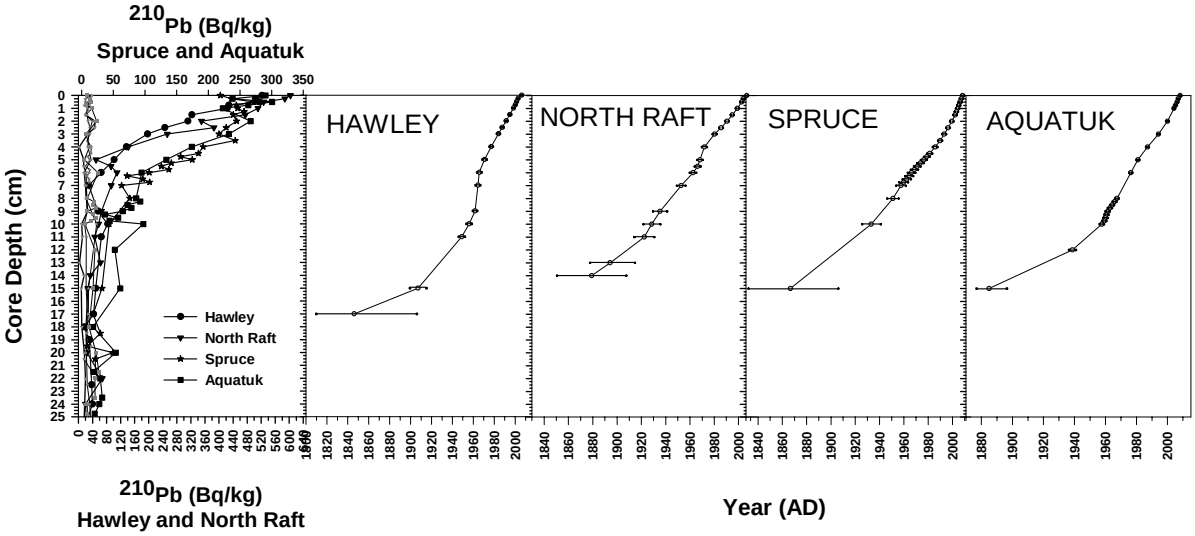
210Pb (Bq/kg)
Spruce and Aquatuk
Core Depth (cm)
Hawley
North Raft
Spruce
Aquatuk
HAWLEY
NORTH RAFT
SPRUCE
AQUATUK
210Pb (Bq/kg)
Hawley and North Raft
Year (AD)

