (12.1)
Fragilaria pinnata (12.2)
Achnanthes minutissima (13.0)
Achnanthes rosenstockii (13.3)
Gomphonema angustum (14.3)
Fragilaria brevistriata (15.0)
Fragilaria lapponica (16.2)
Achnanthes exigua (21.6)
Navicula cf. minuscula (100)
Cyclotella gamma *
Navicula modica *
Navicula schaderi *
Other Cyclotella (6 taxa)
Other Fragilaria (7 taxa)
Other Navicula (13 taxa)
Other Nitzschia (14 taxa)
Rare Pennates
degraded/unidentifiable girdle view
Zone
Cluster - chord
1998
1986
1974
1960
1951
1944
1936
1930
1922
1909
1883
1832*
1780*
1728*
0
5
10
15
20
25
30
35
A
B
20
20 40
0.8
1.6
2.4
Total sum of squares

APPENDIX A

Windermere - Summary File

Pb210 and LOI summary

INTTOP (cm)	INTBOT (cm)	Pb210AC (pCi/g)	LOI(550C %organic	Estimated AD-DATE	SEDRATE (g/cm2/yr)
0	0.5	3.4156	12.51	1997.6	0.0314
1	1.5	3.4618	12.70	1992.5	0.0262
2	2.5	3.2746	12.65	1986.3	0.0238
4	4.5	2.6336	11.37	1973.6	0.0242
6	6.5	2.0683	10.65	1960.3	0.0290
8	8.5	1.6233	12.31	1951.1	0.0606
10	10.5	1.6210	15.30	1944.1	0.0493
12	12.5	1.6700	16.56	1936.1	0.0320
14	14.5	1.5467	15.36	1929.7	0.0451
16	16.5	1.5912	14.72	1921.8	0.0280
18	18.5	1.5404	14.92	1909.4	0.0249
20	20.5	1.6284	14.37	1883.5	0.0074
24	24.5	1.3529	11.82	1831.7	
28	28.5	1.3965	11.76	1780.0	
32	32.5	1.4338	10.58	1728.2	
34	34.5	1.3170	8.62	1702.3	

Diatom analyses summary

Depth (cm) TOP	Depth (cm) BOTTOM	Estimated AD-DATE	log TP	TP (ugL-1)	LogSalinit	mgL-1 salinity	PCA AX1	111lakes minimum sq. chord
0.5	1	1995.1	1.223	16.71	1.949	88.92	110	0.8496
1.5	2	1989.4	1.358	22.80	1.945	88.10	137	0.9345
2.5	3	1983.1	1.364	23.12	1.91	81.28	155	0.9039
3.5	4	1976.8	1.242	17.46	1.966	92.47	90	0.8628
4.5	5	1970.3	1.241	17.42	1.939	86.90	75	0.8446
6.5	7	1958.0	1.316	20.70	1.969	93.11	51	0.8609
8.5	9	1949.3	1.175	14.96	1.971	93.54	7	0.7276
10.5	11	1942.1	1.174	14.93	1.976	94.62	13	0.7895
12.5	13	1934.5	1.084	12.13	1.983	96.16	-59	0.5985
14.5	15	1927.7	1.104	12.71	2.006	101.39	-62	0.5229
16.5	17	1918.7	1.064	11.59	1.974	94.19	-76	0.5544
18.5	19	1902.9	1.155	14.29	1.985	96.61	-53	0.6127
20.5	21	1877.0	1.143	13.90	2.026	106.17	-106	0.4899
22.5	23	1851.1	1.04	10.96	2.014	103.28	-102	0.4675
24.5	25	1825.3	1.046	11.12	2.003	100.69	-7	0.579
26.5	27	1799.4	1.121	13.21	2.033	107.89	-86	0.4996
28.5	29	1773.5	1.061	11.51	2.029	106.91	-116	0.4681
30.5	31	1747.6	1.165	14.62	1.978	95.06	17	0.6568
32.5	33	1721.7	1.072	11.80	1.952	89.54	-30	0.608
34.5	35	1695.9	1.189	15.45	1.993	98.40	42	0.7037

