Assessment of hydroecological changes at the Slave River Delta, NWT, using diatoms in seasonal, inter-annual and paleolimnological experiments

by

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Author's Declaration

I hereby declare that I am the sole author of this thesis. This is a true copy of the thesis, including any required final revisions, as accepted by my examiners.

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Abstract

Relationships between hydrology, limnology and ecology are analyzed in a comprehensive study of water bodies in the Slave River Delta, Northwest Territories, Canada, at a variety of temporal and spatial scales, including seasonal, inter-annual and multi-decadal timescales at individual sites to delta-wide perspectives. Water chemistry and surface sediments were analyzed from 41 shallow lakes representing three previously-defined hydrological categories in the Slave River Delta, in order to identify relationships between hydrological and limnological conditions and their associations with recently deposited diatom assemblages. *Evaporation-dominated* lakes are physically removed from the influence of the Slave River, and are characterized by high alkalinity and high concentrations of nutrients and ions. In contrast, *flood-dominated* lakes tend to receive a pulse of floodwater from the Slave River during the spring thaw and have low alkalinity and low concentrations of most nutrients and ions. *Exchange-dominated* lakes are variably influenced by floodwaters from the Slave River and seiche events from Great Slave Lake throughout the spring thaw and open-water season, and are characterized by a broad array of limnological conditions that are largely dependent on the strength of the connection to these sources of floodwater. Specific diatom 'indicator' taxa have been identified that can discriminate these three hydrological lake categories. Evaporation-dominated lakes are associated with high relative abundance of common epiphytic diatom taxa, while diatoms indicative of flood- and exchange-dominated lakes span a wide range of habitat types (epiphytic, benthic) but also include unique planktonic diatoms (*Stephanodiscus* and *Cyclostephanos* taxa) that were not found in surface sediments of evaporation-dominated lakes.

Water chemistry, diatom phytoplankton communities and macrophyte biomass were monitored seasonally over three years (2003-05) from six hydrologically-diverse lakes of varying

flood susceptibility to determine the effects of river flooding on the seasonal and inter-annual hydroecological conditions of lakes in the Slave River Delta. Results indicate that river flooding is the dominant hydrological process controlling the temporal dynamics of limnological and ecological conditions in lakes of the Slave River Delta. In the absence of river flooding, lakes have relatively high concentrations of nutrients and low concentrations of most ions, but when flooded, concentrations of nutrients decrease and ions increase. The limnological and ecological conditions in frequently-flooded and non-flooded lakes are relatively stable from year to year, whereas lakes that are intermittently flooded fluctuate widely and are subject to variable conditions depending on whether or not they flood. Lakes that do not flood lack planktonic diatom communities, while spring flooding from the Slave River introduces an abundance of planktonic, centric diatoms that persist only for a few weeks in the water column before settling out. Flooding reduces lake water transparency, which decreases macrophyte biomass, while non-flooded lakes exhibit higher macrophyte biomass.

To improve understanding of the role of river flooding and other hydrological factors on epiphytic diatom communities, a natural experiment was conducted to compare diatom communities in two hydrologically distinct lakes in the Slave River Delta (Northwest Territories, Canada) over two years (2004 and 2005) of varying spring flood magnitude of the Slave River. Magnitude and spatial extent of flooding was low in 2004 and high in 2005. Replicate samples were collected from three dominant macrophyte species (Lake SD28: *Potamogeton friesii*, *Myriophyllum exalbescens* and a species of *Equisetum*; and, Lake SD29: *Potamogeton friesii*, *Ceratophyllum demersum*, and a species of floating filamentous green algae) in three separate basins from each lake. Multivariate analyses (PCA, analysis of similarities) of the common macrophyte in both lakes (*Potamogeton friesii*) revealed that yearly differences due to frequency and intensity of flooding account for the greatest differences in epiphytic diatom community

composition (PCA axis 1 = 0.302 and ANOSIM SD29 – 2004 versus 2005 Global R value = 0.982, $p < 0.001$ and d.f. = 23), followed by hydrolimnological differences between the two study lakes (PCA axis 2 = 0.262 and ANOSIM SD28 versus SD29 – 2004 and 2005 Global R value = 0.814, $p < 0.001$ and d.f. = 47), and by spatial variability within lakes (variation along both PCA axes and ANOSIM from both lakes in both years Global R value = 0.940-1.000, $p < 0.001$ and d.f. = 47). Epiphytic diatom community composition differed significantly ($p < 0.001$) at all levels of comparison. Observed patterns of epiphytic diatom composition between years and lakes indicated that hydrological effects on the limnological conditions, coupled with changes in the light environment, exert the strongest control on epiphytic diatom community composition, whereas spatial variability of limnological conditions within lakes and host-macrophyte specificity appear to play statistically significant but less important roles. Epiphytic diatom community composition is a sensitive indicator of hydrological change and knowledge gained concerning the roles of hydrological factors, limnological conditions and macrophyte host species on epiphytic diatom communities is important to inform interpretations of hydroecological changes from analyses of sedimentary diatom assemblages, which are often dominated by epiphytic taxa, in ongoing monitoring and paleolimnological studies in the Slave River Delta and other floodplain environments.

Sediment cores were collected from a lake in each of the three hydrological lake categories in the Slave River Delta, to evaluate the ability of diatom assemblages to detect differences in the hydrological state and temporal variability of hydroecological conditions within individual lakes of this complex deltaic environment. Results indicate that diatoms provide sensitive records of environmental change and important information on past changes in hydrological conditions such as river flooding. The composition and temporal patterns of variation in diatom assemblages differ among lakes from different hydrological categories in consistent and predictable ways. The

flood-dominated lake (SD2) provides a high resolution record of hydroecological variability and changes in flood-frequency over time. Sedimentary diatom assemblages repeatedly shift in dominance from taxa indicative of low river influence to taxa indicative of high river influence. Sedimentary diatom assemblages from the exchange-dominated lake (SD28) are dominated by taxa indicative of high river influence and were relatively static during the past ~100 years, but the total sum of planktonic diatoms (% abundance) can provide robust records of large, spatially extensive flood events in the Slave River Delta. Both flood- and exchange-dominated lakes show marked correspondence with gauged Slave River discharge levels over the past 46 years indicating an ability of diatoms to track periods of higher and lower flood frequency and high-magnitude flood events. Sedimentary diatom assemblages from the evaporation-dominated lake (SD20) in this study were poorly preserved below 6 cm depth, but assemblages from above 6 cm had distinct community composition similar to assemblages in surface sediments of evaporation-dominated lakes of the Slave River Delta. These diatoms correctly identify this lake as having evaporation-dominated hydrology. Overall, the sediment records provide no evidence for reduced flood frequency or a decrease in high magnitude flood events to indicate that upstream river regulation or another driver of change may be causing perceived changes of lower flood frequency and low water levels throughout the delta.

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Chapter 1
General introduction

1.1 Deltaic environments and drivers of change

Floodplains and deltas are highly productive landscapes, and include important aquatic ecosystems that are characterized by their close interaction with rivers (Junk 2005). River flooding exerts strong control on the structure and function of ecological systems of deltas and the hydrological, limnological and ecological conditions are often highly responsive to spatial and temporal variability of river discharge and flooding (Junk et al. 1989; Amoros and Bornette 2002; Thomaz et al. 2007). In deltaic systems of northern Canada, the frequency, duration and extent of flooding affects the physical, chemical and biological properties of lakes within them (Lesack et al. 1998; Squires et al. 2002; Hall et al. 2004; Wolfe et al. 2007b). These ecosystems are among the most biologically productive and environmentally sensitive elements of riverine systems in northern Canada (Milburn et al. 1999; Prowse et al. 2002). Due to their sensitivity to changes in river discharge, as well as their importance as productive natural habitat, concern is mounting about the effects of hydroclimatic and human alteration of river hydrology on the ecological state of lakes and wetlands of floodplain and delta environments (Prowse and Conly 2001; Schindler and Donahue 2006).

It is generally accepted among the scientific community that climate warming will be amplified in arctic and subarctic regions (Overpeck et al. 1997; Serreze et al. 2000), and it is already apparent that climate-driven decline in glacier volumes in the Rocky Mountains has reduced flows of the Athabasca River during the past 40 years (Schindler and Donahue 2006). Importantly, river-ice processes are highly sensitive to both short- and long-term hydro-climatic variability, and there is concern over the potential effects of changing climatic patterns on the ice regimes of northern rivers, including the timing and amount of river discharge and the changing

conditions for ice-jam flood development (Beltaos 2002; Prowse et al. 2002). Most flooding in northern river systems is caused by ice jams due to dynamic breakup of river ice during the spring (Prowse and Conly 2001). Ice-jam floods are important to the maintenance of riparian ecosystems in river basins, rejuvenating early successional plant communities and replenishing many lakes and wetlands with water and sediment nutrients (Marsh and Hey 1989; Milburn and Prowse 1998). As climate warming progresses, snowpacks and peak spring water levels are expected to decline and the snowmelt period is expected to initiate earlier and become more protracted (Pietroniro et al. 2006). Consequently, the likelihood for the formation of ice-jam floods is expected to decrease (Schindler and Smol 2006). Northern lakes are also particularly susceptible to climate change due to their small water volumes, extended ice-cover periods, and relatively short growing season (Korhola et al. 2002). The expected effects of climate change on these lakes include changes in duration of ice-free season, light regimes, water levels, biological productivity, water balance and flooding regimes in deltaic environments (Rouse et al. 1997).

Human activities have had major impacts on river flows in many northern areas and more than half of the world's large river systems have been subject to hydrological modifications by regulation and fragmentation of river flow (Nilsson et al. 2005). In many floodplain systems, hydrological variability has been altered by human regulation and fragmentation of river flow, often resulting in negative impacts on downstream wetlands and deltas (Junk 2005). In northern North America, accelerated industrial development has stimulated installation of hydroelectric dams, and the demand for power production along with increased consumptive water use, will likely continue to alter the discharge and flooding regimes of large northern rivers with commensurate effects on their floodplains (Schindler and Smol 2006). Consequently, there is an increasing need to develop and improve scientifically rigorous methods for the assessment and prediction of potential impacts of multiple stressors (i.e. human disturbance, climate variability

and warming, geomorphic processes) on northern deltaic environments (Prowse and Conly 2001; Timoney 2002). This need is particularly acute because there is very limited scientific knowledge of the hydroecology of many large river floodplains and the data that exist are usually too sparse and too short in duration to distinguish the relative roles of natural, climatic or human processes on hydroecological conditions of northern floodplains.

1.2 The Slave River Delta

In the Slave River Delta, Northwest Territories (Figure 1.1), the lack of long-term data currently prevents assessment of the importance of climatic variability, river regulation and natural variability or geomorphic changes on the hydrology, limnology and ecology of the system. The Slave River Delta is thought to have undergone considerable drying as a result of regulation of the Peace River upstream that has reduced frequency of flooding. High biological productivity and diversity in the delta are closely linked to hydrology and periodic flooding of the Slave River, which are believed to be of central importance to maintaining riparian habitat and overall ecological vitality (English et al. 1997; Prowse et al. 2002). The delta provides important feeding, staging, and breeding habitats for a large number of waterfowl, muskrat, and other wildlife (English et al. 1997), and these natural resources of this ecosystem are also of central importance to the livelihood and socio-cultural integrity of the indigenous community of Fort Resolution, NWT (Wolfe et al. 2007a).

The Slave River Delta is part of the much larger Mackenzie River Drainage Basin, which includes the Peace-Athabasca Delta, the Mackenzie Delta, and many tributary rivers. The Slave River Delta consists of a large wetland complex comprising numerous river channels, marshes, fens, bogs, swamps and forests. Scattered throughout this landscape are numerous small, shallow (<5m) lakes with variable hydrological connectivity and flood susceptibility, creating a landscape with a range of hydrological settings. In the absence of flooding, these shallow lakes tend to have

clear water and extensive macrophyte growth throughout all or most of the system. The abundant growth of macrophytes can reduce turbulence in the water and prohibit resuspension of sediment (Scheffer 1998). Although this type of clear-water macrophyte-dominated state is dominant in the Slave River Delta, flooding by turbid river and seiche waters (a pulse disturbance) promotes a shift to a turbid state of high suspended sediment content. The turbid state does not appear to be an alternate stable state (*sensu* Scheffer 1998) such as occurs in shallow European lakes that receive press disturbance of increasing nutrient loads. Instead, the turbid state in deltaic lakes appears to persist only when flood waters enter a lake. Following flooding, lakes revert rather rapidly to a clear-water , macrophyte-dominated state (see Chapter 3).

Extensive studies have been undertaken in the Slave River Delta to understand river and delta hydrology. English et al. (1997) characterized the active delta into three distinct biogeographical zones based on vegetation patterns and geomorphological differences as influenced by Slave River flood frequency: the outer-delta, the mid-delta, and the apex. The outer-delta is a flat, low-lying area adjacent to Great Slave Lake that is susceptible to annual spring flooding from the Slave River and from periodic seiche events on Great Slave Lake, and it supports a wide variety of submergent and emergent aquatic vegetation. The mid-delta is a transitional area between the outer-delta and the apex, where alder-willow vegetation complexes dominate and floods have been estimated to occur approximately every 5-7 years on average (Prowse et al. 2002). The apex occupies a drier, more elevated area of the delta that receives infrequent flooding and ranges from small wetlands to mature forests that support white spruce (Prowse et al. 2002). Gardner et al. (2006) have provided a historical analysis of seiche activity on Great Slave Lake and the complex temporal and spatial effects of seiche events on the hydrodynamics of the delta. They suggest that during the late summer and autumn, water levels on the lake are much more variable than earlier in the open-water season. Seiches begin to occur

on the lake during mid to late July; however, there has been a delay in the onset date of seiches by 14–19 days since 1968.

Brock et al. (2007) have identified three main hydrological categories of lakes based on differences in the major hydrological processes that control their water balances using stable water isotope tracers: flood-dominated, evaporation-dominated and exchange-dominated. The water balances of flood-dominated lakes, located in the active part of the delta, are strongly influenced by Slave River floodwater during the spring melt, while evaporation-dominated lakes, located in the older non-active part of the delta, receive spring snowmelt and summer precipitation and evaporation becomes the over-riding process controlling lake water balances during the ice-free season. Exchange-dominated lakes, located along the Slave River and delta front adjacent to Great Slave Lake, receive inputs from channel connections with the Slave River or from Great Slave Lake water via seiche events, which result in variable water balances depending on the strength of these connections. The hydrological classification by Brock et al. (2007) was based on seasonal isotopic data collected during thaw season 2003. Notably, Slave River discharge during spring break-up of 2003 was average compared to 46 years of gauge data at the nearest hydrometric station. Therefore the hydrological classification (based on water samples collected in 2003), which is strongly influenced by Slave River spring discharge, likely reflects average contemporary hydrological conditions of the delta. However, biological indicators such as diatoms incorporated in surface sediments may be a more accurate assessment of hydroecological lake conditions as they represent longer timescales.

The climate of the Slave River Delta is highly seasonal, characterized by long, cold winters and short, warm summers. Based on 1971-2000 Canadian climate normals for Hay River, NWT (Environment Canada 2002), mean yearly temperature is -2.9°C, with mean January and July

temperature of -23.1°C and 15.9°C, respectively. A total of 320 mm of precipitation falls annually, half as rain during the May to September ice-free season.

1.3 Hydrological and limnological conditions, and diatom assemblages

The frequency of flooding and the degree of connection between floodplain lakes and their associated rivers strongly regulates limnological conditions in lakes of the Mackenzie Delta (Squires et al. 2002) and the Peace-Athabasca Delta (Wolfe et al. 2007b). Analyses of sediment cores from lakes in these deltas have provided a wealth of information about past flood events and the dynamic hydrological, geochemical and biotic responses to such events (Hay et al. 1997, 2000; Michelutti et al. 2001; Hall et al. 2004; Wolfe et al. 2005, 2006). Biological communities have been shown to be useful paleo-indicators of hydroecological change in delta lakes, but achieving scientifically robust interpretations requires understanding and quantifying contemporary relationships between basin hydrology, environmental conditions and biological communities of delta lakes (Hall et al. 2004; Wolfe et al. 2005, 2006). Diatom algae are particularly useful biomonitors for such studies, because they are sensitive to changes in physical, chemical and biological conditions and microhabitat availability (Hay et al. 1997; Hall et al. 2004). In deltaic systems, diatom community composition often changes from dominance by epiphytic taxa in closed-drainage lakes or when river connection is low (due to high abundance of macrophytes under clear-water, nutrient-rich conditions) to dominance by planktonic taxa and non-epiphytic taxa (e.g. benthic and tychoplanktonic *Fragilaria* taxa) in turbid open-drainage lakes and under flood conditions (Hall et al. 2004). While previous studies in the Mackenzie Delta (Hay et al. 1997, 2000) and the Peace-Athabasca Delta (Hall et al. 2004) have found strong relationships between diatom communities and the hydrolimnological conditions of delta lakes, no such study has been conducted for the Slave River Delta.

1.4 Effects of river flooding

Biological communities (e.g. macrophytes, phytoplankton, benthic algae) have been found to respond rapidly and sensitively to river flooding and hydrological changes in both the Mackenzie (Squires and Lesack 2003; Squires et al. 2002) and Peace-Athabasca deltas (J. Wiklund, unpublished data). In the Slave River Delta, however, it remains uncertain how river flooding affects delta lakes over seasonal to annual time scales with respect to limnological conditions, development of phytoplankton communities and macrophyte productivity. Flooding can be variable between years and does not regularly occur in all delta lakes, therefore hydroecological conditions and the seasonal and inter-annual patterns of change can vary widely among lakes. Although flooding affects the limnological and ecological conditions in delta lakes, the temporal dynamics (e.g. timing and duration of the effects of flooding) of lake water chemistry conditions remain unclear, and it is also not currently known how biological communities in delta lakes respond to flooding.

Increased river influence often results in decreased light transparency and macrophyte coverage in open-drainage lakes of the Peace-Athabasca Delta and no-closure lakes of the Mackenzie Delta, which are continuously flooded by rivers and thus highly turbid (Hay et al. 2000; Squires et al. 2002; Hall et al. 2004). However, this situation does not appear to be the case in the Slave River Delta, and such lakes do not appear to exist. Flood- and exchange-dominated lakes are dominated by macrophytes, in spite of high minerogenic turbidity, and are more similar to restricted-drainage lakes in the Peace-Athabasca Delta and low-closure lakes in the Mackenzie Delta which received periodic flooding (Hay 1997; Hall et al. 2004). Evaporation-dominated lakes in the Slave River Delta are analogous to closed-drainage (isolated) lakes in the Peace-Athabasca Delta and high-closure lakes in the Mackenzie Delta which are removed from the influence of rivers and do not flood (Hay 1997; Hall et al. 2004)

1.5 Epiphytic diatom communities

Diatom assemblages in the surface sediments of many lakes in the Mackenzie Delta and Peace-Athabasca Delta are dominated by epiphytic taxa, reflecting the extensive habitat (macrophyte surface area) available in these shallow deltaic lakes that support prolific macrophyte growth (Hay et al. 1997, 2000; Hall et al. 2004). Epiphytic algae are often the major primary producers in small, shallow lakes and provide an important supply of autochthonous carbon and energy to higher trophic levels (Cattaneo and Kalff 1980; Lalonde and Downing 1991; Sand-Jensen and Borum 1991; Hecky and Hesslein 1995; Wetzel 1996; Robinson et al. 1997). The importance of epiphytic algae to aquatic ecosystems is due in part to their ability to maintain high rates of photosynthesis, which is facilitated by the higher efficiency of nutrient retention and recycling in algal-microbial-substratum communities compared to planktonic communities (Wetzel 1996). Despite their ecological importance, however, studies on epiphytic algae remain overshadowed by the large number of studies devoted to phytoplankton (Stevenson 1996). Studies have shown that light, temperature, nutrients, wave action, water-level fluctuations and plant architecture affect the quantity and productivity of epiphyton (Boston and Hill 1991; Lalonde and Downing 1991; Cattaneo et al. 1998; Romo and Galanti 1998; Gross et al. 2003). In floodplain environments, such as the Slave River Delta, hydrological factors may also play an important role in regulating epiphyte communities. River flooding and hydrological variability strongly influence submerged macrophytes, phytoplankton and benthic algal communities (Van den Brink et al. 1993, 1994; Squires and Lesack 2001, 2002, 2003; Squires et al. 2002), but very few studies have investigated epiphytic algal community structure in floodplain lakes (Engle and Melack 1993; Tesolin and Tell 1996).