Figure S1

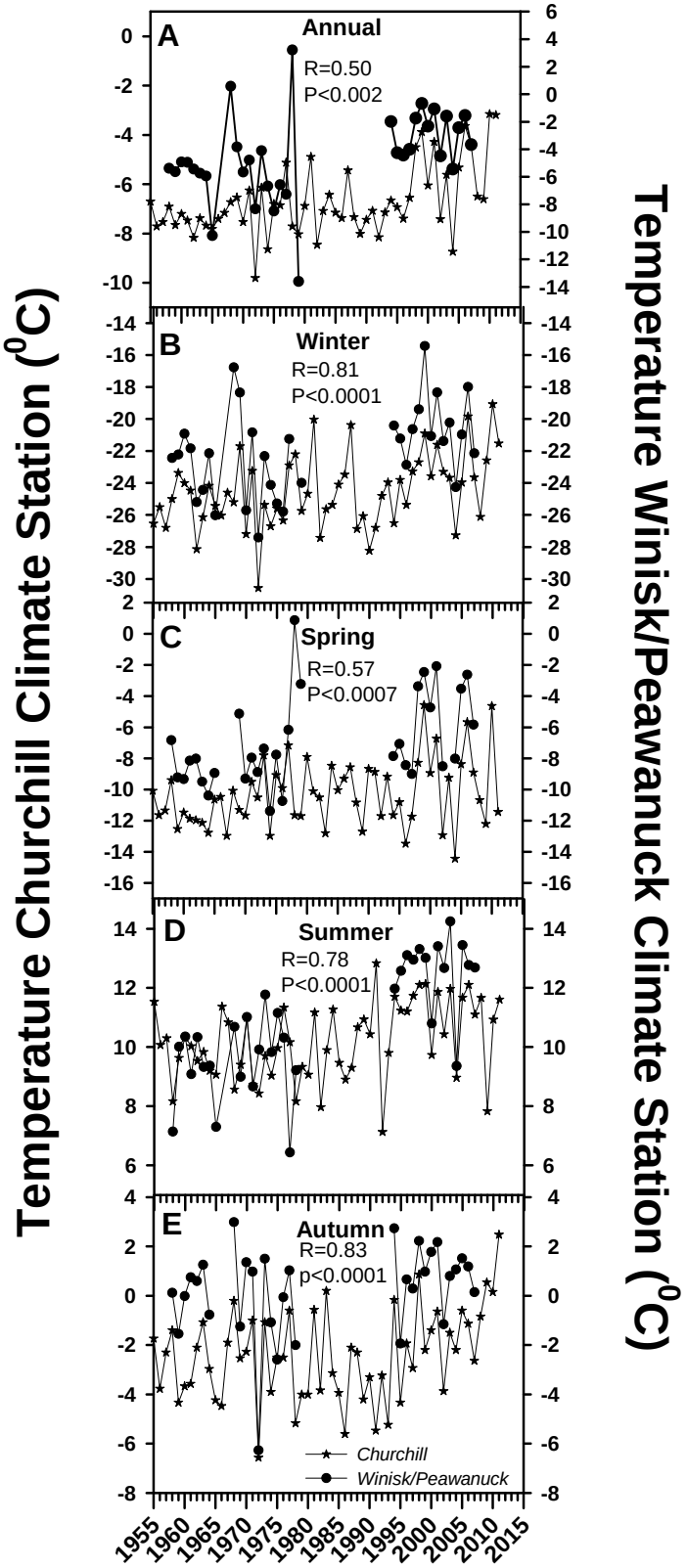
A
Annual
R=0.50
P<0.002
B
Winter
R=0.81
P<0.0001
C
Spring
R=0.57
P<0.0007
D
Summer
R=0.78
P<0.0001
E
Autumn
R=0.83
p<0.0001
Churchill
Winisk/Peawanuck
Temperature Churchill Climate Station (°C)
Temperature Winisk/Peawanuck Climate Station (°C)
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
2010
2015