APPENDIX B-1

SUMMARY PB210 ANALYSES BY MYCORE - WINDERMERE

Sample Number	Disk #	Section Top (cm)	of Cor Bottom (cm)	Sample Weight used (mg)	209 Po Counts	210 Po Counts	210 Po Meas (Bq/g)	210 Po (Bq/g)	Precisn 1 STD (%)
Windermere Lake									
17	791	0	0.5	1255	1836	398	0.098	0.125	5.5
18	792	1	1.5	1358	3311	807	0.106	0.126	3.9
19	793	2	2.5	1304	4928	1113	0.100	0.120	3.3
20	794	4	4.5	1392	6628	1318	0.084	0.096	3.0
21	795	6	6.5	1298	5755	855	0.066	0.076	3.7
22	796	8	8.5	1403	7051	907	0.052	0.059	3.5
23	797	10	10.5	1321	5595	663	0.052	0.059	4.1
24	798	12	12.5	1208	12653	1427	0.054	0.061	2.8
25	799	14	14.5	1215	6137	635	0.050	0.056	4.2
26	800	16	16.5	1337	5474	651	0.053	0.058	4.1
27	801	18	18.5	1345	5129	600	0.051	0.056	4.3
28	802	20	20.5	1295	6239	758	0.054	0.059	3.8
29	803	24	24.5	1406	5094	582	0.045	0.049	4.4
30	804	28	28.5	1431	4036	460	0.046	0.051	4.9
31	805	32	32.5	1446	2160	258	0.047	0.052	6.6
32	806	34	34.5	1495	6185	698	0.044	0.048	4.0

SUMMARY PB210 CALCULATIIONS FOR DETERMINING DATES - WINDERMERE

Back calculate to coring (KRL)

Section Top (cm)	of Core Bottom (cm)	Date Po Sample Extracte (year)	(month)	(day)	Date of coring (year)	(month)	(day)	Time since coring (days)	Decay Corr. to Extractn (Bq/g)	Decay Corr. to Coring (Bg/g)	Sample Weight used (g)	Std dev (Bg/g)
Windermere Lake												
0	0.5	98	12	23	98	7	23	153	0.125	0.1264	1.255	0.0071
1	1.5	98	12	23	98	7	23	153	0.126	0.1281	1.358	0.0053
2	2.5	98	12	23	98	7	23	153	0.120	0.1212	1.304	0.0041
4	4.5	98	12	23	98	7	23	153	0.096	0.0974	1.392	0.0032
6	6.5	98	12	23	98	7	23	153	0.076	0.0765	1.298	0.0030
8	8.5	98	12	23	98	7	23	153	0.059	0.0601	1.403	0.0024
10	10.5	98	12	23	98	7	23	153	0.059	0.0600	1.321	0.0027
12	12.5	98	12	23	98	7	23	153	0.061	0.0618	1.208	0.0018
14	14.5	98	12	23	98	7	23	153	0.056	0.0572	1.215	0.0025
16	16.5	98	12	23	98	7	23	153	0.058	0.0589	1.337	0.0027
18	18.5	98	12	23	98	7	23	153	0.056	0.0570	1.345	0.0027
20	20.5	98	12	23	98	7	23	153	0.059	0.0603	1.295	0.0025
24	24.5	98	12	23	98	7	23	153	0.049	0.0501	1.406	0.0025
28	28.5	98	12	23	98	7	23	153	0.051	0.0517	1.431	0.0029
32	32.5	98	12	23	98	7	23	153	0.052	0.0530	1.446	0.0040
34	34.5	98	12	23	98	7	23	153	0.048	0.0487	1.495	0.0023

APPENDIX B-2

CALCULATIONS FOR INPUT INTO BINFORD PROGRAM

Windermere-Pb210

INTTOP (cm)	INTBOT (cm)	Back calculated to coring Pb-210 (Bq/g) activity	Std dev (Bg/g)	Pb210 activity (pCig-1)	Std dev (pCig-1)	Rho (g cm-3)
0	0.5	0.1264	0.0071	3.4156	0.1918	0.1256
1	1.5	0.1281	0.0053	3.4618	0.1420	0.1643
2	2.5	0.1212	0.0041	3.2746	0.1121	0.1456
4	4.5	0.0974	0.0032	2.6336	0.0856	0.1585
6	6.5	0.0765	0.0030	2.0683	0.0806	0.1957
8	8.5	0.0601	0.0024	1.6233	0.0638	0.1615
10	10.5	0.0600	0.0027	1.6210	0.0724	0.2187
12	12.5	0.0618	0.0018	1.6700	0.0486	0.1160
14	14.5	0.0572	0.0025	1.5467	0.0677	0.1207
16	16.5	0.0589	0.0027	1.5912	0.0721	0.1599
18	18.5	0.0570	0.0027	1.5404	0.0729	0.1685
20	20.5	0.0603	0.0025	1.6284	0.0673	0.1786
24	24.5	0.0501	0.0025	1.3529	0.0665	0.1951
28	28.5	0.0517	0.0029	1.3965	0.0779	0.2088
32	32.5	0.0530	0.0040	1.4338	0.1073	0.2424
34	34.5	0.0487	0.0023	1.3170	0.0609	0.3402
			avg	1.375035	= supported Pb210	
			stds	0.050898	1.476831	