1.6 Paleolimnology

Deltas are extremely dynamic systems and are in a state of perpetual change, but it is important to disentangle effects due to natural variability from those induced by anthropogenic changes. In the absence of direct records of environmental change, paleoecological proxy-data can be used to quantify past variability within these ecosystems. For example, alteration of the flood regime of delta lakes may result in changes in macrophyte abundance that ultimately affects the abundance of epiphytes growing attached to them, and such changes may leave a record in the sediments that permits assessment of past hydroecological changes from analyses of preserved diatoms. Although deltaic sediments may be challenging for paleoenvironmental interpretations due to their highly dynamic nature (e.g. Michelutti et al. 2001), they are providing important records of environmental change (Sakaguchi et al. 2006; Zalat and Servant Vildary 2007) including information about past flood events and the dynamic hydrological, geochemical and biotic responses to such events that often cannot be obtained using other methods (Hay et al. 1997, 2000; Hall et al. 2004; Wolfe et al. 2005, 2006). In complex depositional environments such as the Slave River Delta, a multi-proxy paleolimnological approach can provide key insights into hydroecological dynamics of this northern delta.

1.7 Thesis Overview

The thesis presented here is part of a broad multi-disciplinary research program whose aim is to understand how the Slave River Delta ecosystem functions and how it responds to various environmental stressors (see Wolfe et al. 2007b). The overall objective of this thesis is to analyze the relationships between hydrology, limnology and ecology, in a comprehensive study of Slave River Delta water bodies at a variety of temporal and spatial scales, including seasonal, inter-annual and multi-decadal timescales from individual sites to a delta-wide perspective. This thesis is divided into four independent data chapters (Chapters 2-5), and each chapter deals with a

specific aspect of my overall research objectives. At the time of thesis submission Chapter 2 has been accepted for publication in the Journal of Paleolimnology (DOI: 10.1007/s10933-007-9128-8) and Chapter 3 has been submitted for publication in Freshwater Biology (note: Freshwater Biology journal format requires numbered summary points as a replacement for the abstract and the absence of a conclusions section). Chapters 4 and 5 will be submitted to the Journal of the North American Benthological Society and the Journal of Paleolimnology, respectively. Data chapters are listed below:

Chapter 2: Sokal MA, Hall RI and Wolfe BB. Relationships between hydrological and limnological conditions in lakes of the Slave River Delta (NWT, Canada) and quantification of their roles on sedimentary diatom assemblages. Journal of Paleolimnology. (in press DOI: 10.1007/s10933-007-9128-8)

Chapter 3: Sokal MA, Hall RI and Wolfe BB. Effects of flooding on the limnology, diatom phytoplankton communities and macrophyte biomass of lakes in the Slave River Delta (NWT, Canada). Freshwater Biology. (submitted)

Chapter 4: Sokal MA, Hall RI and Wolfe BB. Effects of flooding on epiphytic diatom communities in two floodplain lakes of the Slave River Delta (Northwest Territories, Canada). Journal of the North American Benthological Society. (in preparation)

Chapter 5: Sokal MA, Hall RI and Wolfe BB. An assessment of sedimentary diatom assemblages for paleohydrological reconstructions in a complex floodplain environment. Journal of Paleolimnology. (in preparation)

The study presented in Chapter 2 uses a spatial survey of 41 lakes in the Slave River Delta to determine if hydrological differences among the lakes correspond with predictable differences in physical and chemical characteristics of lakes, and if these differences are related to the composition of diatom assemblages in recently-deposited surficial lake sediments. Knowledge

gained from this study is being used in biomonitoring and paleolimnological investigations of the Slave River Delta to further understand the complex interactions among hydrology, limnology, and aquatic ecology in this freshwater ecosystem. In particular, ongoing multi-proxy (stable isotopes, diatoms, plant macrofossils) paleolimnological studies at several lakes situated throughout the delta will use the information provided by this study to assess the relative roles of river discharge, frequency of ice-jam floods, climatic variability and geomorphic change on the Slave River Delta ecosystem.

The study presented in Chapter 3 identifies the responses of limnological conditions, composition of diatom phytoplankton communities and macrophyte biomass to river flooding in six lakes representing the three hydrological categories of lakes in the Slave River Delta. The study spanned three years (2003-2005) of varying spring flood magnitude, which collectively provided a useful experimental design and temporal context to examine the role of river flooding on seasonal and inter-annual dynamics in delta lakes. This research provides insights into the hydroecological evolution of northern deltaic landscapes, and further improves our understanding of the complex interactions among hydrology, limnology, and aquatic ecology, ultimately contributing to future resource management decisions in the Slave River Delta.

In Chapter 4, the role of hydrological factors on epiphytic diatom communities is determined by comparing diatom communities in two hydrologically distinct lakes over two years (2004 and 2005) of varying spring flood magnitude. The relative roles of hydrology, flooding variability, spatial within-lake variability of chemical conditions and macrophyte host species in regulating the community composition of epiphytic diatoms are determined. Knowledge gained concerning the roles of hydrological factors, limnological conditions and macrophyte host species on epiphytic diatom communities is important to inform interpretations of hydroecological changes from analyses of sedimentary diatom assemblages in ongoing paleolimnological studies

in the Slave River Delta and other floodplain environments, because the diatom assemblages are often dominated by epiphytic taxa.

In Chapter 5, analyses of diatom assemblages in sediment cores from a lake in each of the three hydrological lake categories (flood-, exchange- and evaporation-dominated) in the Slave River Delta, NWT, were used to evaluate the ability of diatom assemblages to detect differences in the hydrological state among lakes and to track temporal variability of hydroecological conditions within individual lakes of this complex deltaic environment. This study is important to determine if sedimentary diatom assemblages can track these changes over time and accurately assess shifts in hydrological conditions within a lake.

1.8 Major contributions of authors and others

Chapter 2

Idea + planning: MA Sokal, RI Hall and BB Wolfe

Field work: MA Sokal, RI Hall, BB Wolfe, KP Clogg-Wright, TWD Edwards and MC English

Laboratory analyses: MA Sokal, except water chemistry analyses which were conducted by Richard Carignan and his staff at the Water Chemistry Laboratory, University of Montreal.

Data analysis: MA Sokal

Figures: MA Sokal (Figures 2.2-2.6), P Schaus (Original Figure 2.1, subsequently modified by MA Sokal)

Writing: MA Sokal (main part of the text), RI Hall and BB Wolfe (comments and contributions to text)

Chapter 3

Idea + planning: MA Sokal, RI Hall and BB Wolfe

Field work: MA Sokal, KP Clogg-Wright, C Mongeon, J Bailey, B Brock, M Adam and G Lafferty

Laboratory analyses: MA Sokal, except isotope analyses ($\delta^{18}O$ and $\delta^{2}H$ surface water samples) provided by B. Brock and water chemistry analyses were conducted by Taiga Environmental Laboratory, Yellowknife, and the Environment Canada National Laboratory for Environmental Testing, Burlington.

Data analysis: MA Sokal

Figures: MA Sokal (Figures 3.2-3.7), P Schaus (Original Figure 3.1, subsequently modified by MA Sokal)

Writing: MA Sokal (main part of the text), RI Hall and BB Wolfe (comments and contributions to text), SN Higgins (comments to text)

Chapter 4

Idea + planning: MA Sokal and RI Hall

Field work: MA Sokal, C Mongeon, J Bailey, B Brock and M Adam

Laboratory analyses: MA Sokal, except water chemistry analyses were conducted by Taiga Environmental Laboratory, Yellowknife, and the Environment Canada National Laboratory for Environmental Testing, Burlington.

Data analysis: MA Sokal and RI Hall, MC Crenshaw (comments on statistical techniques)

Figures: MA Sokal (Figures 4.3-4.8), P Schauss (Original Figure 4.1, subsequently modified by MA Sokal), B Brock (Created bathymetric maps, subsequently modified by MA Sokal)

Writing: MA Sokal (main part of the text), RI Hall and BB Wolfe (comments and contributions to text)

Chapter 5

Idea + planning: MA Sokal, RI Hall and BB Wolfe

Field work: MA Sokal, RI Hall, BB Wolfe, KP Clogg-Wright, TWD English, MC English, C Mongeon

Laboratory analyses: MA Sokal

Data analysis: MA Sokal

Figures: MA Sokal (Figures 5.2-5.6), P Schauss (Original Figure 5.1, subsequently modified by MA Sokal), B Brock provided Slave River discharge levels for Figure 5.6

Writing: MA Sokal (main part of the text), RI Hall and BB Wolfe (comments and contributions to text)

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1.10 Figures

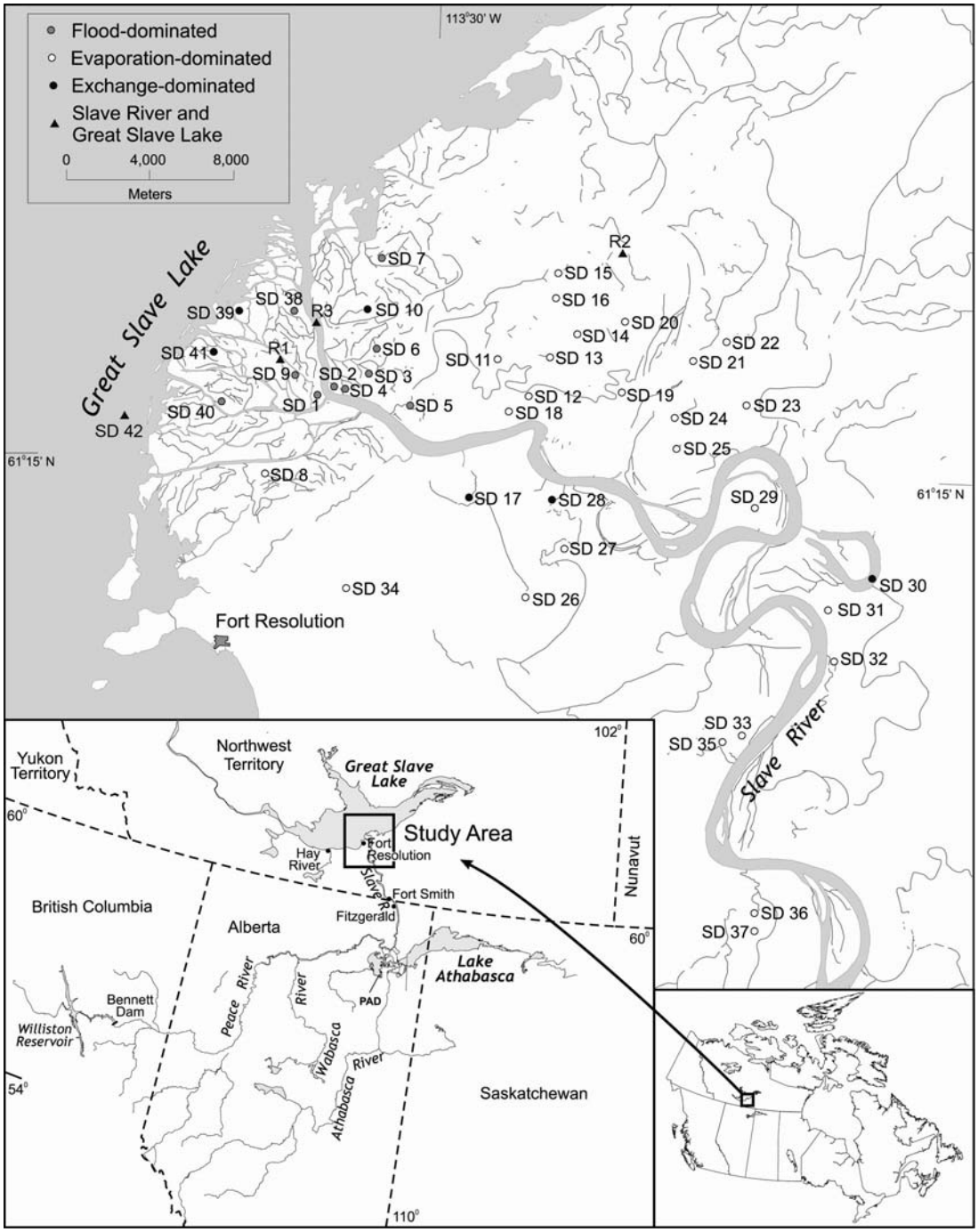

Figure 1.1 Location of the Slave River Delta and study sites, including rivers (R1, R2, R3) and Great Slave Lake (SD 42, black triangles), and delta lakes (SD1-41) classified according to the hydrological categories of Brock et al. (2007): flood-dominated (grey circles), exchange-dominated (black circles), and evaporation-dominated (open circles) lakes.

Chapter 2

Relationships between hydrological and limnological conditions in lakes of the Slave River Delta (NWT, Canada) and quantification of their roles on sedimentary diatom assemblages

2.1 Abstract

Water chemistry and surface sediments were analyzed from 41 shallow lakes representing three previously-defined hydrological categories in the Slave River Delta, Northwest Territories, Canada, in order to identify relationships between hydrological and limnological conditions and their associations with recently deposited diatom assemblages. Evaporation-dominated lakes are physically removed from the influence of the Slave River, and are characterized by high alkalinity and high concentrations of nutrients and ions. In contrast, flood-dominated lakes tend to receive a pulse of floodwater from the Slave River during the spring thaw and have low alkalinity and low concentrations of most nutrients and ions. Exchange-dominated lakes are variably influenced by floodwaters from the Slave River and seiche events from Great Slave Lake throughout the spring thaw and open-water season, and are characterized by a broad array of limnological conditions that are largely dependent on the strength of the connection to these sources of floodwater. Specific diatom 'indicator' taxa have been identified that can discriminate these three hydrological lake categories. Evaporation-dominated lakes are associated with high relative abundance of common epiphytic diatom taxa, while diatoms indicative of flood- and exchange-dominated lakes span a wide range of habitat types (epiphytic, benthic) but also include unique planktonic diatoms (*Stephanodiscus* and *Cyclostephanos* taxa) that were not found in surface sediments of evaporation-dominated lakes. The planktonic diatom taxa originate from the Slave River, and thus are indicative of river influence. In complex, remote, freshwater ecosystems like

the Slave River Delta, integration of results from hydrological and limnological approaches provides a necessary foundation to assess present, past and future hydroecological responses to changes in river discharge and climate.

2.2 Introduction

Deltas are highly productive landscapes, and include important aquatic ecosystems that are responsive to spatial and temporal variability of river discharge and flooding (e.g. Lewis et al. 2000; Junk 2005). Due to strong control of river connection on the physical, geochemical and biological conditions of floodplain lakes (English et al. 1997; Hay et al. 1997; Lesack et al. 1998; Prowse and Conly 2001, 2002; Squires and Lesack 2001, 2002, 2003; Squires et al. 2002; Spears and Lesack 2006; Brock et al. 2007; Wolfe et al. 2007b), there is concern regarding the downstream effects of human (Nilsson et al. 2005) and hydro-climatic (Overpeck et al. 1997; Serreze et al. 2000) alteration of river hydrology on the ecological state of floodplain and delta lakes and wetlands (Prowse and Conly 2001; Junk 2005; Schindler and Donahue 2006; Schindler and Smol 2006). Consequently, there is increasing need to develop improved and scientifically rigorous methods for the assessment and prediction of potential impacts of multiple stressors on deltaic environments. This need is particularly acute for remote, northern deltas as there is limited scientific knowledge of ecosystem hydroecology, and the data that exist are usually too sparse and too short in duration to distinguish the relative roles of natural and anthropogenic changes. Such is the case for the Slave River Delta, one of three major deltas within the Mackenzie River Drainage System in northern Canada, which is thought to have undergone considerable drying as a result of regulation of the Peace River upstream (English et al. 1997; Figure 2.1). Periodic flooding has created a landscape with high biological productivity and diversity of plant species that provides important feeding, staging, and breeding habitats for a large number of waterfowl,

muskrat, and other wildlife (English et al. 1997). The natural resources of this ecosystem are also of central importance to the livelihood and socio-cultural integrity of the indigenous community of Fort Resolution, NWT (Wolfe et al. 2007a).

The limnological conditions in lakes of the Mackenzie Delta and the Peace-Athabasca Delta, two other major deltaic ecosystems in the Mackenzie River Drainage Basin, are strongly regulated by the frequency of flooding and the degree of connection between floodplain lakes and their associated rivers (Hay et al. 1997; Squires et al. 2002; Wolfe et al. 2007b). Although deltaic sediments may be challenging for paleoenvironmental interpretations due to their highly dynamic nature (e.g. Michelutti et al. 2001), they are providing important records of environmental change (Sakaguchi et al. 2006; Zalat and Servant Vildary 2007) and a wealth of information about past flood events and the dynamic hydrological, geochemical and biotic responses to such events (Hay et al. 1997, 2000; Hall et al. 2004; Wolfe et al. 2005, 2006). Biological communities have been shown to be useful paleo-indicators of hydroecological change in these environments, but developing scientifically robust interpretations requires understanding and quantifying contemporary relationships between basin hydrology, environmental conditions and biological communities of delta lakes (Hall et al. 2004; Wolfe et al. 2005, 2007b). Diatoms are particularly useful biomonitors for such studies, because they are sensitive to changes in physical, chemical and biological conditions and microhabitat availability (Hay et al. 1997; Hall et al. 2004). In the Peace-Athabasca Delta, for example, epiphytic taxa dominate in closed-drainage lakes, whereas planktonic taxa and non-epiphytic taxa (e.g. benthic and tychoplanktonic *Fragilaria* taxa) proliferate in turbid open-drainage lakes and under flood conditions (Hall et al. 2004). Previous studies in the Mackenzie Delta (Hay et al. 1997, 2000) and the Peace-Athabasca Delta (Hall et al. 2004) have found strong relationships between diatom communities and the hydrolimnological conditions of delta lakes, which are important for accurate interpretations of hydroecological

changes from diatom assemblages analyzed in sediment cores. While no such study has been conducted for the Slave River Delta, extensive hydrological studies have been undertaken that have identified three main groups of lakes based on the major hydrological processes that control their water balances (Brock et al. 2007, detailed below).

In this study, we determine if hydrological differences among lakes in the Slave River Delta result in predictable differences in physical and chemical characteristics of lakes, and if these differences are related to the composition of diatom assemblages in recently-deposited surficial lake sediments. Our approach is to: 1) quantify relationships between basin hydrology and limnological conditions, and determine if limnological conditions differ among the three hydrological lake categories, 2) identify the main environmental gradients associated with the composition of diatom assemblages contained in surface sediments and determine whether diatom assemblage composition differs among the hydrological lake categories and 3) identify the diatom taxa that best discriminate among the hydrological lake categories. Results from this study provide a scientific framework for effective biomonitoring of hydroecological changes in the Slave River Delta and for quantifying roles of river hydrology, human impacts and climatic changes over decadal to millennial time scales from ongoing and future paleolimnological analyses.