Figure S2

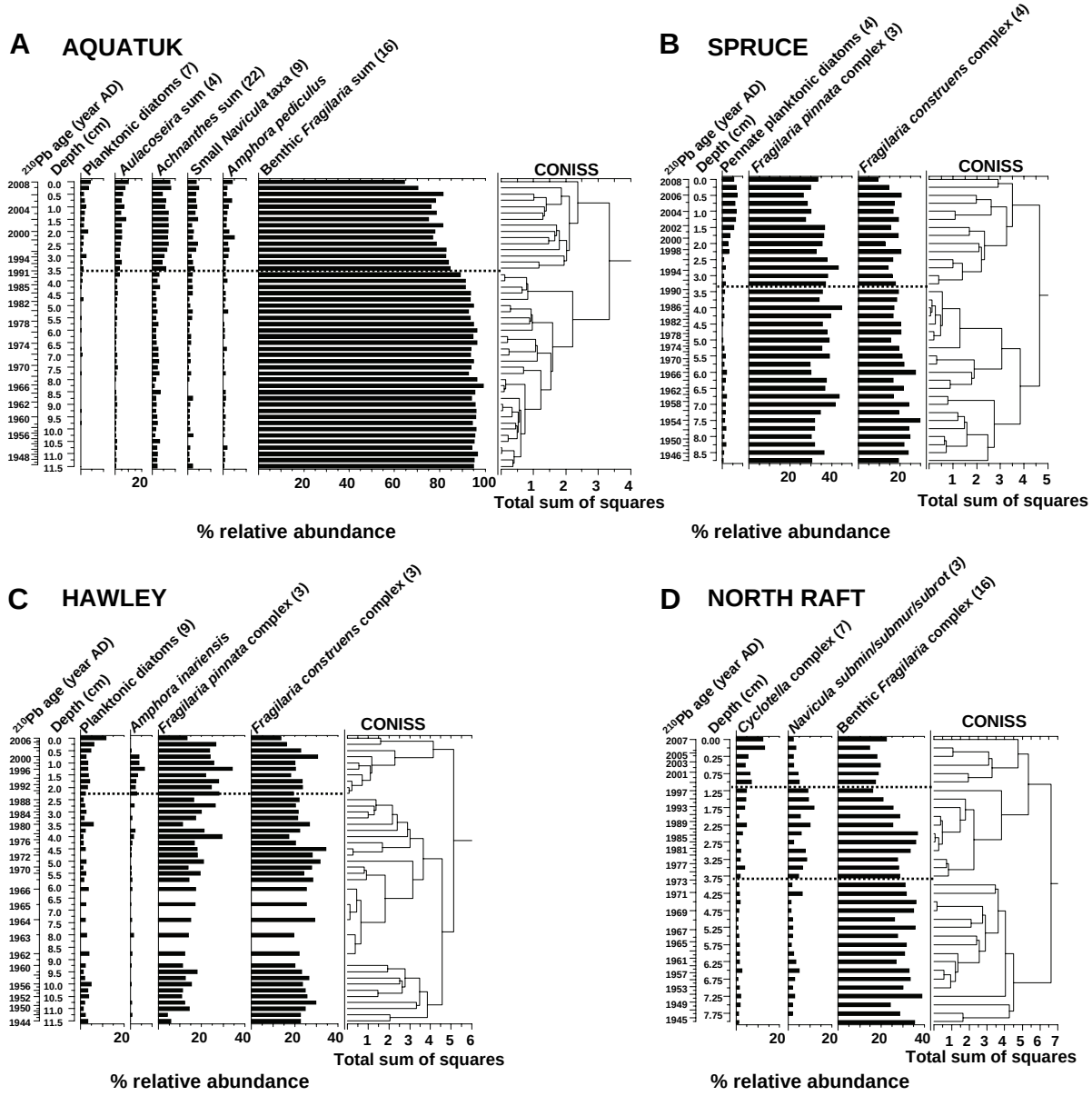
A
AQUATUK
^{210}Pb age (year AD)
Depth (cm)
Planktonic diatoms (7)
Aulacoseira sum (4)
Achnanthes sum (22)
Small Navicula taxa (9)
Amphora pediculus
Benthic Fragilaria sum (16)
CONISS
Total sum of squares
% relative abundance
B
SPRUCE
^{210}Pb age (year AD)
Depth (cm)
Pennate planktonic diatoms (4)
Fragilaria pinnata complex (3)
Fragilaria construens complex (4)
CONISS
Total sum of squares
% relative abundance
C
HAWLEY
^{210}Pb age (year AD)
Depth (cm)
Planktonic diatoms (9)
Amphora inariensis
Fragilaria pinnata complex (3)
Fragilaria construens complex (3)
CONISS
Total sum of squares
% relative abundance
D
NORTH RAFT
^{210}Pb age (year AD)
Depth (cm)
Cyclotella complex (7)
Navicula submin/submur/subrot (3)
Benthic Fragilaria complex (16)
CONISS
Total sum of squares
% relative abundance