BINFORD FILE INPUTS FOR CALCULATION OF DATES AND SEDIMENTATION RATES

Windermere
C1
16
0.0509

INTTOP (cm)	INTBOT (cm)	Pb210 Total (pCig-1)	Pb210 Unsup. (pCig-1)	Rho (g cm-3)	OM proportion	CUMTOP (g cm-2)	CUMBOT (g cm-2)	std Pb210 (pCig-1)
0.00	0.50	3.4156	2.0406	0.1256	0.125	0.0000	0.0628	0.1918
1.00	1.50	3.4618	2.0868	0.1643	0.127	0.1455	0.2276	0.1420
2.00	2.50	3.2746	1.8995	0.1456	0.127	0.3032	0.3760	0.1121
4.00	4.50	2.6336	1.2586	0.1585	0.114	0.5894	0.6687	0.0856
6.00	6.50	2.0683	0.6933	0.1957	0.106	0.9454	1.0432	0.0806
8.00	8.50	1.6233	0.2483	0.1615	0.123	1.3374	1.4182	0.0638
10.00	10.50	1.6210	0.2460	0.2187	0.153	1.6586	1.7680	0.0724
12.00	12.50	1.6700	0.2950	0.1160	0.166	1.9876	2.0456	0.0486
14.00	14.50	1.5467	0.1716	0.1207	0.154	2.2424	2.3028	0.0677
16.00	16.50	1.5912	0.2161	0.1599	0.147	2.5130	2.5929	0.0721
18.00	18.50	1.5404	0.1654	0.1685	0.149	2.8133	2.8976	0.0729
20.00	20.50	1.6284	0.2534	0.1786	0.144	3.1241	3.2135	0.0673
24.00	24.50	1.3529	0.0000	0.1951	0.118	3.8423	3.9399	0.0665
28.00	28.50	1.3965	0.0000	0.2088	0.118	4.6394	4.7438	0.0779
32.00	32.50	1.4338	0.0000	0.2424	0.106	5.5627	5.6839	0.1073
34.00	34.50	1.3170	0.0000	0.3402	0.086	6.2944	6.4645	0.0609

OUTPUT FROM BINFORD PROGRAM

YOU ARE ANALYZING CORE C1 FROM LAKE Windermere

THE DATA ARE:

INTTOP	INTBOT	PB210ACT	UNSUPACT	RHO	PERCORG	CUMMASST	CUMMASSB	SDACT
0.0	0.5	3.41560	2.04060	0.12560	0.120	0.0000	0.0628	0.1918
1.0	1.5	3.46180	2.08680	0.16430	0.120	0.1455	0.2276	0.1420
2.0	2.5	3.27460	1.89950	0.14560	0.120	0.3032	0.3760	0.1121
4.0	4.5	2.63360	1.25860	0.15850	0.110	0.5894	0.6687	0.0856
6.0	6.5	2.06830	0.69330	0.19570	0.100	0.9454	1.0432	0.0806
8.0	8.5	1.62330	0.24830	0.16150	0.120	1.3374	1.4182	0.0638
10.0	10.5	1.62100	0.24600	0.21870	0.150	1.6586	1.7680	0.0724
12.0	12.5	1.67000	0.29500	0.11600	0.160	1.9876	2.0456	0.0486
14.0	14.5	1.54670	0.17160	0.12070	0.150	2.2424	2.3028	0.0677
16.0	16.5	1.59120	0.21610	0.15990	0.140	2.5130	2.5929	0.0721
18.0	18.5	1.54040	0.16540	0.16850	0.140	2.8133	2.8976	0.0729
20.0	20.5	1.62840	0.25340	0.17860	0.140	3.1241	3.2135	0.0673
24.0	24.5	1.35290	0.00000	0.19510	0.110	3.8423	3.9399	0.0665
28.0	28.5	1.39650	0.00000	0.20880	0.110	4.6394	4.7438	0.0779
32.0	32.5	1.43380	0.00000	0.24240	0.100	5.5627	5.6839	0.1073
34.0	34.5	1.31700	0.00000	0.34020	0.080	6.2944	6.4645	0.0609