2.3 Site description

The Slave River Delta is located at the mouth of the Slave River in the Northwest Territories (61°15’ N; 113°30’ W) where it enters Great Slave Lake (Figure 2.1). The delta consists of a large wetland complex with numerous river channels, marshes, fens, bogs, swamps and forests. Scattered throughout this landscape is a multitude of small, shallow (<4 m) ponds and lakes

(hereafter referred to collectively as lakes) that span broad hydrological gradients and support extensive macrophyte growth.

Including non-active areas of sedimentation, the delta is 170 km long by 70 km wide, extending north-northwest from the Slave River rapids at the south end to Great Slave Lake at the north end (Milburn and Prowse 1998). The entire delta covers an area of 8,300 km^2, but much of it is no longer active (Vanderburgh and Smith 1988). The active part of the delta is arcuate, spans an area approximately 400 km^2, and is prograding into Great Slave Lake through a system of active distributaries (Prowse et al. 2002). Natural levees in this area of the delta are between 0.1-1.5 m above Great Slave Lake low summer water levels, making lakes in the outer delta more susceptible to flooding by the Slave River, whereas the upstream relict portion of the delta has levee heights greater than 2.5 m which impede most river floodwaters (English et al. 1997). The extent and frequency of flooding can vary considerably, but periodic spring ice-jams are the main mechanism that promotes river flooding into Slave River Delta lakes (Prowse et al. 2002).

English et al. (1997) divided the active delta into biogeographical zones based on vegetation patterns and geomorphological differences (e.g. levee height), but this has limited application for assessing hydroecological changes in lakes because it assumes that all lakes within a zone are influenced by similar hydrological processes. More recently, Brock et al. (2007) examined the roles of major hydrological processes (including precipitation, snowmelt runoff, river flooding, Great Slave Lake seiche events and evaporation) on the water balances of lakes in the Slave River Delta using water isotope tracers and identified three distinct hydrological lake categories. The water balances of *flood-dominated* lakes, located in the active part of the delta, are strongly influenced by Slave River floodwater during the spring melt. *Evaporation-dominated* lakes, located in the older non-active part of the delta, receive spring snowmelt and evaporation becomes the over-riding process controlling lake water balances during the remainder of the

open-water season. *Exchange-dominated* lakes are located along the Slave River and delta front adjacent to Great Slave Lake and receive periodic inputs throughout the spring and open-water seasons from channel connections with the Slave River or Great Slave Lake water during seiche events, resulting in variable water balances depending on the strength of these connections.

The hydrological classification by Brock et al. (2007) was based on seasonal isotopic data collected during thaw season 2003. Notably, Slave River discharge during spring break-up of 2003 was average compared to 46 years of gauge data at the nearest hydrometric station. This feature is important for our study, because both the hydrological classification (based on water samples collected in 2003), which is strongly influenced by Slave River spring discharge, and surface sediments used in this study (collected in September 2002), which integrate diatoms deposited over a few years, likely reflect average contemporary hydrological and hydroecological conditions of the delta.

2.4 Materials and methods

2.4.1 Sample collection and laboratory analyses

The water bodies in this study are the same as those sampled and analyzed by Brock et al. (2007). River sites include the Slave River (site R3) and two of its distributaries (sites R1 [East Channel] and R2 [Jean River]). Water samples from Great Slave Lake (SD 42) were collected 100 m offshore of the outer delta to characterize the chemistry of seiche input waters to exchange-dominated basins. The 41 lakes sampled encompass the three hydrological categories (flood-dominated [n = 10], evaporation-dominated [n = 25], and exchange-dominated [n = 6]), as defined by Brock et al. (2007) (Figure 2.1).

Water and surface sediment samples were collected with the aid of a helicopter in September 2002. Water samples were collected from the central or deepest part of 41 delta lakes,

while 3 river samples were collected at mid-channel (in all cases from 10 cm below the water surface). *In situ* limnological measurements (water depth, temperature, pH and conductivity) were recorded at each sampling site and water samples were collected for standard chlorophyll and chemical analyses (dissolved phosphorus (dP), total phosphorus (TP), total nitrogen (TKN), nitrate + nitrite (NO_3^- + NO_2^-) dissolved organic carbon (DOC), colour, major ions (Ca^{2+}, Mg^{2+}, K^+, Na^+, Cl^-, SO_4^{2-}), dissolved silica (SiO_2), and alkalinity. Large particles were removed prior to analyses of water chemistry and chlorophyll by passing water through a 650 µm screen. The water was then filtered and the particles retained by a 0.7 µm filter were frozen and analyzed for chlorophyll-a (chl-*a*) using standard spectrophotometric methods (Jeffrey et al. 1997). Water samples (1 L) for chemical analyses were kept at 4ºC and sent to the Water Chemistry Laboratory, University of Montreal, for analysis using methods described in Environment Canada (1996) within 3-5 days of collection.

Surface sediment samples (0-1 cm) were collected at the time of water sampling from the same 41 delta lakes at the central or deepest part of each basin using a mini-Glew gravity corer (Glew 1991), and were stored in Whirl-pak® bags at 4ºC until processed for subsequent analyses. Microscope slides for diatom analysis were prepared from wet sediment samples by acid digestion following standard methods (Hall and Smol 1996). For each sample, a minimum of 400 diatom valves were identified and enumerated along transects using a Zeiss Axioskop II Plus compound microscope with differential interference contrast optics (1000X magnification, numerical aperture = 1.30). Diatom taxonomy followed Krammer and Lange-Bertalot (1986-1991). Diatom data were expressed as taxon relative abundances (%) of the total sum of diatom valves in each sample.

2.4.2 Numerical methods

Prior to numerical analyses, all limnological variables were tested for non-normal distribution by constructing histograms using the computer program SPSS version 12.0, and deviation from normality was assessed visually. To correct for skewed distributions, ln (x + b) transformation (where b is 0.5 x the minimum non-zero value) was applied to $NO_3^- + NO_2^-$, TP, colour, SiO_2, K and chl-*a*. Diatom taxa that were encountered at <3 sites and with a maximum abundance <1% were classified as rare taxa and were omitted from numerical analyses to avoid the influence of taxa whose distributions were poorly characterized by the samples we analyzed. Diatom percent abundance data were square-root transformed to reduce the influence of dominant taxa.

Principal Components Analysis (PCA), an indirect gradient, multivariate ordination technique, was used to assess the main limnological differences among hydrological lake categories. Rivers were included passively and lakes were coded in ordination plots based on Brock et al.'s (2007) hydrological categories (flood-, evaporation- and exchange-dominated). Analysis of variance (ANOVA) was used to assess limnological differences ($p \leq 0.05$) among river sites (including Great Slave Lake) and the three hydrological lake categories. ANOVA analyses included *post hoc* tests ($p \leq 0.05$) based on Tukey's HSD test statistic using SPSS version 12.0.

Detrended Correspondence Analysis (DCA) was performed on the diatom data to quantify the gradient length (in SD units) of the first axis, which was used to determine if linear or unimodal based ordination methods were most appropriate for analyzing the diatom data. All gradient lengths were <2 standard deviation units, therefore, linear ordination techniques (PCA and Redundancy Analysis (RDA)) were employed (Birks 1995). PCA was used to assess distributions of surface sediment diatom assemblages among the hydrological lake categories. Direct gradient ordination by RDA was used to identify relationships between the surface

sediment diatom assemblages and the limnological gradients among the lakes. RDA was performed using forward selection (and Monte Carlo tests with 999 permutations) to determine a subset of variables that explained significant ($p \leq 0.05$) and independent amounts of variation in the diatom data (ter Braak and Šmilauer 2002). Sample scores (or surface sediment diatom assemblages) in the ordination diagrams were coded *a priori* according to the three hydrological lake categories to visualize variation in limnological conditions and diatom assemblage composition among the categories. All ordinations were performed using CANOCO version 4.5 (ter Braak and Šmilauer 2002).

Analysis of Similarities (ANOSIM), a non-parametric multivariate test that is analogous to a one-factor ANOVA (Clarke and Warwick 2006), was used to determine if the composition of surface sediment diatom assemblages differed among the three hydrological lake categories. The sample statistic (Global R value) reflects the observed difference among groups of samples contrasted with the difference among replicates within each group of samples. A Global R value of zero indicates that the similarity between and within groups of samples is the same on average. A value of one, on the other hand, indicates that all the replicates within a group of samples are more similar to each other than any replicates from different groups of samples (Clarke and Warwick 2006). Within- and across-group rank Bray-Curtis dissimilarities were computed (5000 permutations) and the distribution of these values was compared to the initial rank dissimilarity and reported as the Global R value (Clarke and Warwick 2006). For example, if a Global R value was significantly greater than zero ($p \leq 0.05$), this would indicate that differences in diatom assemblages between hydrological categories are greater than variability within the hydrological categories.

Similarity Percentage tests (SIMPER; Clarke and Warwick 2006) were performed to identify specific diatom taxa that accounted for the greatest observed differences between

hydrological categories. Taxa contributing >2% of the average Bray-Curtis similarity within a hydrological category were considered 'indicator' taxa that are most representative of that hydrological category. ANOSIM and SIMPER analyses were performed using the program PRIMER version 6.1.5 (Clarke and Warwick 2006). In a final step, Canonical Variates Analysis (CVA), a form of multiple discriminant analysis (Birks et al. 1975), was used to assess if the 'indicator' taxa identified by SIMPER analyses significantly discriminate ($p \leq 0.05$) the three Slave River Delta hydrological lake categories. The CVA was performed by using the SIMPER-identified diatom taxa as explanatory variables and hydrological lake categories (coded as dummy variables for each site) as the response variables. These data were used in a Canonical Correspondence Analysis with Hill's scaling focused on inter-species distances and run using Monte Carlo tests with 999 permutations to assess the significance of the CVA axes.

2.5 Results

2.5.1 Physical and chemical limnological characteristics

Lakes in the Slave River Delta are shallow (mean maximum depth = 126 cm; range: 30-280 cm), high in nutrients (mean TP = 48.85 µg L^{-1}; range: 15.3-175.3 µg L^{-1} and mean TKN = 1299.64 µg L^{-1}; range: 308.3-2637.7 µg L^{-1}), alkaline (mean pH = 7.99; range: 7.4-8.4), and contain relatively high concentrations of major ions (Table 2.1). One exception is SD30 (Ring Lake), a relatively deep (Z_{max} = 10 m) oxbow lake that is continuously connected to the Slave River by a single channel (Figure 2.1). Great Slave Lake, the Slave River and its distributaries have high concentrations of TP (mean = 111.79 µg L^{-1}; range: 30.9-285.0 µg L^{-1}) and SO_4 (mean = 6.01 mg L^{-1}; range: 5.6-7.0 mg L^{-1}), while most other chemical parameters are relatively low compared to the lakes (Table 2.1). Although TP concentrations are high at the river sites, dP concentrations are low (mean = 5.06 µg L^{-1}; range: 3.0-8.1 µg L^{-1}), indicating that most of the phosphorus is in

particulate forms. Since chl-*a* concentrations are low (mean = 2.61 μg L^{-1}; range: 2.37-2.84 μg L^{-1}), most of the phosphorus is contained in the suspended mineral sediments rather than phytoplankton and other suspended biota.

Principal Components Analysis of the water chemistry data showed that lakes differed mainly along gradients of concentrations of nutrients (N, P, DOC), ions, alkalinity and chl-*a* (Figure 2.2). Eigenvalues for the first and second PCA axes were 0.787 and 0.213 respectively, and explained all of the variation in the data set. TKN, TP, dP, DOC, Colour, chl-*a*, K, Mg, alkalinity and conductivity were all strongly and negatively correlated to axis 1, while pH and Na were closely associated with axis 2. Concentrations of SiO_2, Ca, Cl, SO_4 and NO_3+NO_2 contributed nearly equally to the variation along the first and second PCA axes. The main gradient of variation among sites (axis 1) separates lakes that have no river influence (evaporation-dominated lakes) from those that receive periodic inputs of water from the Slave River or Great Slave Lake (flood- and exchange-dominated lakes). Evaporation-dominated lakes tend to have high alkalinity and high concentrations of nutrient and ions. Exceptions are lakes SD8 and SD32, which were classified as evaporation-dominated (Brock et al. 2007) but had water chemistry more typical of flood-dominated lakes (Figure 2.2). The PCA plot also shows that evaporation-dominated lakes have the broadest range of limnological conditions. In contrast, flood-dominated lakes cluster more tightly along the main PCA axis (axis 1), characterized by high concentrations of Cl and SO_4 and low concentrations of nutrients, whereas exchange-dominated lakes are distributed along axis 1 spanning a broader range of nutrient and ion concentrations. The exchange-dominated lakes SD30, SD39 and SD41 plot close to the rivers indicating their water chemistries are similar to that of river water, characterized by low concentrations of nutrients, ions, chl-*a* and alkalinity. However, other exchange-dominated lakes possess quite different limnological properties. Lakes SD28 and SD17 plot near the evaporation-

dominated lakes due to moderately high nutrient and ion concentrations and alkalinity, while SD10 is chemically similar to flood-dominated lakes, due to relatively high pH and concentrations of Cl and SO_4 (Figure 2.2).

Concentrations of several nutrients (TKN, dP, DOC) and major ions (K, SO_4) differ significantly ($p \leq 0.05$) among flood-, exchange- and evaporation-dominated lake categories (Figure 2.3), while some variables (e.g. pH and concentrations of NO_3+NO_2, Cl and chl-*a* [not shown]) did not vary significantly. River sites and Great Slave Lake had significantly lower alkalinity, conductivity and K concentration compared to the three hydrological categories of deltaic lakes. Similar, but non-significant tendencies occurred for concentrations of TKN, dP, DOC, Na and Mg, whereas TP, SiO_2 and SO_4 were higher in rivers. Generally, concentrations of nutrients and the majority of ions are higher in evaporation-dominated lakes relative to flood- and exchange-dominated lakes. Exchange-dominated lakes have the lowest values and are most similar to river sites compared to lakes in the other hydrological categories (Figures 2.2, 2.3).

2.5.2 Relationships between surface-sediment diatoms and hydroecological conditions

A total of 88 diatom taxa from 23 genera were found in the surface sediment samples collected from the 41 study lakes (Table 2). Most of the diatom taxa encountered typically occupy epiphytic and benthic habitats and have been reported from spatial surveys of shallow lakes and ponds in the Mackenzie and Peace-Athabasca deltas (Hay et al. 2000; Hall et al. 2004). Planktonic diatoms (e.g. *Cyclostephanos* spp., *Stephanodiscus minutulus* (Kützing) Cleve & Möller, *S. parvus* Stoermer & Håkansson) were found at low to modest relative abundance in most flood- and exchange-dominated lakes, but were largely absent from lakes in the evaporation-dominated hydrological category.

Ordination of the diatom data by PCA showed that composition of surface sediment assemblages differs among the hydrological lake categories (Figure 2.4). Eigenvalues for the first and second axes were 0.167 and 0.118 respectively, and explained 28.5% of the variation in the data set. The main gradient of variation separated diatom assemblages in the river-influenced lakes (flood- and exchange-dominated; positioned to the left in Figure 2.4) from evaporation-dominated lakes (positioned to the right). Surface sediment diatom assemblages in river-influenced lakes (flood- and exchange-dominated categories) included taxa that occupy a wide diversity of habitats (e.g. river-borne planktonic taxa (*Cyclostephanos* spp. and *Stephanodiscus* spp.), benthic taxa (*Gyrosigma attenuatum* (Kützing) Rabenhorst and *Rhopalodia gibba* (Ehrenberg) O. Müller) and a variety of common epiphytes (*Navicula* and *Nitzschia* taxa)). Composition of diatom assemblages overlaps considerably between flood- and exchange-dominated lakes. Surface sediment diatom assemblages of evaporation-dominated lakes generally cluster as a discrete group with positive axis 1 scores, and are almost entirely composed of common epiphytic taxa such as *Navicula minima* Grunow, *Nitzschia amphibia* Grunow, and taxa belonging to *Achnanthes*, *Cocconeis* and *Gomphonema*. One exception to this pattern is lake SD32, which has a diatom assemblage that is more similar to those of flood-dominated lakes (i.e. with modest abundance of *Cyclostephanos* PAD sp. 2, *Gyrosigma attenuatum* and *Rhopalodia gibba*).

Three lakes (SD7, SD13 and SD24) are conspicuous in the PCA because they are positioned high on axis 2, clearly separated from the other sites (Figure 2.4). Although these lakes have quite different water chemistry (i.e. they are positioned far apart in the PCA performed on water chemistry variables; see Figure 2.2), their diatom assemblages are all dominated by small benthic *Fragilaria* taxa (e.g. *F. pinnata* Ehrenberg, *F. pinnata* var. *intercedens* Ehrenberg, *F.*

construens (Ehrenberg) Grunow, *F. construens* var. *venter* (Ehrenberg) Grunow and *F. construens* f. *binodis* (Ehrenberg) Grunow).

Ordination by RDA identified five variables (TKN, TP, K, Mg and SiO_2) that explained significant and independent amounts of variation in the surface sediment diatom assemblages among sites (Figure 2.5). The eigenvalues of the first two RDA axes ($\lambda_1 = 0.129$, $\lambda_2 = 0.061$) were both significant ($p \leq 0.05$) and captured 46.2% and 21.8% of the variation in the species-environment relationships, respectively. Concentrations of TKN, TP and K are highly correlated with the first RDA axis (intraset correlations = 0.781, 0.735 and 0.700, respectively) and SiO_2 shows the strongest correlation with the second axis (intraset correlation = 0.575), while Mg contributes nearly equally to the variation along both the first and second axes (intraset correlations = 0.252 and 0.275, respectively). The first RDA axis mainly separated diatom assemblages typical of evaporation-dominated lakes (higher nutrient and ion concentrations and dominated by *Navicula minima*, *Nitzschia amphibia* and *Achnanthes* taxa) from assemblages typical of river-influenced (flood- and exchange-dominated) lakes (lower concentrations of nutrients and ions that were dominated by *Gyrosigma attenuatum*, *Rhopalodia gibba*, and taxa of the genera *Navicula*, *Nitzschia*, *Cyclostephanos* and *Stephanodiscus*). To a lesser degree, the second RDA axis separated the diatom assemblages of flood-dominated lakes (positioned in the lower left quadrant, associated with relatively low concentrations of SiO_2 and relatively abundant *Navicula libonensis* Schoeman and *Cocconeis* taxa) from exchange-dominated lakes (positioned in the upper left quadrant, associated with higher concentrations of SiO_2 and abundant *Eunotia bilunaris* (Ehrenberg) Mills, *Fragilaria capucina* var. *gracilis* (Oestrup) Hustedt and *Cymbella* taxa).

In terms of diatom assemblage composition (Figure 2.4) and relationships between water chemistry and diatom assemblage composition (Figure 2.5), lake SD32 shares more affinity with

lakes in the flood-dominated hydrological category than the evaporation-dominated lakes. This appears to be a singular inconsistency in relating the limno-ecological data to the hydrological classification of lakes developed by Brock et al. (2007) from analysis of stable isotopes in point-in-time lake water samples. Consequently, lake SD32 was placed in the flood-dominated hydrological category for subsequent ecological analyses.