Figure S3

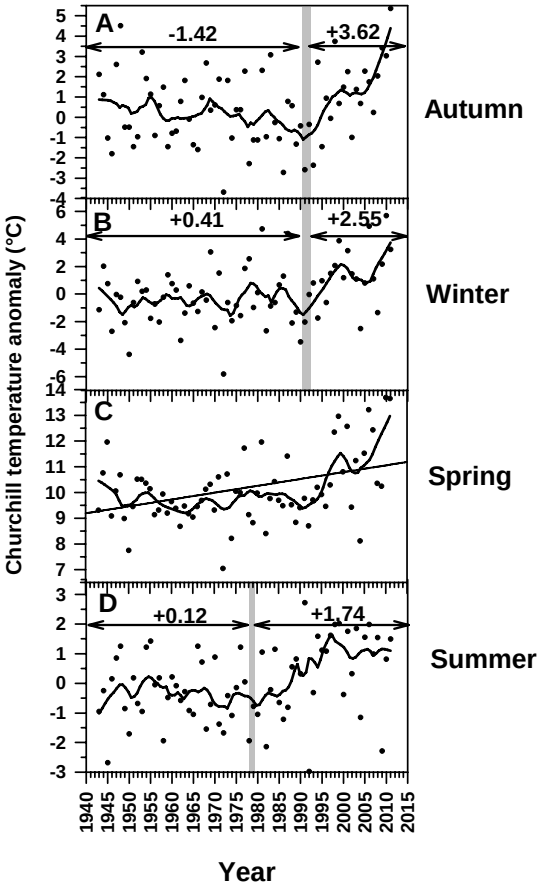
A
-1.42
+3.62
Autumn
B
+0.41
+2.55
Winter
C
Spring
D
+0.12
+1.74
Summer
Churchill temperature anomaly (°C)
Year

Figure S4

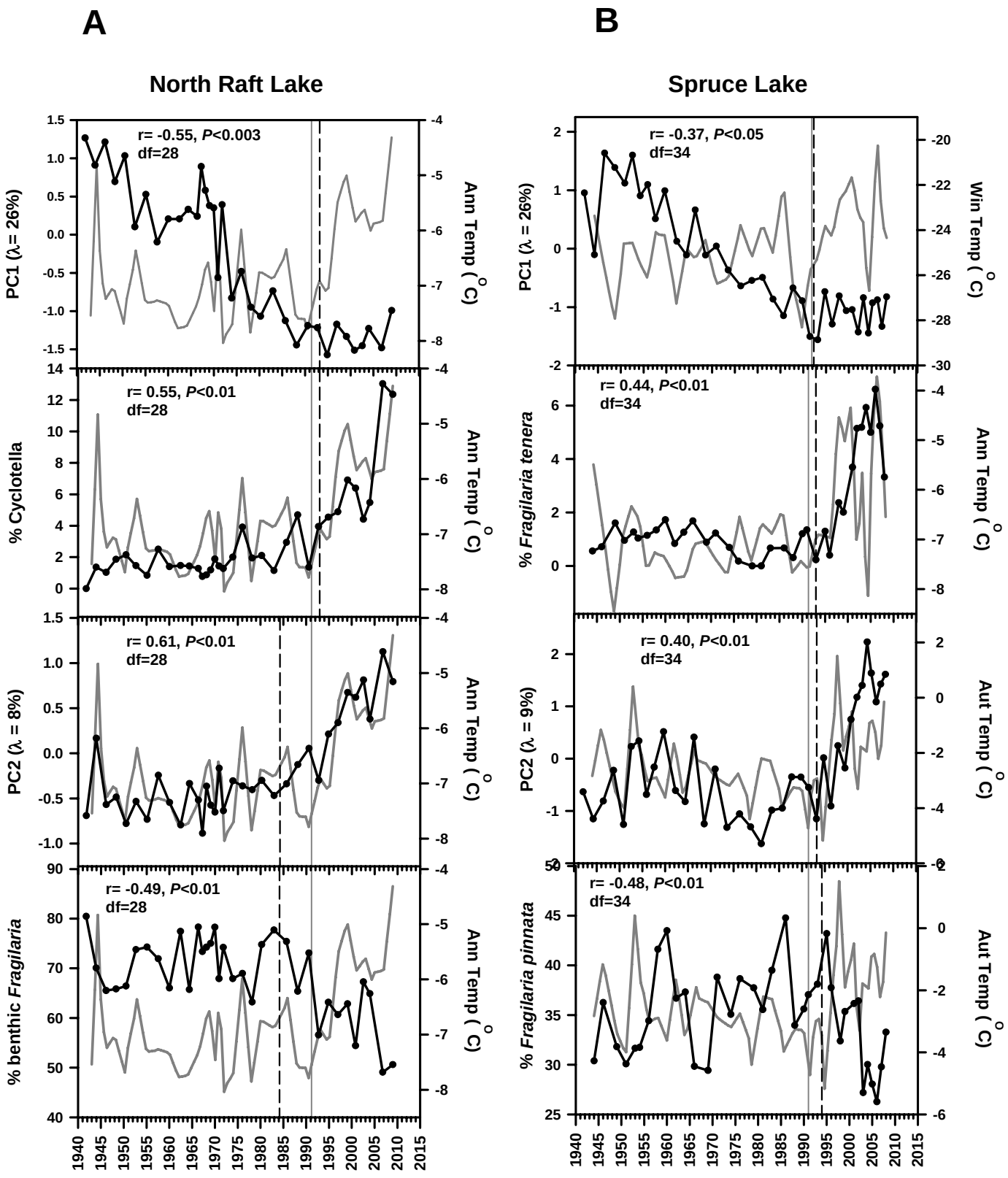
A
North Raft Lake
r= -0.55, P<0.003
df=28
PC1 (λ= 26%)
Ann Temp (C)
r= 0.55, P<0.01
df=28
% Cyclotella
r= 0.61, P<0.01
df=28
PC2 (λ = 8%)
r= -0.49, P<0.01
df=28
% benthic Fragilaria
B
Spruce Lake
r= -0.37, P<0.05
df=34
Win Temp (C)
r= 0.44, P<0.01
df=34
% Fragilaria tenera
r= 0.40, P<0.01
df=34
Aut Temp (C)
r= -0.48, P<0.01
df=34
% Fragilaria pinnata