STANDARD DEVIATION OF SUPPORTED PB-210 = 0.0509

Pb-210 dates for Lake Windermere core C1

INTTOP	INTBOT	MIDINT	TTOP	SDTTOP	TBOT	SDTBOT	SEDRATE	SDSEDRT	SUMTOP
0.0	0.5	0.2	0.00	1.05	2.00	1.07	0.0314	0.0100	2.1214
1.0	1.5	1.2	4.49	1.11	7.62	1.15	0.0262	0.0081	1.8445
2.0	2.5	2.2	10.73	1.22	13.80	1.28	0.0238	0.0074	1.5188
4.0	4.5	4.2	23.31	1.56	26.59	1.66	0.0242	0.0084	1.0266
6.0	6.5	6.2	36.60	2.12	39.99	2.28	0.0290	0.0120	0.6786
8.0	8.5	8.2	46.86	2.71	48.19	2.78	0.0606	0.0255	0.4931
10.0	10.5	10.2	53.33	3.15	55.54	3.26	0.0493	0.0243	0.4031
12.0	12.5	12.2	61.62	3.83	63.44	4.02	0.0320	0.0165	0.3113
14.0	14.5	14.2	68.18	4.59	69.51	4.73	0.0451	0.0271	0.2539
16.0	16.5	16.2	75.37	5.56	78.22	5.95	0.0280	0.0201	0.2029
18.0	18.5	18.2	87.51	7.72	90.91	8.35	0.0249	0.0219	0.1390
20.0	20.5	20.2	108.96	14.16	121.22	20.13	0.0074	0.0123	0.0713

Execution terminated : 0

C:\pb210>

APPENDIX C

WINDERMERE LAKE - DIATOM RELATIVE ABUNDANCES (%)