Composition of surface sediment diatom assemblages differed significantly among all three hydrological lake categories of the Slave River Delta, as assessed by ANOSIM tests (Table 2.3). Analysis by SIMPER identified a number of unique 'indicator' diatom taxa that can discriminate among hydrological lake categories (i.e. the taxa that accounted for >2% of the average Bray-Curtis similarity within groups; Figure 2.6a). Diatom taxa identified as indicators of a particular hydrological lake category account for 98% of the similarity within that category although several diatom taxa, mainly those occupying epiphytic habitats, were identified as indicators of more than one hydrological lake category (Figure 2.6b). *Navicula minima* and *Nitzschia amphibia* were identified as unique indicators of evaporation-dominated lakes, whereas *Eunotia bilunari*s (Ehrenberg) Mills, *Fragilaria capucina* var. *gracilis*, *Nitzschia perminuta* (Grunow) M. Peragallo, *Cyclostephanos* cf. *tholiformis* Stoermer, Håkansson & Theriot and *Stephanodiscus minutulus* were uniquely associated with exchange-dominated lakes. *Navicula libonensis*, *Gyrosigma attenuatum*, *Rhopalodia gibba* and *Cyclostephanos* PAD sp.2 were identified as unique indicators of flood-dominated lakes. Most of the 'indicator' diatom taxa occupy epiphytic and benthic habitats, with the exception of the centric diatoms *Cyclostephanos* cf. *tholiformis*, *Stephanodiscus minutulus* (exchange-dominated) and *Cyclostephanos* PAD sp.2 (flood-dominated), which originate from the Slave River and Great Slave Lake (M.A. Sokal, personal observation).

Canonical Variates Analysis provided evidence that the 'indicator' taxa identified by the SIMPER analysis account for significant ($p \leq 0.05$) discrimination among the hydrological lake categories. Eigenvalues of the first two CVA axes are 0.876 and 0.832, respectively, and explain 85.3% of the variance among hydrological lake categories. Thus, the threshold criteria used in our SIMPER analyses (i.e., diatom taxa contributing >2% of the average Bray-Curtis similarity within groups) successfully identified 'indicator' taxa that distinguish hydroecological conditions of lakes within the Slave River Delta.

2.6 Discussion

The hydrological settings of lakes in the Slave River Delta are associated with distinctly different limnological conditions and composition of diatom assemblages in surface sediments, as summarized in Table 2.4. Differences are most pronounced between lakes that are influenced by the Slave River or Great Slave Lake (flood- and exchange-dominated lakes) and lakes that are removed from the influence of the river (evaporation-dominated lakes). This is not surprising given the fact that a strong influence of river flood water on the limnology and ecology of floodplain lakes has been observed in both the Mackenzie Delta (Hay et al. 1997, 2000; Squires and Lesack 2002; Squires et al. 2002) and the Peace-Athabasca Delta (Hall et al. 2004; Wolfe et al. 2007b). Evaporation-dominated lakes possess water balances controlled by precipitation, snowmelt runoff and evaporation (Table 2.4). As a result, they are limnologically most dissimilar to the rivers and are highly dominated by epiphytic diatoms. In contrast, flood- and exchange-dominated lakes receive inputs of river or Great Slave Lake water which lower their concentrations of nutrients, chl-*a*, the majority of ions and alkalinity, and their diatom assemblages include a variety of epiphytic diatoms, but most notably include unique benthic and planktonic taxa (Table 2.4).

A strong relationship exists between the hydrological lake category and water chemistry, indicating the hydrological setting strongly regulates limnological properties (Figure 2.2; Table 2.4). The diatom assemblages preserved in the surface sediments also show strong and statistically significant differences in hydro-limnological conditions among all three hydrological lake categories (Figures 2.4 and 2.5). Thus, the isotope-based classification by Brock et al. (2007) captures major limnological and hydroecological differences among lakes of the Slave River Delta. The only consistent exception is lake SD32 which had a diatom composition typical of lakes with flood-dominated hydrology, even though it was categorized by Brock et al (2007) as an evaporation-dominated lake. This suggests that the isotope-based criteria used to classify this lake were strongly influenced by short-term effects of summer evaporation as this lake did not flood in the spring of 2003. However, diatoms incorporated in surface sediments indicate that over longer timescales this lake behaves more like flood-dominated lakes. All of the other evaporation-dominated lakes tend to have the highest concentrations of nutrients and several ions, which can be best explained by increased evaporative enrichment of ions and internal recycling of nutrients in the absence of river flooding (e.g. Hay et al. 1997). The diatom assemblages in evaporation-dominated lakes have high relative abundances of common epiphytes, a feature that is consistent with observed clear water conditions of low phytoplankton abundance and extensive macrophyte coverage throughout all or most of these lake basins. These diatom assemblages are associated with high concentrations of nutrients (TKN and TP) and ions (K and Mg), similar to findings by Hall et al. (2004) for closed-drainage lakes in the Peace-Athabasca Delta which are analogous to evaporation-dominated lakes in the Slave River Delta. Hay et al. (2000) also identified that similar epiphytic diatom assemblages typified the analogous high-closure lakes in the Mackenzie Delta that support dense macrophyte beds in the absence of strong flood influence.

In flood-dominated lakes, flooding from rivers is typically restricted to the spring melt season, but exchange-dominated lakes periodically re-connect to the river or are inundated with water from Great Slave Lake during seiche events throughout the open-water season (Brock et al. 2007). Consequently, limnological conditions of exchange-dominated lakes tend to be more variable compared to lakes of the other hydrological categories. Additionally, local geographic factors (e.g. distance to river and Great Slave Lake, sill elevation, presence of channel connections) likely influence the frequency and magnitude of flooding of lakes in the exchange-dominated category. Thus, it is not surprising that lakes in the exchange-dominated category encompass a broad range of limnological conditions that overlaps to some extent with lakes of hydrological categories at the two extremes (evaporation- and flood-dominated). For example, lakes SD30, SD39 and SD41 have limnological characteristics similar to river sites, suggesting that at the time of sampling, the Slave River was flowing into SD30 and water from Great Slave Lake was entering SD39 and SD41 at the outer portion of the delta. Contrary to this, SD17 and SD28 (both of which have channel connections to the Slave River) were limnologically more similar to evaporation-dominated lakes at the time of sampling, suggesting their channels were acting as outflows or disconnected entirely. Diatom assemblages in exchange-dominated lakes are associated with high levels of SiO_2 which is consistent with prolonged river connection and high concentrations of SiO_2 in river water. Although flood-dominated lakes receive SiO_2-rich flood waters in the spring, the effects appear to be short-lived as is suggested by the separation of flood- from exchange-dominated lakes along a SiO_2 gradient (Figure 2.5).

Increased river influence often results in decreased light transparency, macrophyte coverage and percent abundance of epiphytic diatoms in open-drainage lakes of the Peace-Athabasca Delta and no-closure lakes of the Mackenzie Delta, which are continuously flooded by rivers and thus highly turbid (Hay et al. 2000; Squires et al. 2002; Hall et al. 2004). However, this situation does

not appear to be the case in the Slave River Delta, and such lakes do not exist or at least were not sampled in our study. Flood- and exchange-dominated lakes remain dominated by macrophytes and epiphytic diatom taxa (as are evaporation-dominated basins), in spite of high minerogenic turbidity, and are more similar to restricted-drainage lakes in the Peace-Athabasca Delta and low-closure lakes in the Mackenzie Delta which received periodic flooding (Hay 1997; Hall et al. 2004).

Diatom assemblages in most lakes in this study are dominated by epiphytic taxa, reflecting the large habitat space (macrophyte surface area) available in these shallow deltaic ponds that support prolific macrophyte growth. Many of the epiphytic diatom taxa were distributed broadly among lakes of more than one hydrological category, and thus these taxa are likely unable to distinguish changes in hydrological status of lakes in the Slave River Delta. Importantly, however, we have identified specific 'indicator' taxa that can discriminate the three hydrological lake categories (Table 2.4). The epiphytic diatoms *Navicula minima* and *Nitzschia amphibia* are associated with evaporation-dominated lakes and are almost non-existent in flood- or exchange-dominated lakes. Both of these species are relatively abundant in high-closure lakes of the Mackenzie Delta (Hay et al. 2000) and are indicators of closed-basin lakes in the Peace-Athabasca Delta (Hall et al. 2004). Diatoms indicative of flood- and exchange-dominated lakes span a much wider range of habitat types including epiphytic, planktonic, tychoplanktonic and motile benthic taxa (Figure 2.6). The planktonic 'indicator' taxa *Cyclostephanos* cf. *tholiformis*, *Stephanodiscus minutulus* (exchange-dominated) and *Cyclostephanos* PAD sp.2 (flood-dominated) are important indicators of connectivity to rivers and Great Slave Lake, and similarly they have been associated with high river connectivity in the Peace-Athabasca Delta (Hall et al. 2004). Curiously, *Cyclostephanos* cf. *tholiformis* is found in lakes with exchange-dominated hydrology but not in lakes with flood-dominated hydrology, while the opposite pattern occurs for

Cyclostephanos PAD sp.2, but it is difficult to identify a mechanism responsible for this apparent phenomenon because both taxa are commonly found in Slave River plankton samples.

2.7 Conclusions

We demonstrate that variations in basin hydrology correspond with differences in limnological conditions and composition of diatom assemblages in the surface sediments of lakes in the Slave River Delta. The distinct composition of water chemistry and diatom assemblages among hydrological categories indicates that the lake classification scheme of Brock et al. (2007) based on stable isotope results from the open-water season of 2003 also captures major limnological and ecological differences (Table 2.4). In the absence of river flooding, evaporation-dominated lakes have the highest concentrations of several ions and nutrients and these clear water, macrophyte dominant systems have high relative abundances of common epiphytic diatoms such as *Navicula minima* and *Nitzschia amphibia*. In contrast, flood-dominated lakes have relatively low concentrations of most ions and nutrients, while exchange-dominated lakes have the lowest average concentrations of most ions and nutrients, but tend to be more variable as a result of varying influence by the Slave River and Great Slave Lake. Sedimentary diatom taxa indicative of flood- and exchange-dominated lakes span a wider range of habitat types when compared to evaporation-dominated lakes, and include the planktonic taxa *Cyclostephanos* cf. *tholiformis*, *Stephanodiscus minutulus* (exchange-dominated) and *Cyclostephanos* PAD sp.2 (flood-dominated) which are important indicators of river connectivity in the Slave River Delta.

Our approach has integrated the use of water isotope tracers and chemistry to characterize present hydrolimnological conditions, and demonstrated the potential of sedimentary diatom assemblages as bioindicators of hydrological changes and as proxy indicators of past hydroecological conditions in the Slave River Delta. Knowledge gained from this formative study is being used in biomonitoring and paleolimnological investigations of the Slave River Delta to

further understanding of the complex interactions among hydrology, limnology, and aquatic ecology in this freshwater ecosystem. In particular, ongoing multi-proxy (stable isotopes, diatoms, plant macrofossils) paleolimnological studies at several lakes situated throughout the delta will use the information provided by this study to assess the relative roles of river discharge, frequency of ice-jam floods, climatic variability and geomorphic change on the Slave River Delta ecosystem. This is necessary for anticipating responses to climate change and human modifications of upstream river systems, including effects of river regulation by the WAC Bennett Dam and consumptive water use by the Athabasca Oil Sands operations.

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2.10 Figures

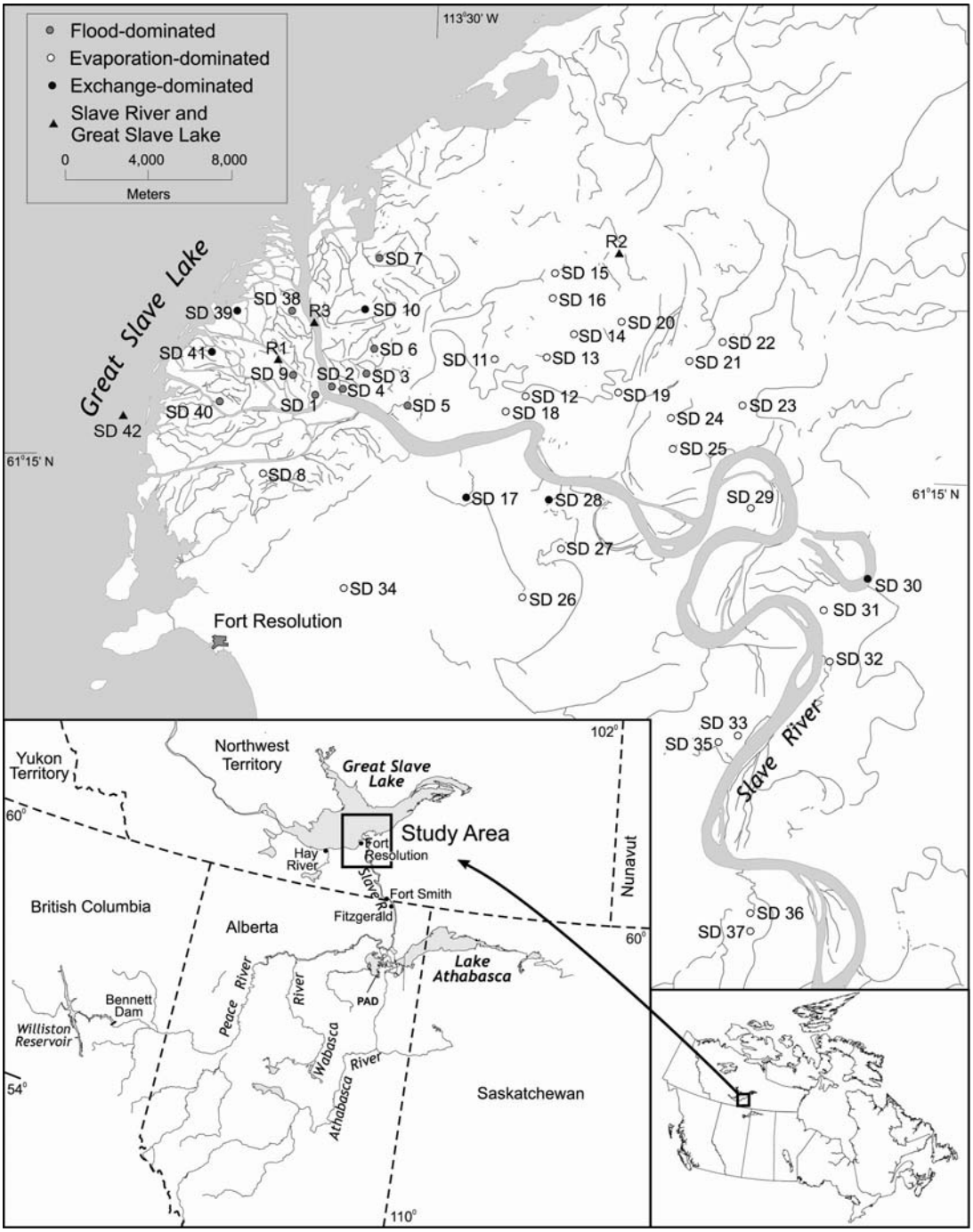

Figure 2.1 Location of the Slave River Delta and sampling sites, including rivers (R1, R2, R3) and Great Slave Lake (SD 42, black triangles), and delta lakes (SD1-41) classified according to the hydrological categories of Brock et al. (2007): flood-dominated (grey circles), exchange-dominated (black circles), and evaporation-dominated (open circles) lakes.

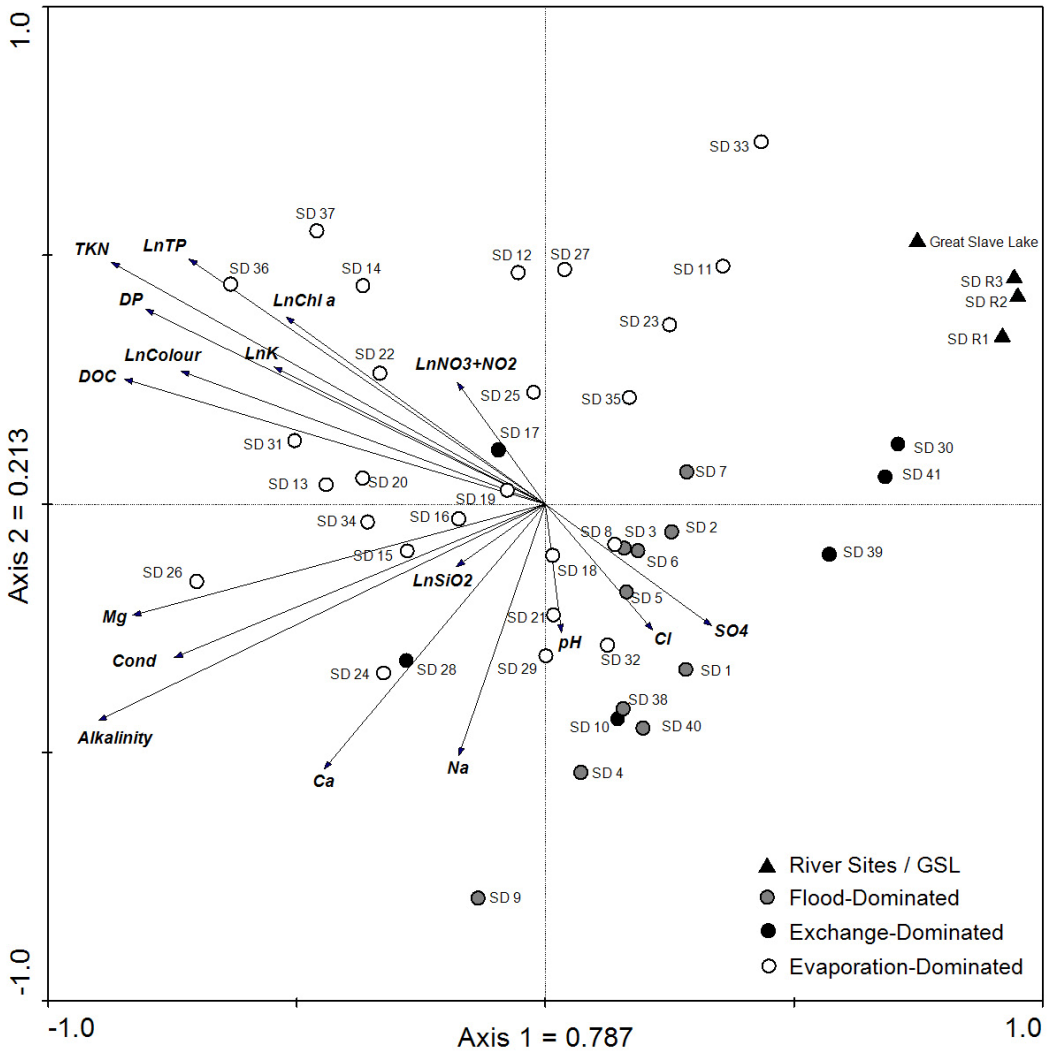

Figure 2.2 Principal components analysis (PCA) ordination diagram illustrating the relative position of Slave River Delta lakes (n=41) with respect to 3 hydrological lake categories and 17 physical/chemical variables. River sites and Great Slave Lake are plotted passively.