Figure S5

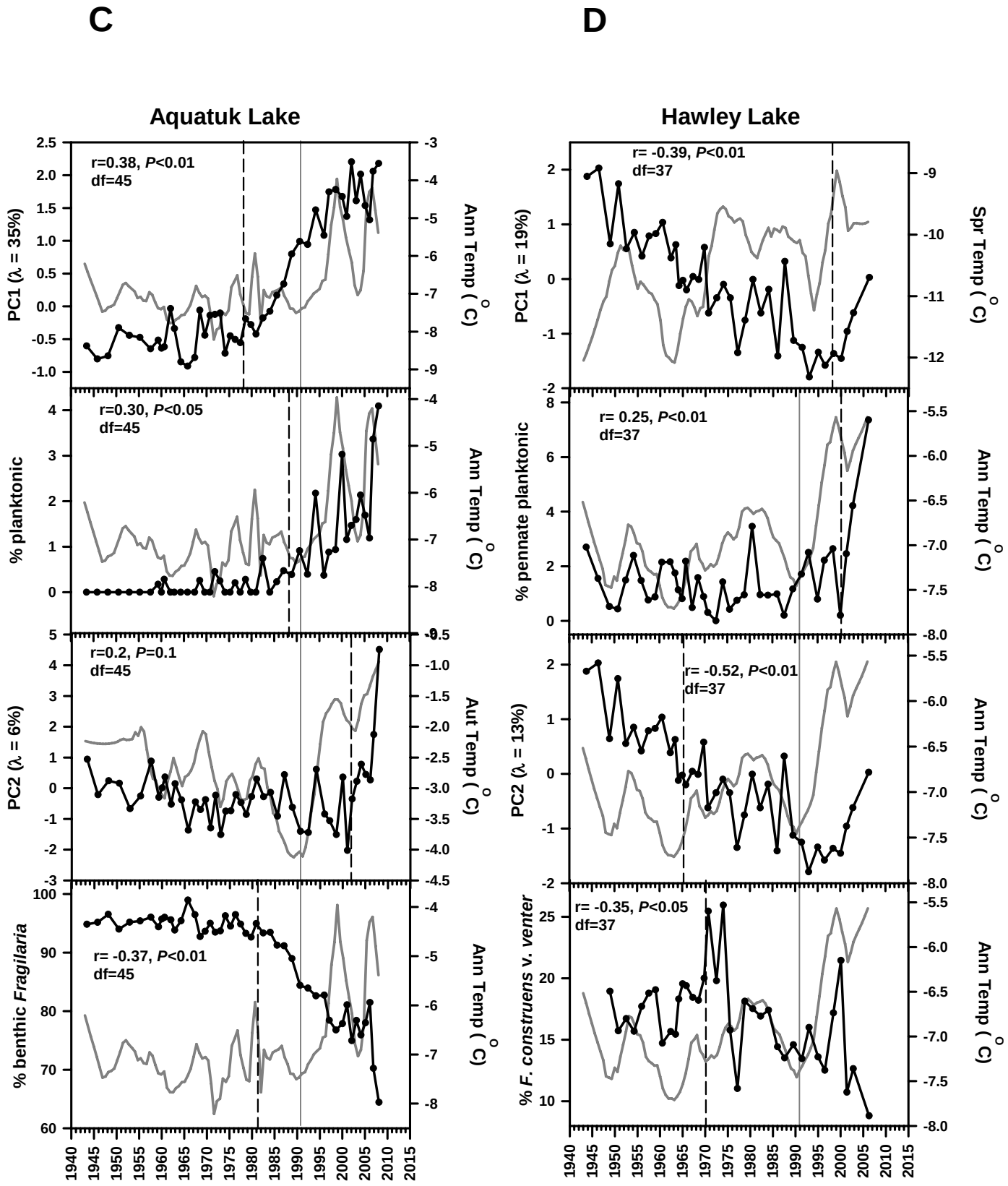

Figure S5 cont'd

Supplementary Table 1. Select limnological data for HBL study lakes. Data presented are 3-year means (2009 to 2011).

LAKE NAME	Lat (N)	Long (W)	Lake Depth	pH	Conductivity	SiO_3	TP	TN	NH4 + NO3	TN:TP	TN:TP	TIN/TP	DOC	NO3	Secchi
	Decimal degree		(m)		µS/cm	mg/L	µg/L	µg/L	TIN (µg/L)	mass ratio	molar ratio	mass ratio	mg/L	µg/L	(m)
North Raft	54.5343	-84.7561	11.1	7.9	152.0	0.9	6.0	278.0	10.7	40.9	90.4	1.7	6.8	4.0	3.7
Hawley	54.5269	-84.6288	34.6	8.1	213.0	1.3	7.0	243.0	16.0	28.9	82.8	2.4	6.3	3.3	4.5
Spruce	54.3282	-85.0079	10.9	7.9	135.0	0.7	11.0	362.0	21.3	33.4	73.7	2.0	7.9	3.3	2.8
Aquatuk	54.3281	-84.5686	12.0	8.1	189.0	1.5	14.0	315.0	25.3	26.7	59.0	1.8	7.6	4.0	2.2

SiO_3 = Reactive silicate

TP = Total Phosphorus

TN = Total Nitrogen unfiltered (TKN (Total Kjeldahl Nitrogen) + Nitrite-Nitrate (NO3/NO2))

DOC = Dissolved Organic Carbon

TIN - Total Inorganic Nitrogen

TN:TP mass ratios: <14 (Downing and McCauley 1992) or <9 (Guildford and Hecky 2000) = N-limitation

TN:TP molar ratios: <20 = N-limitation, >50 = P-limitation (Guildford and Hecky 2000)

DIN:TP mass <1.0 = N-limitation; >4.0=P-limitation; 1.0 - 4.0 = co-limitation (Morris and Lewis 1988)

DIN:TP mass <1.5 = N-limitation; >3.4 = P-limitation; 1.5 - 3.5 = co-limitation (Bergstrom 2012)

Table S2. Mean and standard deviation for each lake of the variables plotted in Figure 3 as z-scores.