TAXA	Sample Depth 0.50	1.50	2.50	3.50	4.50	6.50	8.50	10.50	12.50	14.50	16.50	18.50	20.50	22.50	24.50	26.50	28.50	30.50	32.50	34.50
Achananthes aff. reversa	0.00	0.00	0.00	1.19	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Achnanthes conspicua	0.00	0.00	0.00	0.30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Achnanthes exigua	1.73	1.93	3.87	1.48	1.41	1.67	2.82	2.83	1.15	0.25	1.05	1.72	1.38	1.68	0.29	0.58	0.27	3.09	1.73	1.70
Achnanthes lancelota	0.00	0.00	0.00	0.59	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Achnanthes minutissima	2.02	2.21	2.98	2.37	0.00	1.67	1.97	1.70	1.72	3.45	1.31	2.01	2.21	3.35	9.25	7.89	7.30	3.93	1.15	6.55
Achnanthes rosenstockii	0.29	0.00	0.00	0.00	0.00	0.56	3.66	4.25	4.58	2.46	2.36	2.58	3.31	3.35	2.89	2.34	1.89	2.53	3.75	1.21
Achnanthes ziegleri	0.29	0.55	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Amphora libyca	0.00	0.00	0.00	0.00	0.00	0.00	0.28	0.00	0.29	0.25	0.26	0.29	0.00	0.56	0.00	0.00	0.00	0.00	0.00	0.00
Amphora pediculus	1.73	1.93	1.79	0.59	2.82	2.23	2.82	3.40	4.01	5.91	3.67	2.01	4.70	6.42	5.49	2.63	2.70	8.99	5.76	4.37
Amphora thumensis	0.00	0.55	1.19	1.19	1.97	1.39	1.69	5.67	3.72	1.72	1.05	2.87	2.21	1.68	0.87	4.97	6.22	2.25	1.15	0.97
Asterionella formosa	0.00	0.00	0.00	0.00	0.00	0.28	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Brachysira serians	0.00	0.00	0.00	0.59	0.00	0.28	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Brachysira vitrea	0.00	1.10	0.00	0.59	0.28	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.56	0.00	0.00	0.00	0.00	0.00	0.49
Caloneis silicula	0.00	0.00	0.60	0.00	0.00	0.56	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cocconeis placentula	0.00	0.28	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cyclotella bodanica var. affinis	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.57	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cyclotella gamma	0.87	1.38	0.89	0.89	2.25	0.56	0.00	1.13	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cyclotella glomerata	0.00	0.28	0.00	0.00	0.00	0.00	0.28	0.00	0.57	0.49	0.00	0.00	0.00	0.28	0.00	0.58	0.00	0.00	0.00	0.00
Cyclotella michiganiana	0.00	0.28	0.00	0.00	0.28	0.28	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cyclotella plitvicensis	0.00	0.00	0.30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cyclotella rosii	0.00	0.00	0.00	0.00	0.00	0.00	0.28	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cylotella comensis	0.58	1.66	0.89	0.59	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cymbella gracilis	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.54	0.00	0.00	0.00
Cymbella microcephala	0.00	0.00	0.60	0.59	0.56	0.00	0.00	0.00	0.57	0.00	0.00	0.00	0.00	0.28	0.00	0.00	0.00	0.00	0.00	1.70
Cymbella minuta	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.99	0.00	0.00	0.00	0.00	0.29	0.00	0.00	0.00	0.00	0.00
Cymbella muelleri	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.54	0.00	0.00	0.00
Cymbella sp (PL45)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.49	0.00	0.57	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cymbella sp. 1 PISCES	0.58	0.00	0.60	0.00	1.41	0.28	0.00	0.00	0.00	0.00	0.26	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Denticula keutzingii	0.00	0.55	0.00	0.00	0.00	0.00	0.00	0.28	0.00	0.00	0.00	0.00	0.00	0.28	0.00	0.00	0.54	0.00	0.00	0.49
Diploneis marginestriata	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.57	0.00	0.00	0.00	0.00	0.28	0.00	0.00	0.00	0.00	0.00	0.00
Diploneis oblongella	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.56	0.00	0.00	0.00	0.00	0.00	0.00
Fr rhomboides	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.24
Fragilaria brevistriata	10.40	10.22	4.76	13.65	17.46	21.73	26.76	22.95	32.95	34.24	37.53	34.38	42.54	38.55	22.25	38.30	40.81	21.35	26.22	15.53
Fragilaria capucina	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.28	0.00	0.00	0.00	0.00	0.00	0.28	0.00	0.00	0.00	0.00	0.00	0.00
Fragilaria construens	19.36	17.96	15.18	11.87	16.90	16.16	19.15	12.75	14.90	15.27	19.16	8.60	8.56	12.29	18.21	6.43	12.16	9.27	8.65	8.50
Fragilaria crotonensis	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.24
Fragilaria lapponica	5.78	2.49	0.89	1.78	1.97	1.95	1.41	0.85	2.87	2.71	0.79	1.15	0.55	1.12	1.16	0.00	2.16	0.00	0.00	0.97
Fragilaria nanana	2.31	0.28	0.00	1.19	0.00	0.00	0.56	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.87	0.00	0.00	0.00	0.00	0.00
Fragilaria parasitica	0.58	1.66	0.00	0.59	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.57	0.00	0.00	0.00	0.00	0.00	1.40	0.58	0.00
Fragilaria pinnata	7.80	4.14	14.88	13.95	10.99	4.18	7.04	7.08	9.46	9.36	8.92	11.46	10.50	13.69	15.03	13.74	16.49	12.64	25.36	24.27
Fragilaria sp. 4PIRLA	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.57	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Fragilaria tenera	0.58	0.00	0.00	0.30	0.00	0.00	0.00	0.85	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.29	0.49