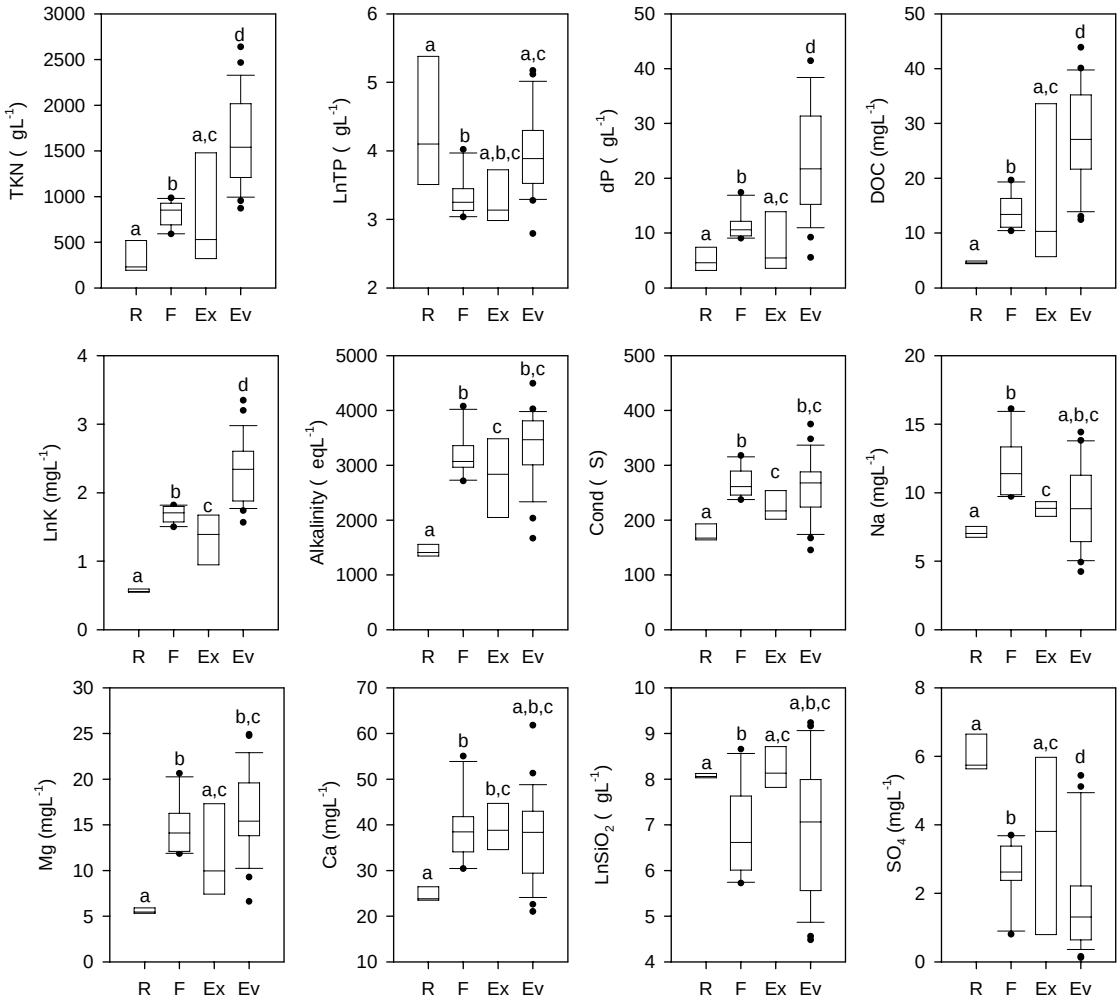

Figure 2.3 Box plots of selected chemical variables for river sites (includes Slave River distributaries and Great Slave Lake) (R; n=4), flood-dominated (F; n=10), exchange-dominated (Ex; n=6), and evaporation-dominated (Ev; n=25) lakes. Outliers (solid dots) are samples outside the 5th and 95th percentiles. Small case letters (a,b,c,d) are used to identify limnological variables with statistically significant differences ($p < 0.05$) in mean values between the hydrological categories based on ANOVA tests.

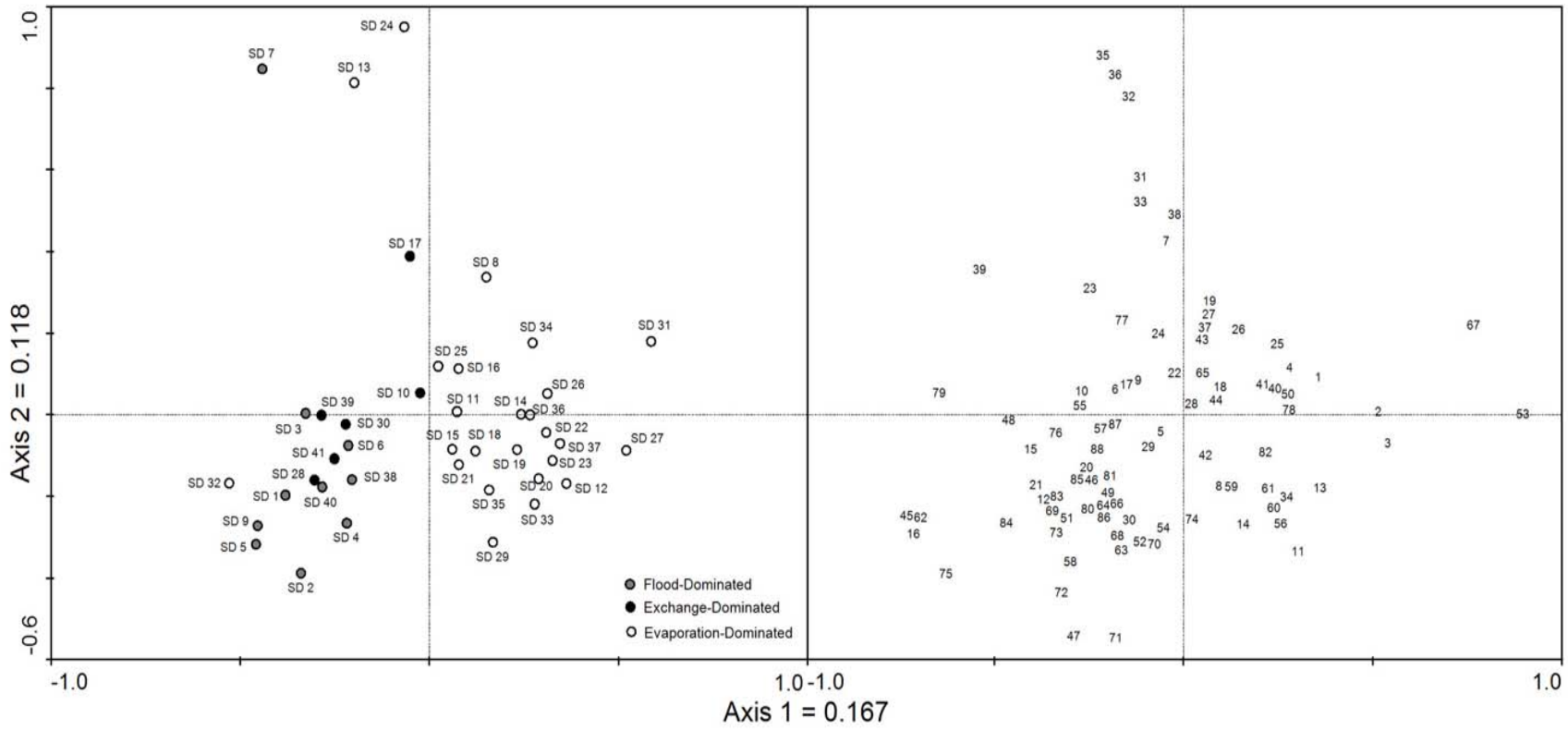

Figure 2.4 Principal components analysis (PCA) of sedimentary diatom taxa (n=88) from lakes in the Slave River Delta (n=41). Site scores are located in the left panel and diatom taxa scores are located in the right panel. Numbers correspond with taxon names provided in Table 2.

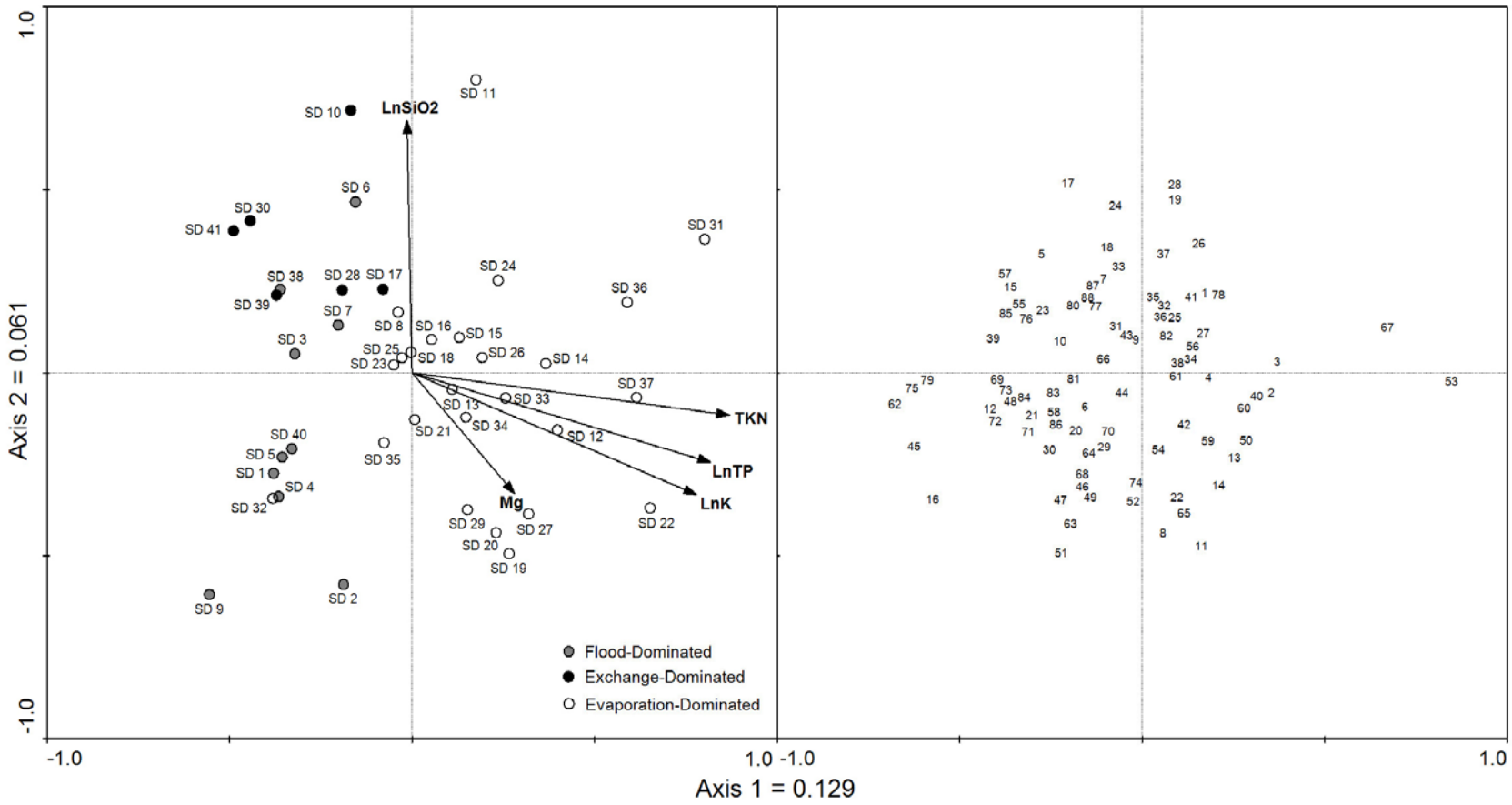

Figure 2.5 Redundancy analysis (RDA) of sedimentary diatom taxa (n=88) and forward-selected environmental variables from Slave River Delta lakes (n=41). Site scores are located in the left panel and diatom taxa scores are located in the right panel. Numbers correspond with taxon names provided in Table 2.

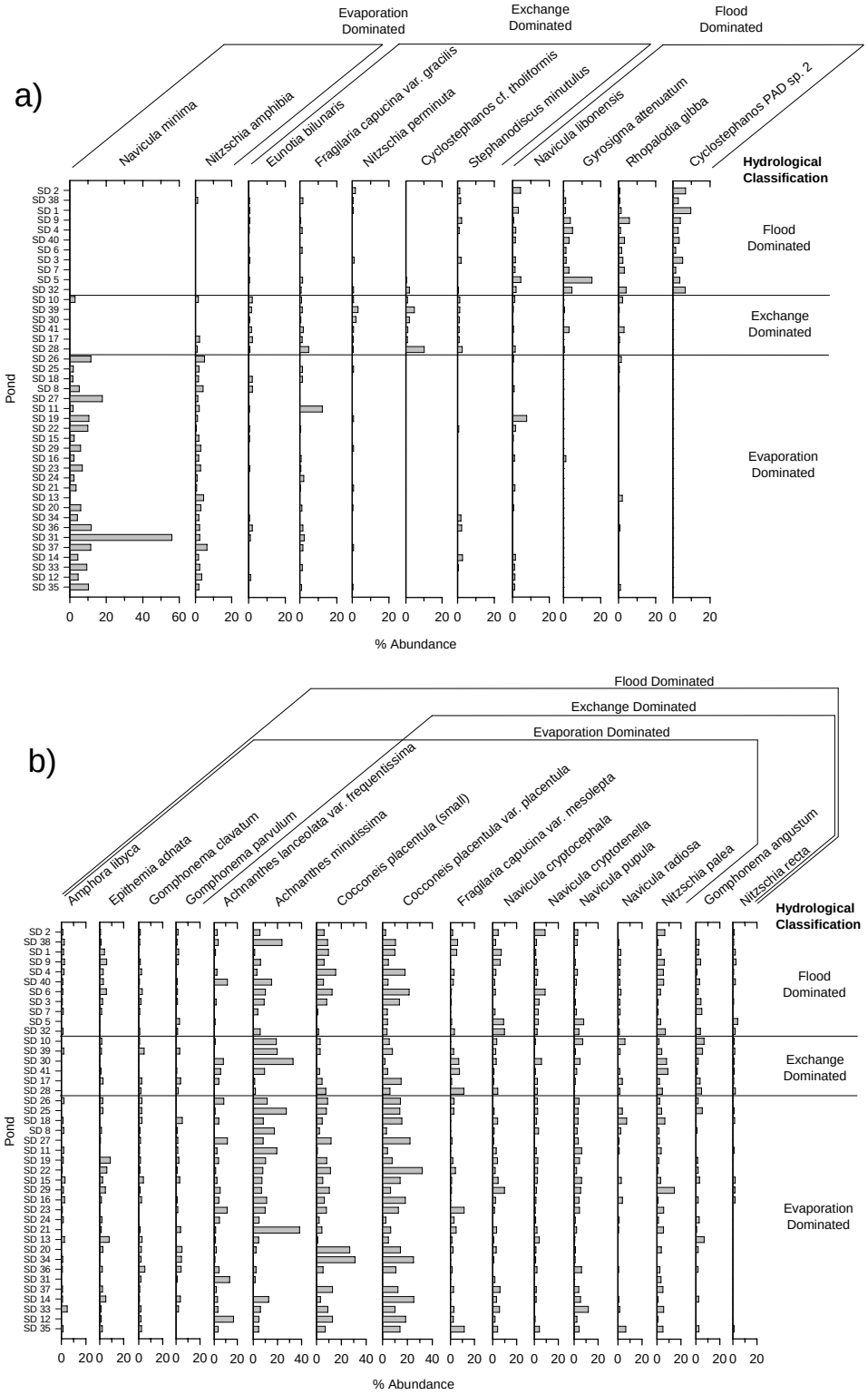

Figure 2.6 Relative abundance (%) profiles of sedimentary diatom taxa contributing >2% of the Bray-Curtis similarity in the assemblages within a hydrological category. Panel a) includes diatom taxa meeting this criterion for only one hydrological category, whereas panel b) includes taxa meeting the criterion for more than one hydrological category.

2.11 Tables

Table 2.1 A summary of selected hydrological, physical and chemical limnological characteristics of Slave River Delta lakes (values outside the square brackets, n = 41) and rivers + Great Slave Lake (values inside the square brackets, n = 4) recorded in September 2002.

Variable	Units	Mean		Std. Dev.		Maximum		Minimum	
Z_{max}	cm	126.00*		54.7*		280.00*		30	
pH		7.99	[8.13]	0.25	[0.02]	8.42	[8.16]	7.38	[8.11]
Cond	$\mu S/cm^2$	257.00	[175.00]	48.00	[18.00]	375.00	[201.00]	145.00	[164.00]
Alkalinity	$\mu eq\ L^{-1}$	3227.89	[1437.39]	622.01	[117.29]	4494.04	[1591.65]	1668.61	[1341.95]
Na	$mg\ L^{-1}$	9.59	[7.11]	2.81	[0.42]	16.12	[7.69]	4.24	[6.68]
K	$mg\ L^{-1}$	7.69	[0.76]	5.52	[0.047]	27.48	[0.83]	1.56	[0.73]
Mg	$mg\ L^{-1}$	15.12	[5.56]	4.42	[0.35]	24.88	[6.07]	6.62	[5.28]
Ca	$mg\ L^{-1}$	37.95	[24.58]	8.46	[1.80]	61.78	[27.25]	21.01	[23.41]
Cl	$mg\ L^{-1}$	6.31	[7.73]	3.53	[0.51]	22.79	[8.38]	2.13	[7.14]
SO_4	$mg\ L^{-1}$	2.25	[6.01]	1.75	[0.63]	7.94	[6.95]	0.12	[5.61]
SiO_2	$\mu g\ L^{-1}$	2357.29	[3196.85]	2627.14	[170.13]	10256.26	[3438.88]	87.07	[3040.61]
colour	ABS	0.08	[0.02]	0.05	[0.00]	0.21	[0.02]	0.02	[0.02]
DOC	$mg\ L^{-1}$	22.65	[4.63]	10.82	[0.27]	43.89	[4.96]	5.51	[4.40]
TKN	$\mu g\ L^{-1}$	1299.64	[313.67]	597.65	[198.58]	2637.72	[608.95]	308.25	[187.33]
NO_3+NO_2	$\mu g\ L^{-1}$	7.89	[5.39]	18.20	[3.87]	86.01	[11.10]	0.01	[2.56]
TP	$\mu g\ L^{-1}$	48.85	[111.79]	37.27	[118.90]	175.26	[285.03]	15.32	[30.87]
dP	$\mu g\ L^{-1}$	18.00	[5.06]	10.43	[2.26]	41.44	[8.11]	2.50	[2.98]
chl-*a*	$\mu g\ L^{-1}$	7.80	[2.61]	10.95	[0.22]	57.57	[2.84]	0.64	[2.37]

*SD30 (a large, deep, partially cut-off meander of the Slave River) Z_{max} values excluded; with SD30 included Mean = 147cm, Std. Dev. = 146.8cm, and Maximum = 1000cm

Table 2.2 Diatom taxa (n = 88) found in ≥3 of the SD study lakes (n = 41) at ≥1% abundance in at least one lake, including number of occurrences, mean and maximum relative abundance. Taxon numbers correspond to those presented in Figures 2.4 and 2.5.