		North Raft	Hawley	Spruce	Aquatuk
Hill's N2	mean	26.9	25.2	27.2	13.3
	SD	5.7	5.6	4.9	6.1
Planktonic diatoms	mean	4.4	2.1	2.2	0.6
	SD	3.9	1.5	2.1	1
Benthic fragilarioid taxa	mean	68.2	16.5	67.7	89.2
	SD	8.1	3.7	5.8	8.4
Chl-*a*	mean	0.008	0.022	0.021	0.024
	SD	0.001	0.006	0.003	0.007

Electronic Supplementary Information

Electronic Supplementary Figure Legends

Fig. S1. Radiometric dating analysis using gamma spectrometry. **(A)** ^{210}Pb activity (black lines) and ^{214}Bi (proxy for background ^{210}Pb activity levels: gray lines) plotted against core depth for the four study lakes in the Hudson Bay Lowlands. Estimated year (AD) plotted against core depth for: **(B)** Hawley Lake; **(C)** North Raft Lake; **(D)** Spruce Lake; and **(E)** Aquatuk Lake. Dates were calculated using the constant rate of supply (CRS) model [1]. Associated standard errors with each date are displayed as horizontal lines. Note the change in x-axes scale in **(A)**.

Fig. S2. Comparisons between temperature data from Churchill and Winisk/Peawanuck climate stations. Relationships between two climate stations in the HBL for (A) mean annual, (B) mean winter, (C) mean spring, (D) mean summer, and (E) mean autumn temperature trends. Because temperature data are missing for one decade at the Winisk/Peawanuck climate station (due to flooding of Winisk in 1986), the continuous records from Churchill were used for this study.

Fig. S3. Simplified diatom profiles for Hudson Bay Lowlands lakes. The most common diatom taxa are presented as stratigraphical sequences with zonations established through constrained incremental sum of squares (CONISS) using Edwards and Cavalli-Sforza's chord distance as the dissimilarity coefficient (TGView v. 1.7.16) [2], for: **(A)** Aquatuk Lake; **(B)** Spruce Lake; **(C)** Hawley Lake; and **(D)** North Raft Lake. For display purposes, planktonic diatom taxa (*Cyclotella/Discostella* taxa in North Raft Lake, both pennate and centric planktonic diatom taxa for Aquatuk and Hawley lakes, and pennate planktonic taxa for Spruce Lake) were grouped. Benthic fragilarioid taxa were grouped into complexes for Spruce and Hawley lakes and were summed for Aquatuk and North Raft lakes. *Aulacoseira* sum for Aquatuk Lake consisted of *A. subarctica, A. granulata,* and *A. ambigua*. Small *Navicula* taxa including *N. subminuscula, N. submuralis,* and *N. subrotundata* were grouped for North Raft Lake. Planktonic diatoms consisted mainly of pennate planktonic *Fragilara tenera* (with minor contributions by *F. crotonensis, F. nanana, F. ulna, Asterionella formosa,* and *Tabellaria flocculosa* str. III for Aquatuk, Spruce, and Hawley lakes whereas *Cyclotella/Discostella* taxa consisted mainly of *D. pseudostelligera* with minor contributions from *C. michiganiana* and *C. comensis/gordonensis* for North Raft Lake. Numbers following taxon labels indicate the number of diatom taxa represented by the grouping.

Fig. S4. Step changes in seasonal air temperatures in the Hudson Bay Lowlands. **(A**) The mean autumn **(B)** mean winter **(C)** mean spring **(D)** mean summer air temperature anomalies from the Churchill, Manitoba climate station (see Fig. 1 for location) from 1943 to 2011. Temperature anomalies are relative to the 1971 to 2000 baseline. To improve the clarity of the figure, a LOESS smoother (span = 0.15) was applied to the climate data to highlight trends. Gray-shaded vertical lines represent the breakpoint and standard errors determined by a 2-segment piecewise linear regression (P<0.0001, Autumn = 1991±0.6, Winter = 1992±1.5, Spring (no breakpoint was identified and therefore a linear regression was applied), Summer = 1978±2.2). Arrows

indicate the magnitude of temperature changes (*i.e.* the slope of a linear regression over the time period of interest) prior to, and following, the identified breakpoints.