Fragilaria ulna var. acus	0.00	0.28	0.00	0.00	0.00	0.56	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Gomphonema angustatum	0.00	0.00	0.00	0.00	0.00	1.39	1.69	1.13	0.57	0.25	0.52	0.57	0.00	0.00	0.00	0.00	0.00	0.00	1.15	0.00
Gomphonema angustum	2.02	0.28	1.79	7.12	2.54	2.23	3.10	2.27	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.58	0.00	0.00	0.00	2.18
Gomphonema gracile	0.00	0.00	0.00	0.00	0.00	0.00	0.28	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mastogloia smithii	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.58	0.00	0.00	0.00	0.24
Navicula aff.veneta	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.58	0.00	0.00	0.00	0.00	0.00
Navicula bacilum	0.00	0.55	0.60	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Navicula cf. minuscula	14.16	24.03	23.81	16.32	17.18	18.94	10.99	10.20	4.58	6.16	3.67	8.60	6.91	1.12	3.47	7.02	1.89	11.52	4.90	11.89
Navicula cf. subtilissima	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.28	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.24
Navicula cocconeiformis	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.58	0.00	0.00	0.00	0.00
Navicula cryptocephala	0.58	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Navicula cryptonella	0.00	0.55	1.79	0.00	0.56	0.28	0.00	0.00	0.00	0.00	0.00	0.00	0.55	0.56	0.87	0.00	0.54	0.00	0.00	1.21
Navicula diluviana	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.57	1.10	2.23	1.16	1.75	2.16	2.81	0.58	0.00
Navicula laevissima	0.58	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.24
Navicula modica	2.60	2.21	4.46	1.48	1.69	1.39	0.00	1.42	1.72	1.23	0.79	0.86	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Navicula oblonga	0.00	0.28	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.55	0.00	0.00	0.00	0.00	0.28	0.00	0.00
Navicula pseudoventralis	0.00	0.00	0.00	0.00	0.00	0.56	0.00	0.00	0.57	0.00	0.00	0.00	0.00	0.28	1.45	0.00	0.00	0.00	0.00	0.49
Navicula pupula	0.58	0.28	0.00	0.00	0.00	0.56	0.00	0.28	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.49
Navicula radiosa	0.00	0.55	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Navicula schaderi	6.36	2.21	3.27	0.59	1.41	0.00	0.00	0.00	0.57	0.49	0.00	2.29	0.28	0.00	1.16	1.17	0.00	3.37	2.88	2.43
Navicula sp., pl. 23	0.00	0.55	0.89	0.00	0.28	0.28	0.00	0.00	0.00	0.00	0.00	0.57	0.00	0.00	0.58	0.00	0.00	0.00	0.00	0.73
Navicula subrotundata	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.58	0.00
Navicula vitabunda	12.14	12.43	9.52	12.46	11.83	7.52	9.30	7.93	3.72	2.71	7.09	7.74	3.87	3.07	4.91	4.68	0.54	6.46	6.63	3.40
Nedium ampliatum	0.00	0.00	0.00	0.00	0.00	0.28	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Nitschia linearis var. tenuis	0.87	0.55	0.00	0.30	0.00	0.28	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Nitzschia acicularis	0.00	0.00	0.30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Nitzschia acicularis	0.00	0.00	0.00	0.30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Nitzschia amphibia	0.00	0.28	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Nitzschia angustatum	0.00	0.00	0.00	0.30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Nitzschia bacilum	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.57	1.43	3.20	0.52	1.15	1.66	1.40	1.73	1.17	0.00	5.06	3.17	1.21
Nitzschia dissipata var. media	0.00	0.00	0.30	0.00	0.00	0.28	0.00	0.28	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.29	0.00	0.00	0.00	0.24
Nitzschia fossilis	0.58	0.55	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Nitzschia liebetruthii fo. 2 PISCES	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.55	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Nitzschia linearis var. subtilis	0.00	0.00	0.00	0.00	0.56	0.00	0.00	0.00	0.29	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Nitzschia palea	0.58	0.28	0.60	0.59	0.00	0.56	0.85	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Nitzschia paleacea	0.00	0.83	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Nitzschia radicula	0.00	0.00	0.00	0.00	0.00	0.00	0.56	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Nitzschia recta	0.00	0.00	0.00	0.59	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Nitzschia valdestriata	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.28	0.00	0.00	0.00	0.00	0.00	0.00
Pi maior	0.00	0.28	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pinnularia interrupta	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.57	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Surirella linearis var. constricta	0.00	0.00	0.00	0.00	0.00	0.56	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
degraded/unidentifiable girdle view	4.05	3.59	3.27	5.64	5.63	10.58	4.51	10.48	9.17	8.37	11.02	8.88	8.56	5.87	7.51	4.68	3.24	5.06	5.48	7.28