Taxon number	Taxon name	Number of occurrences	Mean relative abundance	Maximum relative abundance
1	*Achnanthes conspicua* Mayer	13	0.31	3.14
2	*Achnanthes hungarica* (Grunow) Grunow	21	0.67	6.63
3	*Achnanthes lanceolata* var. *frequentissima* Lange-Bertalot	38	3.79	16.81
4	*Achnanthes lanceolata* var. *rostrata* Hustedt	6	0.29	3.98
5	*Achnanthes minutissima* Kützing	40	9.69	38.34
6	*Amphora libyca* Ehrenberg	35	1.28	4.81
7	*Amphora pediculus* (Kützing) Grunow	20	1.21	16.53
8	*Amphora veneta* Kützing	14	0.26	2.27
9	*Caloneis bacillum* (Grunow) Cleve	13	0.20	1.48
10	*Caloneis silicula* (Ehrenberg) Cleve	9	0.15	1.23
11	*Cocconeis placentula* small (<15µm)	39	7.26	31.03
12	*Cocconeis placentula* var. *euglypta* Ehrenberg	5	0.09	1.40
13	*Cocconeis placentula* var. *placentula* Ehrenberg	40	10.84	31.88
14	*Craticula halophila* (Grunow) Cleve	29	0.72	5.00
15	*Cyclostephanos* cf. *tholiformis* Stoermer, Håkansson & Theriot	8	0.55	10.17
16	*Cyclostephanos* PAD sp.2 Hall et al. 2004	11	1.18	9.60
17	*Cymbella microcephala* Grunow	22	0.77	3.08
18	*Cymbella minuta* Hilse	15	0.24	1.26
19	*Cymbella proxima* Reimer	10	0.11	1.00
20	*Diatoma moniliformis* Kützing	4	0.04	1.06
21	*Diatoma tenuis* Agardh	4	0.07	1.42
22	*Epithemia adnata* (Kützing) Brébisson	38	2.31	8.86
23	*Epithemia turgida* (Ehrenberg) Kützing	23	0.56	2.42
24	*Eunotia bilunaris* (Ehrenberg) Mills	29	0.59	2.09
25	*Eunotia implicata* Nörpel, Lange-Bertalot & Alles	9	0.12	1.26
26	*Eunotia incisa* W. Smith ex Gregory	14	0.24	1.82
27	*Fragilaria brevistriata* Grunow	8	0.13	2.30
28	*Fragilaria capucina* var. *gracilis* (Oestrup) Hustedt	30	1.14	12.16
29	*Fragilaria capucina* var. *rumpens*	22	0.66	4.91

	(Kützing) Lange-Bertalot			
30	*Fragilaria capucina* var. *mesolepta* (Rabenhorst) Rabenhorst	34	2.81	11.65
31	*Fragilaria construens* (Ehrenberg) Grunow	6	0.11	2.19
32	*Fragilaria construens* f. *binodis* (Ehrenberg) Grunow	5	0.10	1.62
33	*Fragilaria construens* var. *venter* (Ehrenberg) Grunow	10	0.25	4.00
34	*Fragilaria famelica* (Kützing) Lange-Bertalot	11	0.41	6.26
35	*Fragilaria pinnata* Ehrenberg	21	2.74	45.05
36	*Fragilaria pinnata* var. *intercedens* Ehrenberg	9	1.06	18.53
37	*Gomphonema acuminatum* Ehrenberg	27	0.69	3.14
38	*Gomphonema angustatum* (Kützing) Rabenhorst	4	0.08	1.14
39	*Gomphonema angustum* Agardh	34	2.19	6.87
40	*Gomphonema clavatum* Ehrenberg	38	1.67	5.10
41	*Gomphonema gracile* Ehrenberg	19	0.53	4.38
42	*Gomphonema minutum* Agardh	34	1.70	5.20
43	*Gomphonema parvulum* (Kützing) Kützing	24	0.45	2.28
44	*Gomphonema truncatum* Ehrenberg	24	0.78	2.95
45	*Gyrosigma attenuatum* (Kützing) Rabenhorst	17	1.12	15.44
46	*Navicula capitata* var. *capitata* Ehrenberg	16	0.53	3.92
47	*Navicula cryptocephala* Kützing	40	3.18	9.88
48	*Navicula cryptotenella* Lange-Bertalot	40	2.43	9.05
49	*Navicula cuspidata* (Kützing) Kützing	22	0.27	1.45
50	*Navicula laevissima* Kützing	11	0.21	1.85
51	*Navicula libonensis* Schoeman	28	1.08	7.73
52	*Navicula menisculus* Schumann	8	0.23	6.60
53	*Navicula minima* Grunow	24	5.00	56.00
54	*Navicula minuscula* var. *muralis* (Grunow in Van Heurck) Lange-Beralot in Lange-Bertalot & Rumrich	4	0.06	1.22
55	*Navicula oblonga* (Kützing) Kützing	18	0.35	3.14
56	*Navicula pupula* Kützing	39	3.33	11.90
57	*Navicula radiosa* Kützing	37	1.62	7.28
58	*Navicula* SD sp.1	13	0.66	8.51
59	*Navicula seminuloides* Hustedt	3	0.05	1.09
60	*Navicula seminulum* Grunow	8	0.22	3.93
61	*Navicula submuralis* Hustedt	7	0.20	2.84

62	*Navicula subplacentula* Hustedt	14	0.30	3.00
63	*Navicula trivialis* Lange-Bertalot	24	0.79	4.66
64	*Navicula veneta* Kützing	21	0.48	2.73
65	*Neidium ampliatum* (Ehrenberg) Krammer	23	0.29	1.23
66	*Nitzschia acicularis* (Kützing) W. Smith	13	0.35	2.95
67	*Nitzschia amphibia* Grunow	28	1.57	6.32
68	*Nitzschia fonticola* Grunow	6	0.10	1.96
69	*Nitzschia gracilis* Hantzsch	6	0.08	1.37
70	*Nitzschia liebetruthii* Rabenhorst	27	0.48	1.41
71	*Nitzschia palea* (Kützing) W. Smith	41	3.71	14.59
72	*Nitzschia paleacea* Grunow	30	0.69	2.96
73	*Nitzschia perminuta* (Grunow) M. Peragallo	17	0.39	3.14
74	*Nitzschia radicula* Hustedt	28	0.52	3.18
75	*Nitzschia recta* Hantzsch	27	0.85	3.92
76	*Nitzschia sigmoidia* (Ehrenberg) W. Smith	15	0.22	1.96
77	*Pinnularia interrupta* W. Smith	6	0.09	1.32
78	*Pinnularia microstauron* (Ehrenberg) Cleve	19	0.34	1.62
79	*Rhopalodia gibba* (Ehrenberg) O. Müller	22	0.90	5.85
80	*Stauroneis anceps* Ehrenberg	29	1.06	13.07
81	*Stauroneis phoenicenteron* (Nitzsch) Ehrenberg	19	0.23	2.21
82	*Stauroneis* SD sp.1	9	0.18	2.18
83	*Stephanodiscus minutulus* (Kützing) Cleve & Möller	22	0.74	4.68
84	*Stephanodiscus parvus* Stoermer & Håkansson	13	0.20	1.60
85	*Surirella angusta* Kützing	8	0.13	2.00
86	*Surirella minuta* Brebissonii ex Kützing	5	0.05	1.20
87	*Synedra ulna* var. *acus* Ehrenberg	16	0.25	1.42
88	*Tabellaria flocculosa* (Roth) Kützing	8	0.15	1.89

Table 2.3 Summary of analysis of similarities (ANOSIM) test results used to compare composition of surface-sediment (0-1 cm) diatom assemblages from flood-dominated (n = 11), exchange-dominated (n = 6) and evaporation-dominated (n = 24) lakes in the Slave River Delta.

	Lake Category	R-statistic	p-value
Global Test:	All Hydrological Categories	0.492	0.001
Pairwise Tests:	Flood vs. Exchange	0.531	0.001
	Flood vs. Evaporation	0.458	0.001
	Exchange vs. Evaporation	0.459	0.003

Table 2.4 Summary of Slave River Delta lake hydrology, limnology and diatom 'indicator' taxa. Hydrologic inputs and outputs from lakes are based on data from Brock et al. (2007), where R = river inputs during elevated (spring flood) flow conditions (R_F) and normal summer flow conditions (R_N), S = catchment-sourced snowmelt inputs, P = thaw season precipitation, O = surface outflow during elevated (spring flood) flow conditions (O_F) and normal summer flow conditions (O_N), and E = surface water evaporation. Dominant processes are shown in bold. Limnological conditions for the exchange-dominated lakes reflect those with generally strong and persistent connections with the Slave River or Great Slave Lake (incl. SD30, SD39, SD41).

	Slave River Delta Hydrological Lake Categories		
	Flood-dominated	Exchange-dominated	Evaporation-dominated
Hydrological Inputs	$\mathbf{R_F}$ + S + P	$\mathbf{R_F}$ + $\mathbf{R_N}$ + S + P	**S** + **P**
Hydrological Outputs	O_F + **E**	$\mathbf{O_F}$ + $\mathbf{O_N}$ + E	**E**
Limnological Characteristics	↓ nutrients ↓ chl-*a* ↓ ions ↓ alkalinity	↓↓ nutrients ↓↓ chl-*a* ↓↓ ions ↓↓ alkalinity	↑ nutrients ↑ chl-*a* ↑ ions ↑ alkalinity
Diatom 'Indicator' Taxa	*Navicula libonensis, Gyrosigma attenuatum, Rhopalodia gibba, Cyclostephanos* PAD sp.2	*Eunotia bilunaris, Fragilaria capucina* var. *gracilis, Nitzschia perminuta, Cyclostephanos* cf. *tholiformis, Stephanodiscus minutulus*	*Navicula minima, Nitzschia amphibia*

Chapter 3

Effects of flooding on the limnology, diatom phytoplankton communities and macrophyte biomass of lakes in the Slave River Delta (NWT, Canada)

3.1 Summary

1. Water chemistry, macrophyte biomass, and planktonic diatom communities were monitored seasonally over three years (2003-05) from six hydrologically diverse lakes of varying flood susceptibility, in the Slave River Delta – an important northern floodplain system for which there are concerns about past and ongoing effects of climate change and river regulation but few previous limnological studies due to its remote location.
2. Results indicate that river flooding is the dominant hydrological process controlling the temporal dynamics of physical and chemical conditions and primary producers in lakes of the Slave River Delta. In the absence of river flooding, lakes have relatively high concentrations of nutrients and low concentrations of most ions, but when flooded, concentrations of nutrients decrease and ions increase. The physical and chemical conditions in frequently flooded and non-flooded lakes are relatively stable from year to year, whereas lakes that are intermittently flooded fluctuate widely depending on whether or not they flood.
3. In flooded lakes, spring flooding from the Slave River introduces an abundance of planktonic, centric diatoms that persist only for a few weeks in the water column before settling out. Non-flooded lakes lack planktonic diatom communities.
4. River flooding reduces water transparency, which decreases macrophyte biomass, while lakes that do not flood exhibit higher macrophyte biomass and clear waters.
5. This research provides insights into the factors that control the hydroecological variability of northern deltaic landscapes, and further improves our understanding of the complex interactions among hydrology, physical and chemical parameters, and primary producers,

ultimately contributing to an improved scientific basis for future resource management decisions in the Slave River Delta and analogous systems.

3.2 Introduction

River flooding exerts strong control on the structure, function and dynamics of ecological systems of floodplains and deltas (Junk et al. 1989; Amoros and Bornette 2002; Thomaz et al. 2007). In northern deltaic systems, the frequency, duration and magnitude of flooding affects the physical, chemical and biological properties of lakes (Lesack et al. 1998; Squires et al. 2002; Wolfe et al. 2007; Chapter 2). They are important wetland and aquatic environments and are among the most biologically productive and environmentally sensitive elements of landscapes in northern Canada (Milburn et al. 1999; Prowse et al. 2002). Due to their sensitivity to river discharge, as well as their importance as productive natural habitat, there is increasing concern over the effects of climate change, consumptive use of river water (e.g. Alberta Oil Sands industry), and upstream river regulation and fragmentation of river flow on the hydroecology of floodplain lakes in deltas of the Mackenzie River basin in northwestern Canada (Prowse and Conly 2001; Schindler and Smol 2006).

In the Slave River Delta, NWT, (Figure 3.1) the central deltaic ecosystem in the Mackenzie River Basin, hydrological processes, and particularly periodic flood events on the Slave River, are believed to play important roles in maintaining riparian habitat and overall ecological vitality, and promoting high biological productivity and diversity (English et al. 1997; Prowse et al. 2002). Among the myriad lakes of the Slave River Delta, hydrological connectivity and flood susceptibility varies considerably, creating a landscape with a range of hydrological lake settings (Brock et al. 2007), which are associated with distinctly different limnological and ecological conditions (Chapter 2). Based on widespread lake water sampling in the Slave River Delta at the end of the ice-free season in 2002, we characterized and identified relationships between hydrological and limnological conditions of lakes in the delta and quantified their roles on surface-sediment diatom assemblages for paleolimnological applications (Chapter 2). We found

that evaporation-dominated lakes are removed from the influence of Slave River flooding and their limnology is characterized by high alkalinity, high concentrations of nutrients and ions, and high relative abundance of common epiphytic diatom taxa. In contrast, flood-dominated lakes commonly receive a pulse of turbid floodwater from the Slave River during the spring thaw and have low alkalinity and low concentrations of most nutrients and ions. Exchange-dominated lakes are variably influenced by floodwaters from the Slave River and seiche events from Great Slave Lake and are characterized by a broad array of limnological conditions depending on the strength, timing and frequency of the connection to these other surface waters. Sedimentary diatom assemblages in flood- and exchange-dominated lakes span a wide range of habitat types (epiphytic, benthic) but also include unique planktonic diatoms that are not found in surface sediments of evaporation-dominated lakes.

Importantly, in Chapter 2 we identified flooding from the Slave River as a key factor affecting limnological conditions and surface-sediment diatom assemblages, but the findings were based on one-time sampling of water and surface sediments of lakes distributed across the Slave River Delta and so could not contribute knowledge about the temporal variability of hydroecological conditions in individual lakes. Thus, in the absence of comprehensive limnological studies, it remains uncertain how flood events affect delta lakes over seasonal to inter-annual timescales with respect to limnological conditions, development of phytoplankton communities and macrophyte productivity. Unlike many tropical floodplains where flooding occurs on a regular annual cycle (e.g. Lewis et al. 2000), flooding in the Slave River Delta can be variable within and between years, and does not regularly occur in all delta lakes. Therefore, hydroecological conditions and the seasonal and inter-annual patterns of change can vary widely among lakes, but the effects of differences in timing and duration of flooding on the temporal dynamics of lake water chemistry remains unclear. Also, it is not known how biological communities in delta lakes respond to flooding. For instance, it is uncertain if flooding reduces, delays or stimulates macrophyte and phytoplankton growth. Such knowledge, however, is of

particular importance to anticipate potential ecological consequences of declining river discharge and alteration of flood regimes due to climate warming and natural resource development.

Here we identify the responses of limnological conditions, composition of planktonic diatom communities and macrophyte biomass to river flooding in six lakes representing the three hydrological categories of lakes in the Slave River Delta. The study spanned three years (2003-2005) of varying spring flood magnitude, which collectively provided a useful experimental design and temporal context to examine the role of river flooding on seasonal and inter-annual dynamics in delta lakes. Two of the six study lakes flooded in all three years, two did not flood in any year and two lakes flooded in one or more years but not in others (Table 1). Overall, moderate flooding occurred in 2003, flooding was almost entirely absent in 2004, and extensive delta-wide flooding occurred in 2005 (Brock et al. in review). Our approach focuses on: 1) determining the seasonal and inter-annual effects of river flooding on physical and chemical conditions of Slave River Delta lakes, 2) comparing the seasonal variability of planktonic diatom communities in the Slave River with that of flooded and non-flooded lakes to determine the importance of flooding on an important group of algae, and 3) evaluating the effects of flooding on underwater light environment and macrophyte biomass.

3.3 Study area and site description

The Slave River Delta, NWT, is located at the mouth of the Slave River (61°15’ N; 113°30’ W) where it enters Great Slave Lake (Figure 3.1). The entire delta covers an area of 8,300 km^2 beginning at the Slave River rapids at Fort Smith, NWT, but most of it is no longer active (Vanderburgh and Smith 1988). The active part of the delta is arcuate, spans an area approximately 400 km^2, and is prograding into Great Slave Lake through a system of active distributary channels (Prowse et al. 2002). The delta consists of a large wetland complex with numerous river channels, marshes, fens, bogs, swamps and forests. Scattered throughout this landscape are hundreds of small (<3 km^2), shallow (<5m) water bodies (hereafter referred to

collectively as lakes) that span broad hydrological gradients and support extensive macrophyte growth.

Analyses of water isotope tracers have been used to identify three distinct hydrological lake categories in the Slave River Delta, which are characterized by varying degrees of hydrological association with the Slave River and its distributaries: flood-dominated, evaporation-dominated and exchange-dominated (Brock et al. 2007).The water balances of flood-dominated lakes, which are located in the active part of the delta, are strongly influenced by Slave River floodwater during the spring melt. In contrast, evaporation-dominated lakes, which are located in the older inactive part of the delta, receive spring snowmelt and evaporation becomes the over-riding process controlling lake water balances during the remainder of the ice-free season. Exchange-dominated lakes are located along the Slave River and delta front adjacent to Great Slave Lake and receive inputs from channel connections when water levels rise in the Slave River or from Great Slave Lake during seiche events, which result in variable water balances depending on the strength of these connections.

The lakes in this study are a subset of those sampled and analyzed in Chapter 2 and by Brock et al. (2007), and encompass all three hydrological categories (flood-dominated [SD2], evaporation-dominated [SD15, SD29 and SD33], and exchange-dominated [SD28 and SD39]; Figure 3.1). Additionally, the degrees of flood activity varied among and within the study lakes during the course of this study (2003-2005; Table 1). River sites include the Slave River (site R3) and two of its distributaries (sites R1 [East channel] and R2 [Jean River]). Great Slave Lake (site SD42) water was collected ~100 m offshore from the outer delta to characterize the input water to delta lakes that are influenced by seiche events on Great Slave Lake. At this location, Great Slave Lake water is chemically similar to the Slave River (Chapter 2); therefore, data from SD42 are grouped together with the other river sites for numerical analyses in this study.

Lake SD2 (unofficial name; 61°16’ N; 113°34’ W) is a small (~1.2 km^2), shallow (~1.5 m maximum water depth), flood-dominated basin located beside Resdelta Channel at the margin of

the active outer delta and the older inactive portion of the delta, adjacent to the location where the Slave River bifurcates into numerous distributary channels (Figure 3.1). There are no active inflow or outflow channels, and flooding was variable during three years of monitoring (flooding in 2003 and 2005, no flooding in 2004). The lake is surrounded by dense willow stands and highly productive conditions have been observed, characterized by extensive emergent (*Equisetum*, *Typha* and *Carex*) and submergent (dominated by *Potamogeton* and *Myriophyllum exalbescens*) macrophyte communities.

Lake SD15 (unofficial name; 61°19' N; 113°23' W) is a small (~1.8 km^2), relatively deep (~4.5 m maximum water depth), evaporation-dominated basin located north of the Slave River in close proximity to the Jean River (distributary of the Slave River; Figure 3.1). The basin is surrounded by a mature, spruce-forested peatland, with steeply banked shores ans is possibly a relict channel. There are no active inflow or outflow channels, and there is no evidence of recent flooding. We have observed highly productive conditions in the basin characterized by the floating-leaved macrophyte *Nuphar variegatum* and dense growth of the submergent macrophytes *Potamogeton zosteriformis*, *Drepanocladus* spp. and *Ceratophyllum demersum*.