Fig. S5. Step changes in diatom trends from the four study lakes relative to regional temperature records. A selection of diatom trends (principal components analysis sample scores (PCA) for axis 1 (PC1), axis 2 (PC2), percent relative abundances for planktonic diatom taxa and for benthic fragilarioid taxa) compared to averaged air temperature data from the Churchill (Manitoba) climate station from 1943 to 2011 for the four study lakes: **(A)** North Raft Lake; **(B)** Spruce Lake; **(C)** Aquatuk Lake; and **(D)** Hawley Lake. Gray vertical lines represent the breakpoint and standard errors determined by a 2-segment piece-wise linear regression (P<0.0001, annual air temperature = 1991±0.6, autumn air temperature = 1991±0.6, winter air temperature = 1992±1.5). No significant breakpoint was identified for spring air temperature. For each lake, the diatom assemblage trends were summarized through PCA using the default options available in the program CANOWIN, version 4.5 [3]. Only diatom species that occurred in at least 1% relative abundance in at least two lakes were included in the analysis. All percent relative abundance species data were square-root transformed prior to analyses to equalize the variance among taxa. Results of correlation analysis (Spearman rank) are given in each panel for the diatom trends in relation to the temperature data. The timing of breakpoints for PCA axes one and two, % relative abundance for planktonic and fragilarioid taxa are presented by a black dashed line in each panel. For each sedimentary interval in each lake, the average air temperature during the period of its accumulation was calculated, thereby integrating the temperature data with the diatom data [4].

Electronic Supplementary Table Legend

Electronic Supplementary Table 1. Select limnological data for HBL study lakes. Data presented are 3-year means (2009 to 2011).

Electeronic Supplementary Table 2. Mean and standard deviation for each lake of the variables plotted in Figure 3 as z-scores.

Electronic Supplementary Information: Materials and Methods

Each HBL sediment core was sectioned into 0.25-cm, continuous intervals for the entire core using a Glew [5] extruder. Lakes were sampled off the pontoon of a floatplane with the exception of Hawley Lake which was accessed by motor boat. Because bathymetric maps were not available for these study lakes, attempts were made to sample

near the deepest part of the lake by taking several depth readings from the float plane and in Hawley Lake, by taking several readings from a hand-held depth sounder. In addition, the approximate location of the deepest point of these lakes (e.g. North Raft) was known from local traditional knowledge (Albert Chookomolin, personal communication, August 2009). For each lake, limnological data were collected each field season between 2009 and 2011 from late July to early August. All chemical analyses were undertaken at the Ontario Ministry of the Environment's (MOE) Dorset Environmental Science Centre using standard MOE protocols (Ontario Ministry of the Environment, 1983). Further details on the water sampling procedures can be found in [6].

Electronic Supplementary Material: References

1. Appleby, P.G. 2001Chronostratigraphic techniques in recent sediments. In *Tracking environmental change using lake sediments*, vol.1 (eds. Last, W.M. & Smol, J.P.) pp. 171-203. Dordrecht: Springer.
2. Grimm, E. 1991 TILIA and TILIA-GRAPH. (Illinois State Museum, Springfield, IL).
3. ter Braak, C.J.F. & Šmilauer, P. 2002 CANOCO reference manual and CanoDraw for Windows user's guide: Software for canonical community ordination v.4.5. Microcomputer Power.
4. Sorvari, S. & Korhola, A. 1998 Recent diatom assemblage change in subarctic Lake Saanajärvi, NW Finnish Lapland. *J. Paleolimnol.* **20**, 205-215.
5. Glew, J.R. 1988 A portable extruding device for close interval sectioning of unconsolidated core samples. *J. Paleolimnol*. **1**, 235-239.
6. Rühland,K.M., Hargan, K., Jeziorski, A., Paterson, A.M., Keller, W. & Smol, J.P. A multi-trophic exploratory survey of recent environmental changes using lake sediments in the Hudson Bay Lowlands, Ontario, Canada. *Arctic, Antarctic, and Alpine Research* (accepted).