Lake SD28 (unofficial name; 61°14' N; 113°23' W) is a small (~1.9 km^2), exchange-dominated basin with maximum water depth of ~4.0 m and is located within the more elevated area of the Slave River floodplain upstream of the active delta (Figure 3.1). SD28 flooded in all three years of monitoring (2003-2005) when Slave River water entered the lake during high river levels via a small channel. During the ice-free season, this connection serves as an inlet or outlet depending on relative levels of the river and lake. The basin is surrounded by the emergent macrophytes *Equisetum* and *Carex*, and the lake bottom is dominated mostly by *Potamogeton*, while shallow areas have dense growth of the floating-leaved macrophyte *Nuphar variegatum*.

Lake SD29 (unofficial name; 61°14' N; 113°12' W) is a small (~1.0 km^2), shallow, evaporation-dominated basin located within a large meander loop of the Slave River (Figure 3.1). There are no inflows or outflows and the lake underwent rapid water level declines following two

springs without flooding (2003 and 2004), while water depth more than doubled after flooding in 2005 (Z_{max} = 0.8 m [2003], 0.6 m [2004] and 1.5 m [2005]). The basin is surrounded by a sedge marsh with mature spruce forest on higher elevations and is a highly productive system dominated by submerged macrophytes (*Potamogeton* spp. and *Ceratophyllum demersum*) and extensive growth of floating filamentous algae.

Lake SD33 (unofficial name; 61°8' N; 113°12' W) is a small (~0.6 km^2), shallow, evaporation-dominated basin located upstream of the outer delta in an older relict floodplain. There are no inflows or outflows and the volume and depth of the lake decreased markedly over the three-year monitoring period (~1.3 m maximum water depth in 2003 to ~0.7 m maximum water depth in 2005). The basin is surrounded by a dry sedge meadow and a mature spruce forest, and observations have documented high levels of biological productivity characterized by frequent algal blooms and extensive growth of submerged macrophytes dominated by *Potamogeton* spp. and *Ceratophyllum demersum*.

Lake SD39 (unofficial name; 61°18' N; 113°39' W) is a small (~1.1 km^2), shallow (~1.1 m maximum water depth), exchange-dominated basin located on the outer margin of the delta, in close proximity to Great Slave Lake (Figure 3.1). It flooded frequently during the monitoring period (annually in the spring and from seiche events on Great Slave Lake) and, as a result, the water column of SD39 remains turbid throughout most of the growing season. The lake is surrounded by a large marsh dominated by *Equisetum* and *Carex* and supports a submergent macrophyte community dominated by *Potamogeton* spp.

3.4 Materials and methods

3.4.1 Sample collection and laboratory analyses

Water bodies were sampled on several occasions (3-10 times) between May 2003 and September 2005. Sampling was most intensive during 2003, when collections occurred approximately biweekly. In following years lakes were sampled once in May, July and September). All samples

were collected from 10 cm below the water surface at the central or deepest part of the six study lakes, and at mid-channel for the three river sites. Great Slave Lake water was sampled ~100 m offshore of the outer delta (Figure 3.1) in order to characterize input waters from seiche events. *In situ* limnological measurements (water depth, temperature, pH and conductivity) were recorded at each sampling site and water samples were collected for chlorophyll and chemical analyses (dissolved phosphorus (dP), total phosphorus (TP), total nitrogen (TKN), dissolved organic carbon (DOC), major ions (Ca^{2+}, Mg^{2+}, K^{+}, Na^{+}, Cl^{-}, SO_4^{2-}), dissolved silica (SiO_2), and alkalinity). Large zooplankton and other particles were removed prior to analyses of water chemistry and chlorophyll by passing water through a 650 µm screen. Samples for chlorophyll-*a* (chl-*a*) analysis were filtered onto a 0.7 µm GF/F filter, frozen and analyzed using standard spectrophotometric methods (Jeffrey et al. 1997). Water samples (1 L) for chemical analyses were kept at 4ºC and sent to Taiga Environmental Laboratory, Yellowknife (May 2003 – September 2004), and the Environment Canada National Laboratory for Environmental Testing, Burlington (May 2005 – September 2005), for analysis within 3–7 days of collection. Water samples (30 ml) for isotope analyses were transported to the University of Waterloo - Environmental Isotope Laboratory for determination of oxygen and hydrogen isotope composition using conventional techniques (Epstein and Mayeda 1953; Coleman et al. 1982) and are reported in standard -notation.

Phytoplankton samples (2 L of water) were collected at the time of water sampling from the same lakes and river sites (2003–2005). Samples were preserved with 15 mL of Lugol's solution, allowed to settle for 24 hours and decanted into 125 mL bottles for later analyses. Microscope slides for diatom analysis were prepared by treating and digesting decanted samples with strong acid (a mixture of H_2SO_4/HNO_3 [1:1 by volume] at 85°C for 3 hours) in order to remove organic material. After allowing diatom frustules to settle for 24 hours, the acid residue was removed from the cleaned diatom slurries through repeated cycles of settling, decanting and washing. For each sample, at least 400 diatom valves were identified and enumerated along transects using a

Zeiss Axioskop 2_{plus} compound microscope with differential interference contrast optics (1000X magnification, numerical aperture = 1.30). Diatom taxonomy follows Krammer and Lange-Bertalot (1986-1991). Diatom data are expressed as taxon relative abundances (%) of the total sum of diatom valves in each sample.

Macrophytes were sampled in late July near the time of maximum aboveground biomass in each of the three years of study. Aboveground biomass was harvested from multiple 0.25 m^2 quadrats (minimum 10, maximum 13, average 11 per lake) along two, three or four transects in each lake. Plant material was oven dried (100ºC for 3-5 hours) and weighed by species. The extinction of photosynthetically active radiation (PAR) through the water column (k_d) was measured within each quadrat during late May-early June, with an spherical irradiance sensor (Apogee Instruments Model QMSS-SUN, Logan, Utah) to determine the effect of flooding on the underwater light environment.

3.4.2 Numerical methods

Prior to numerical analyses, all limnological variables were assessed for non-normal distribution by visual assessment of histograms constructed using the computer program SPSS version 12.0. To correct for skewed distributions, ln (x + b) transformation (where b is 0.5 x the minimum non-zero value) was applied to TP, dP, TKN, DOC, K, SiO_2, Mg, Alkalinity and chl-*a*.

Principal Components Analysis (PCA), an indirect gradient, multivariate ordination technique, was performed to assess the main limnological differences (intra- and inter-annual) among the six study lakes between 2003 and 2005 (rivers were included passively) using the software CANOCO version 4.5 (ter Braak and Šmilauer 2002). River samples were included as passive samples in PCA to assess the influence of flooding on limnological conditions of the lakes without influencing comparisons of limnological differences among the lakes. Analysis of variance (ANOVA) was used to test for differences in limnological variables ($p \leq 0.05$) among river sites (including Great Slave Lake), lakes that flooded and lakes that did not flood (all years combined). ANOVA was also used to determine inter-annual differences in mean macrophyte

biomass from flooded and non-flooded lakes (year by year). Where appropriate, ANOVA analyses included *post hoc* tests ($p \leq 0.05$) based on Tukey's HSD test statistic using SPSS version 12.0.

3.5 Results

3.5.1 Physical and chemical parameters

Principal Components Analysis (PCA) of the water chemistry and isotope data from all six study lakes over three years (2003-2005) indicated that lakes differed primarily along gradients of water balance (as $\delta^{18}O$ and $\delta^{2}H$), nutrient and ion concentrations, and pH (Figure 3.2). Eigenvalues for the first and second PCA axes are 0.680 and 0.187 respectively, and explain a relatively large amount of the variation in the data set (86.7 %). Water balance ($\delta^{18}O$ and $\delta^{2}H$), TKN, TP, dP, chl-*a*, K and pH are all strongly and negatively correlated to axis 1, while Na, Cl and SiO_2 are positively correlated to axis 1. Alkalinity and concentrations of DOC and Mg are strongly associated with axis 2, whereas concentrations of SO_4 and Ca contribute nearly equally to the variation along the first and second PCA axes. The main gradient of variation (axis 1) largely separates lakes that did not receive flood waters (SD33, 2003-2005; SD15, 2003-2005; SD29, 2003-2004; SD2, 2004) from lakes that exchanged water with the Slave River and Great Slave Lake or flooded in the spring (SD28, 2003-2005; SD39, 2003-2005; SD2, 2003 and 2005; SD29, 2005). The lakes that were not flooded are positioned on the left side of the PCA, associated with high values of $\delta^{18}O$ and $\delta^{2}H$, nutrients, pH and K, whereas lakes that flooded are located on the right side of PCA, associated with high values of most ions, SiO_2 and alkalinity. The chemistry of the Slave River, its distributaries and Great Slave Lake did not fluctuate widely over the course of the three years, as indicated by the cluster of sample scores positioned within the lower right quadrant of the PCA plot (Figure 3.2).

Hydrological differences among the study lakes resulted in distinctly different limnological conditions, as indicated by clear separation of samples scores in the PCA for lakes in the different

hydrological categories (Figure 3.2). Also, lakes within the same hydrological category plot relatively close together in the PCA plot, indicating common limnological conditions occur under similar hydrological regimes. For example, sample scores for SD28 and SD39, the exchange-dominated lakes that flooded in all three years, lie close together and near samples from the rivers and Great Slave Lake. The sample scores for lake SD2 are positioned near rivers and exchange-dominated lakes during years in which it flooded (2003, 2005), but is positioned closer to evaporation-dominated lakes during the year when flooding did not occur (2004). Sample scores from evaporation-dominated lakes (SD29 and SD33) are generally positioned along the left side of PCA axis 1, with the exception of spring 2005 when the lake SD29 flooded (Figure 3.2).

The only main exception to these systematic patterns is the evaporation-dominated site SD15, which plotted at an intermediate distance between evaporation-dominated and flood- and exchange-dominated lakes along PCA axis 1. SD15 had water chemistry conditions and seasonal trajectories of change that are very different compared with the other lakes, including the two other evaporation-dominated lakes (SD29, SD33). SD15 had exceptionally high concentrations of DOC (on average 2.5 times higher than the other evaporation-dominated lakes) which are likely derived from its forested peatland catchment.

Evaporation-dominated lakes (SD15, SD29 and SD33) had limnological characteristics that were distinct from the rivers. For example, these lakes had high concentrations of nutrients (TKN, TP, dP, [DOC mainly in SD15]), K, chl-*a*, higher pH and values of $\delta^{18}O$ and $\delta^{2}H$, and low concentrations of most ions (Figure 3.2). In the absence of flooding, spring samples plot towards the left half of the PCA and are distinct from the rivers. Limnological conditions tend to show consistent trends towards evaporative enrichment of lake waters and increased concentrations of nutrients, chl-*a*, pH and K, as indicated by similar trajectories characterized by relatively short distances between sample scores along PCA axis 1. When flooded, the limnological conditions in these lakes can change substantially. Such is the case for lake SD29, an evaporation-dominated lake that was inundated by a large ice-jam flood in the spring of 2005 but not in other years. Prior

to 2005, SD29 underwent rapid seasonal water level decline following two springs without flooding, whereas water depth more than doubled after flooding (Z_{max} = 0.8 m [2003], 0.6 m [2004] and 1.5 m [2005]), and a previously dry sedge meadow surrounding the lake was inundated and maintained standing water (10-20 cm deep) throughout the ice-free season greatly increasing the lake water surface area (Figure 3.3). Spring flooding resulted in markedly increased concentrations of most ions (Ca, Na, Cl, Mg, SO_4) and SiO_2, increased alkalinity and substantially reduced nutrient concentrations and values of $\delta^{18}O$ and $\delta^{2}H$. The limnological effects of this large flood are most conspicuous in the spring, but flooding also altered seasonal patterns of change with conditions fundamentally different at the end of the ice-free season in 2005 compared to the previous two years without flooding (Figure 3.2, compare trajectories for SD29 (yellow circles) in panels b-d). Water chemistry analyses in late September of 2005 at SD29 revealed low concentrations of most nutrients (TKN, TP, dP), chl-*a* and K, while concentrations of Mg, Ca, SiO_2 and alkalinity remained relatively high compared to the end of the 2003 and 2004 open-water seasons.

Exchange-dominated lakes (SD28 and SD39) are most susceptible to spring flooding (both sites flooded in all three years of monitoring) and can be influenced by high Slave River levels or seiche events from Great Slave Lake throughout the ice-free season (Brock et al. 2007). The chemical conditions of these lakes are strongly influenced by flood waters. As a result, these lakes had the highest concentrations of most ions (Ca, Na, Cl, Mg, SO_4) and SiO_2, high alkalinity, low nutrient (TKN, TP, dP) concentrations, and low $\delta^{18}O$ and $\delta^{2}H$ throughout the ice-free season (Figure 3.2). These lakes are most similar to the rivers in the spring when they are flooded, but limnological conditions can be highly variable throughout the rest of the ice-free season depending on the frequency and magnitude of water exchanges with the Slave River or Great Slave Lake. For example, in 2003, SD28 periodically re-connected to the Slave River when river water levels exceeded lake water levels. SD39 was repeatedly inundated with water from Great Slave Lake during seiche events in 2003, which resulted in highly variable physical and chemical

conditions during the ice-free season (Figure 3.2; Clogg-Wright 2007). River flooding and seiche events dilute nutrient concentrations in these lakes, but increase concentrations of SO_4, Cl and SiO_2 (Figure 3.2).

Patterns of limnological change at the flood-dominated site SD2 were unique compared to the other study lakes and exhibited qualities of both evaporation- and exchange-dominated sites depending on the influence of flooding. When flooded in the spring of 2003 and 2005, the water chemistry of SD2 was similar to the Slave River and comparable to exchange-dominated sites that flooded (with high concentrations of most ions and SiO_2, high alkalinity and low values of nutrients, $\delta^{18}O$ and $\delta^{2}H$; Figure 3.2). In the absence of flooding (2004), the limnological characteristics of this lake were more similar to those of the evaporation-dominated sites (with high concentrations of nutrients, chl-*a* and K, high pH and high values of $\delta^{18}O$ and $\delta^{2}H$; Figure 3.2). Unlike exchange-dominated lakes, which flooded each year and can receive periodic flood waters from seiche events throughout the season, river flooding at SD2 is variable from year to year and has only occurred during dynamic breakup of ice in the spring (personal observation and Brock et al. in review). After spring flooding, SD2 becomes hydrologically disconnected from the Slave River and the water balance of this lake becomes strongly influenced by evaporation (Brock et al. 2007). Limnological conditions subsequently become increasingly dissimilar to the Slave River and evolve along a trajectory that is comparable to evaporation-dominated basins (Figure 3.2).

Limnological conditions differed significantly among the rivers, the lakes that flooded and the lakes that did not flood (Figure 3.4). When averaged over all years of this study, concentrations of several nutrients (TKN, TP, dP), major ions (K, Ca, Cl, SO_4, Na), SiO_2 and chl-*a* differed significantly ($p \leq 0.05$) between flooded and non-flooded lakes. However, pH, alkalinity and concentrations of DOC and Mg did not vary significantly between flooded and non-flooded lakes. River sites and Great Slave Lake had significantly higher concentrations of TP and SO_4, but significantly lower alkalinity and concentrations of TKN, DOC, K and Mg than both

flooded and non-flooded lakes. While river water has higher concentrations of TP than lakes, dP is higher in non-flooded lakes indicating most of the TP in rivers and flooded lakes is in the suspended sediment and likely not immediately available to biota. Generally, flooding in the Slave River Delta reduced lake-water concentrations of nutrients and increased concentrations of the majority of major ions (Figures 3.2 and 3.4).

3.5.2 Phytoplankton

The Slave River, its distributaries and Great Slave Lake contain abundant planktonic diatoms. The planktonic diatom communities are dominated mainly by small centric taxa from the genera *Cyclostephanos* and *Stephanodiscus*, with distinct seasonal changes (Figure 3.5). In early-spring, river diatom communities are dominated by *Stephanodiscus* taxa (*S. hantzschii* Grunow and *S. parvus* Stoermer and Håkansson) with lower relative abundance of *Cyclostephanos* taxa (*C.* cf. *tholiformis* Stoermer, Håkansson & Theriot and *C.* PAD sp. 2 Hall et al. 2004). In late-summer (2003) and late-autumn (2004 and 2005), dominance shifts to *Cyclostephanos* taxa (*C.* cf. *tholiformis* and *C.* PAD sp. 2). Although these taxa were the most dominant, other planktonic taxa were present in lower abundances including *Asterionella formosa* Hassall, *Tabellaria flocculosa* (Roth) Kützing and a variety of centric diatoms from the genera *Aulacoseira*, *Cyclostephanos*, *Cyclotella* and *Stephanodiscus*.

Lakes that receive spring flood waters contain planktonic diatom communities similar to the rivers (Figure 3.5). In contrast, there is a complete lack of diatoms in the plankton of lakes that do not flood. The only exception was lake SD33 in 2005, when the planktonic diatom community was completely dominated by *Nitzschia acicularis* (Kützing) W. Smith (91.8 % relative abundance), a diatom taxon not usually found in the Slave River or Great Slave Lake. Diatoms are also absent from phytoplankton samples collected during the mid- and late-seasons from flooded lakes, indicating that they persist in the water column for only a very short period of time after spring flooding (usually, less than one month).

3.5.3 Macrophyte biomass

Average aboveground macrophyte biomass (as dry weight) from all six study lakes during 2003, 2004 and 2005 was 188.6, 215.6 and 175.7 g/m^2, respectively, and ranged from 71.6 – 304.4 g/m^2 (Figure 3.6). Macrophyte biomass in lakes that flooded every year (SD39 and SD28) and lakes that received no flooding in all years (SD33 and SD15) did not differ significantly from year to year, but there were significant differences between years in lakes that flooded once or twice during the three-year monitoring period (SD2 and SD29). In lake SD2, the mean macrophyte biomass in the non-flood year (2004) was significantly higher (p = <0.05) than the two years with flooding (2003 and 2005). Similarly, mean macrophyte biomass in lake SD29 was significantly lower (p = <0.05) in 2005 (flood year) compared to the previous two years without flooding. Macrophyte biomass differences among hydrological lake categories were also evident. Exchange-dominated lakes had the lowest mean macrophyte biomass (mean = 126.8 g/m^2; range = 71.6 – 182.3 g/m^2), while evaporation-dominated lakes had the highest (mean = 231.9 g/m^2; range = 134.3 – 304.4 g/m^2) and the flood-dominated lake had intermediate values (mean = 210.6 g/m^2; range = 191.1 – 248.1 g/m^2).

A strong negative correlation (R^2 = 0.76) existed between mean macrophyte biomass in mid-season and the light environment of lakes in the early spring (Figure 3.7), and there were significant differences (p = <0.05) between lakes that flood and lakes that do not flood in the spring. Lakes that flooded have high light extinction coefficients in the spring (mean = 3.77; range = 2.94 – 4.81) and low macrophyte biomass at mid-season (mean = 142.1 g/m^2; range = 71.6 – 192.6 g/m^2). In contrast, lakes that did not flood have lower light extinction coefficients in the spring (mean = 1.35; range = 1.03 – 1.63) and much higher mean macrophyte biomass at mid-season (mean = 244.5 g/m^2; range = 202.1 – 304.4 g/m^2).

3.6 Discussion

River flood waters act as a dominant hydrological process controlling limnological and ecological conditions in lakes of the Slave River Delta, and these shallow aquatic systems appear to respond

in predictable ways to flooding as summarized in Table 3.2. Flooded lakes are limnologically similar to the rivers and, as a result, have low concentrations of nutrients and high concentrations of most major ions. River flood waters introduce planktonic diatoms to lakes, which have short water column residence times, and associated turbidity reduces macrophyte biomass. In contrast, lakes that do not flood have high concentrations of nutrients and macrophyte biomass and a complete absence of planktonic diatoms in the water column (Table 2).

Limnological differences between flooded and non-flooded lakes of the Slave River Delta as observed in this study of six lakes over three years are broadly consistent with findings in Chapter 2, which were based on single point-in-time water samples collected during a spatial survey of more than 40 lakes in September of 2002. Specifically, lakes that receive river flooding have high concentrations of most ions, SiO_2 and alkalinity, while lakes that do not flood have high concentrations of nutrients, pH and K. Flooded and non-flooded lakes in the delta have consistently distinct limnological conditions, and the three additional years of data confirm that the limnological differences between flooded and non-flooded lakes identified in Chapter 2 are not unique to that particular year of sampling. Importantly, however, this study indicates that river flooding plays an important role in determining seasonal and inter-annual patterns of limnological and ecological variability in lakes of the Slave River Delta. Inter-annual variability is low for lakes that did not receive flooding in any year and for lakes that flooded every year. In the absence of flooding, evaporation-dominated lakes (SD15, SD33) have narrow ranges of limnological inter-annual variability, but are distinguished from each other due to different catchment characteristics. Frequently flooded lakes (exchange-dominated: SD28, SD39) also have relatively low limnological variability from year to year but are much more limnologically similar to each other. Frequent river flooding can increase the similarity between floodplain lakes and the rivers that flood them, creating a more homogeneous landscape (e.g. Thomaz et al. 2007). In contrast, lakes with variable flood frequency (SD2, SD29) show strong inter-annual variability, which is largely dependent on whether or not river floodwaters entered the basins in the spring.

During flood years, limnological conditions are similar to the rivers and other flooded lakes, but in non-flood years conditions are more similar to evaporation-dominated lakes.

In tropical river floodplains, flooding occurs in most lakes and is an annual event that elicits predictable and consistent patterns of change (Lewis et al. 2000). River flooding also results in predictable changes at the Slave River Delta, but not all lakes flood every year resulting in a broad range of conditions across the entire ecosystem. Lakes dominated by evaporation during the ice-free season show consistent trends towards evaporative enrichment of lake waters and increased concentrations of nutrients, chl-*a*, pH and K. Exchange-dominated lakes, however, have limnological conditions that are controlled by the frequency of the exchange of water from the rivers or Great Slave Lake, resulting in highly dynamic conditions throughout any one season. In 2003, for example, lake SD39 received Great Slave Lake waters from three seiche events in mid-June, mid-July and early-August which raised water levels by 20-40 cm each time (Clogg-Wright 2007). This repeated inundation is reflected by the multiple shifts toward more dilute water chemistry. Following spring flooding, lake water chemistry in SD39 was very similar to the river, but as the season progressed it attained a unique chemical signature characterized by higher concentrations of most nutrients, K, chl-*a*, Mg, Na, Ca and higher alkalinity than the river. When inundated from multiple seiche events, the limnological conditions of SD39 becomes more similar to river water, as represented by water samples from this lake (06/23/03, 07/25/03 and 08/15/03) plotting closer to the river sites in the PCA diagram (Figure 3.2). Seasonal limnological conditions in flood-dominated lakes are also controlled by river flooding, but differ between flood and non-flood years. In years when flood-prone lakes do not flood, they can rapidly acquire characteristics of non-flooded lakes. In 2004, lake SD2 (flood-dominated) did not flood and had limnological characteristics and seasonal patterns of change similar to evaporation-dominated lakes (SD33, SD29). When flooded in 2003 and 2005, SD2 has spring chemical conditions similar to the Slave River, but not long after flooding (late-spring/early-summer) it had limnological conditions similar to evaporation-dominated lakes. Similar seasonal limnological

patterns of change have also been found in infrequently flooded lakes of the Rhine and Meuse river floodplains (Van den Brink et al. 1993), in restricted-drainage lakes of the Peace-Athabasca Delta (J. Wiklund, unpublished data) and in many low-closure and some high-closure lakes of the Mackenzie Delta (Lesack et al. 1998).

The temporal duration of the physical and chemical responses to flooding in flood-susceptible lakes can be quite brief. However, the effects of flooding on evaporation-dominated lakes that do not usually flood can last much longer. Lake SD29 had similar limnological conditions in 2003 and 2004, but after being inundated by a large ice-jam flood in 2005 the water chemistry dramatically changed. Unlike SD2, the effects of flooding on the water chemistry of SD29 lasted the entire ice-free season. We postulate that the long lasting changes to infrequently flooded lakes might be due to inundation of nearshore wetland environments along the margins of evaporation-dominated lakes (see Figure 3.3). In addition to changing the light environment (increased inorganic turbidity) and increasing the available habitats, the inundation of areas that have long been subaerially exposed and are highly organic may release substances and alter biogeochemical cycles in these lakes that last the entire ice-free season.

Planktonic diatom communities in lakes of the Slave River Delta are strongly controlled by river flooding. In the absence of flooding, there is a complete lack of planktonic diatoms in the water column, while lakes that flood in the spring contain planktonic diatom communities similar to the rivers that flood them. In Chapter 2 we found that the surface sediments of evaporation-dominated lakes are dominated by epiphytic diatoms and lack planktonic taxa, consistent with shallow, macrophyte-dominated systems removed from the influence of flooding. Conversely, the flood-prone lakes of the delta (flood- and exchange-dominated) have a more diverse flora including a variety of benthic and planktonic taxa. In fact, a number of common planktonic diatoms were identified as indicator taxa of these river-influenced lakes and are common in large rivers and river-influenced lakes of the Mackenzie Delta (Hay et al. 2000) and the Peace-Athabasca Delta (Hall et al. 2004). Diatoms were also absent from phytoplankton samples

collected from all lakes in the mid- and late-seasons of 2003 to 2005, suggesting that the diatom plankton communities in flooded lakes are short-lived and appear unable to persist in the absence of flooding. Most planktonic diatoms require a sufficiently deep water column or frequent mixing to remain suspended, and since Slave River Delta lakes are shallow (<5 m) and macrophyte-dominated, these diatoms do not appear to be able to survive long in these systems or quickly settle out after a flood event. Despite the generally low abundance of planktonic diatoms in the surface sediments of flood- and exchange-dominated lakes, which is likely due to their brief presence in the water column following spring flood events and suitable habitat created by short-lived hydrological conditions, identification of these taxa in lake sediment profiles is a promising indicator for identifying past flood events and assessing changes in flood frequency in paleolimnological studies.

Macrophytes are abundant and important components of delta water bodies and have been found to respond rapidly and sensitively to flooding and hydrological change in both the Mackenzie Delta (Squires et al. 2002; Squires and Lesack 2003) and Peace-Athabasca Delta (J. Wiklund, unpublished data). In the Slave River Delta, flooding also plays a strong role in the development and production of macrophyte communities. The mean aboveground biomass of macrophytes in Slave River Delta lakes decreases with increased flood frequency so lakes that are closely associated with the river and regularly flood have much lower macrophyte biomass than lakes that did not receive flood waters. For example, lake SD39, which flooded every year and was commonly inundated by turbid water from Great Slave Lake during seiche events, had the lowest macrophyte biomass, approximately two to three times lower than lakes that did not flood. Lakes that frequently flood in the Mackenzie Delta are turbid due to river-borne sediment, suppressing both macrophyte growth and primary production (Squires et al. 2002; Squires and Lesack 2003). Significant inter-annual differences were found in lakes that flooded in some years and not in others (e.g. SD29 and SD2), with lower average biomass occurring in years with floods. Lake SD29 is an evaporation-dominated basin and does not normally flood, but a large

ice-jam flood in 2005 was associated with a significant decrease in mean macrophyte biomass compared to the previous two years in which flood waters did not enter the basin. In lake SD2, the macrophyte biomass in two years having differing flood intensity (moderate in 2003 and severe in 2005) did not differ significantly, but biomass was significantly higher in the absence of a flood (2004), suggesting that the presence or absence of a spring flood may be a stronger controlling factor of macrophyte biomass than the intensity of flooding.

Macrophyte production is strongly controlled by light availability in Mackenzie Delta lakes, with peak biomass ranging several orders of magnitude across natural gradients of water clarity (Ramlal et al. 1991, Squires et al. 2002, 2003). In lakes of the Slave River Delta, a strong negative correlation ($n = 18$, $R^2 = 0.76$) was apparent between mean macrophyte biomass and spring light extinction (Figure 3.7). There is a strong gradient of light penetration among the lakes, which is a function of flood frequency and duration. Flooding reduces lake water transparency as a result of the high concentration of suspended sediments in the Slave River, and isolation from the river results in relatively high transparencies. At the onset of the growing season following a flood, lake water transparency is low, reducing the available light for early macrophyte growth suggesting that macrophyte biomass is limited by water transparency and the availability of light, consistent with findings by Squires et al. (2002) in the Mackenzie Delta. Alternatively, it is possible that other factors not directly measured in this study, such as sediment nutrient content, may also affect macrophyte biomass. Squires and Lesack (2003) found that the mean aboveground biomass of macrophytes in the Mackenzie Delta generally increased with increased sediment organic matter and nitrogen, but concluded that macrophyte biomass was likely affected by a combination of sediment fertility and water transparency, both of which are related to flood frequency. Although flooding reduces macrophyte productivity, submerged macrophyte biomass in lakes of the Slave River Delta is still quite high (mean = 193.3 g/m^2 and range = 71.6 – 304.4 g/m^2) and is comparable to other northern (Mackenzie Delta; Squires and

Lesack 2003), temperate (Upper Mississippi River; Peck and Smart 1986) and tropical (Amazon; Junk and Piedade 1993) floodplain environments.

It is widely believed that periodic flooding is required to maintain high biological productivity in northern floodplain ecosystems because rivers are considered a primary source of nutrients (Marsh and Hey 1989; English et al. 1997; Lesack et al. 1998; Prowse and Conly 1998, 2002; Prowse et al. 2002). Our data suggest that this is an unlikely situation in the Slave River Delta. In the absence of flooding, delta lakes remain nutrient-rich and are highly productive. For example, lake SD33 has among the highest nutrient concentrations and macrophyte biomass of the study lakes but is one of the least flood-prone lakes, whereas lakes that flood more frequently are at the opposite end of the spectrum. Although river water has higher concentrations of TP than lakes, dP is higher in non-flooded lakes indicating most of the TP in rivers and flooded lakes is in the suspended sediment and likely not immediately available to biota. Since infrequently flooded lakes in the Slave River Delta are very productive aquatic ecosystems, nutrient recycling must play an important role in maintaining high biological productivity. Climate warming may cause reduced river flows, and coupled with human modifications of upstream river systems and decreased ice-jam flooding, may lead to reduced frequency of flooding in northern deltas of the Mackenzie Basin (Marsh and Lesack 1996; Schindler and Smol 2006). Since our results indicate that river flooding is a key factor in controlling physical, chemical and biological conditions of lakes in the Slave River Delta, a reduction in flooding will undoubtedly alter the aquatic ecosystem. In some lakes, a reduction in flood frequency may result in reduced water levels leading to an increasingly terrestrialized system, while in others (previously flood-prone lakes) nutrient concentrations may ultimately increase and these basins may become increasingly more productive systems, although these too will eventually evolve to more terrestrial conditions in the absence of water replenishment from the Slave River.

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3.9 Figures

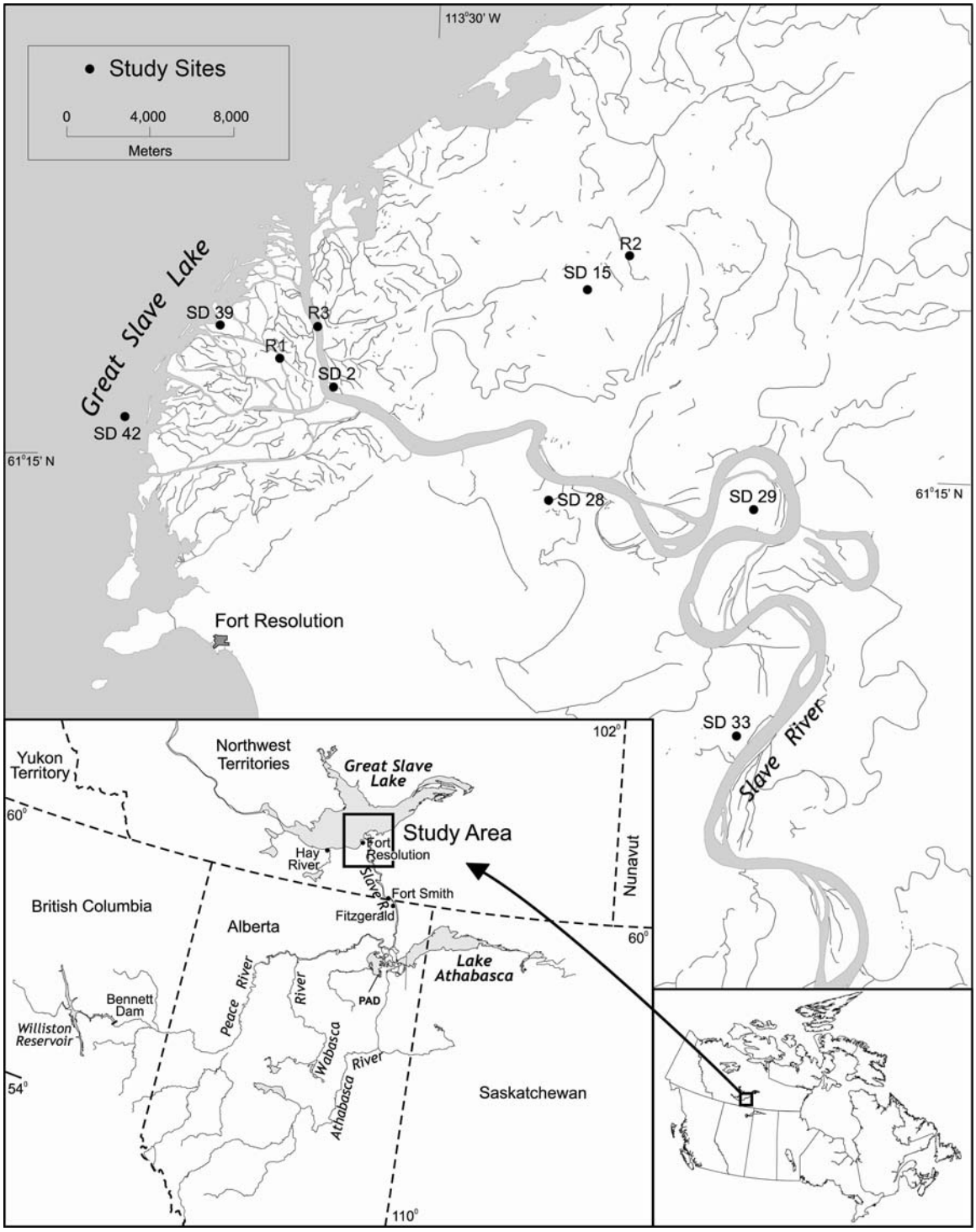

Figure 3.1 Location of the Slave River Delta and sampling sites, including rivers (R1, R2, R3) and Great Slave Lake (SD 42), and delta lakes (SD2: flood-dominated, SD28 and SD39: exchange-dominated, SD15, SD29 and SD33: evaporation-dominated).

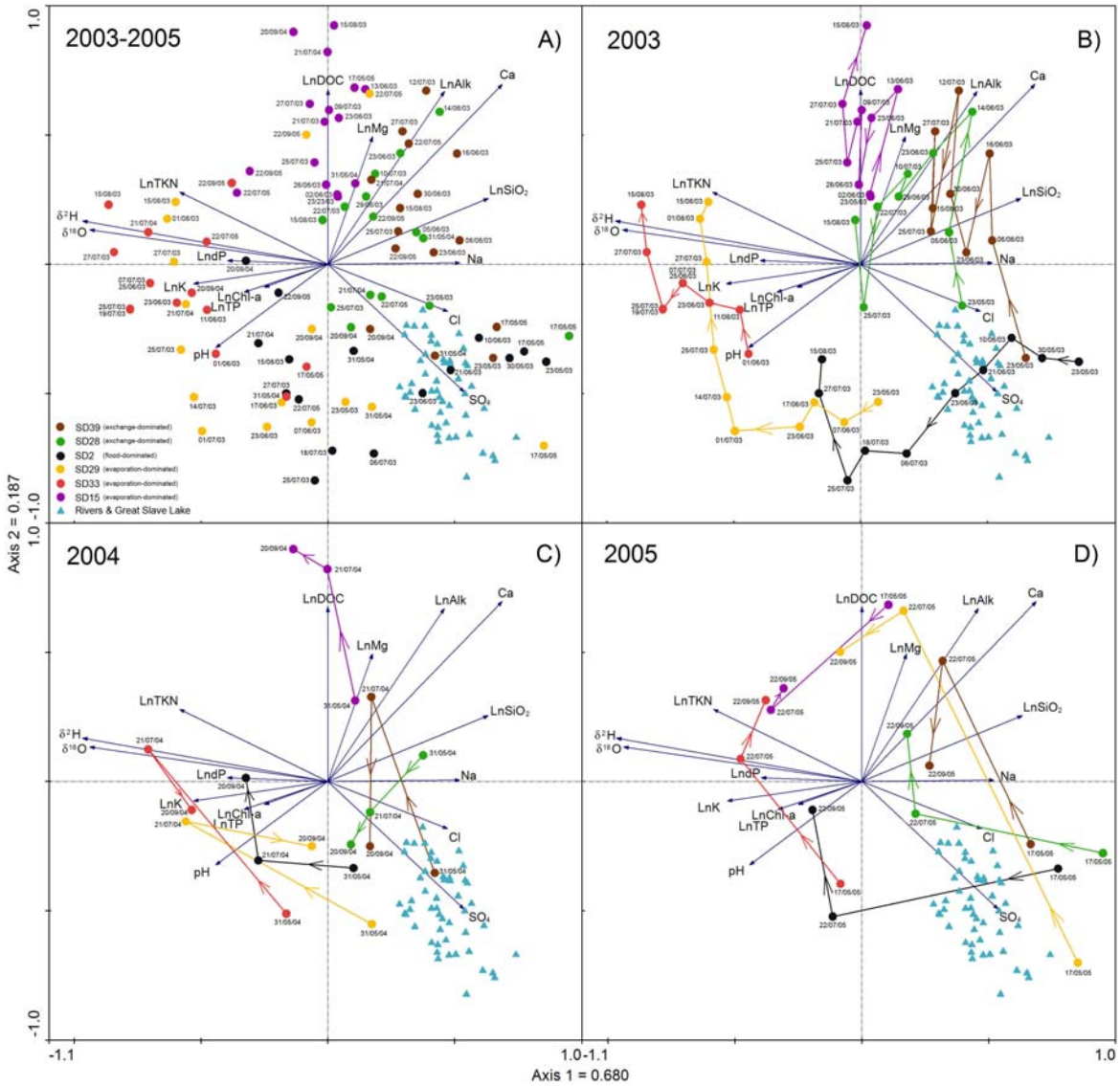

Figure 3.2 Principal components analysis (PCA) ordination diagram illustrating the relative position of water samples from Slave River Delta lakes collected during the ice-free seasons of 2003–2005 with respect to 16 hydrological and limnological variables. River sites and Great Slave Lake are plotted passively. Panel A) includes all samples from all years, whereas panels B), C) and D) are a subset from panel A) and include only seasonal samples from 2003, 2004 and 2005, respectively.

Figure 3.3 Photographs of lake SD29 under non-flood conditions in July 2004 (left) and shortly after being inundated by a large ice-jam flood in May 2005 (right).

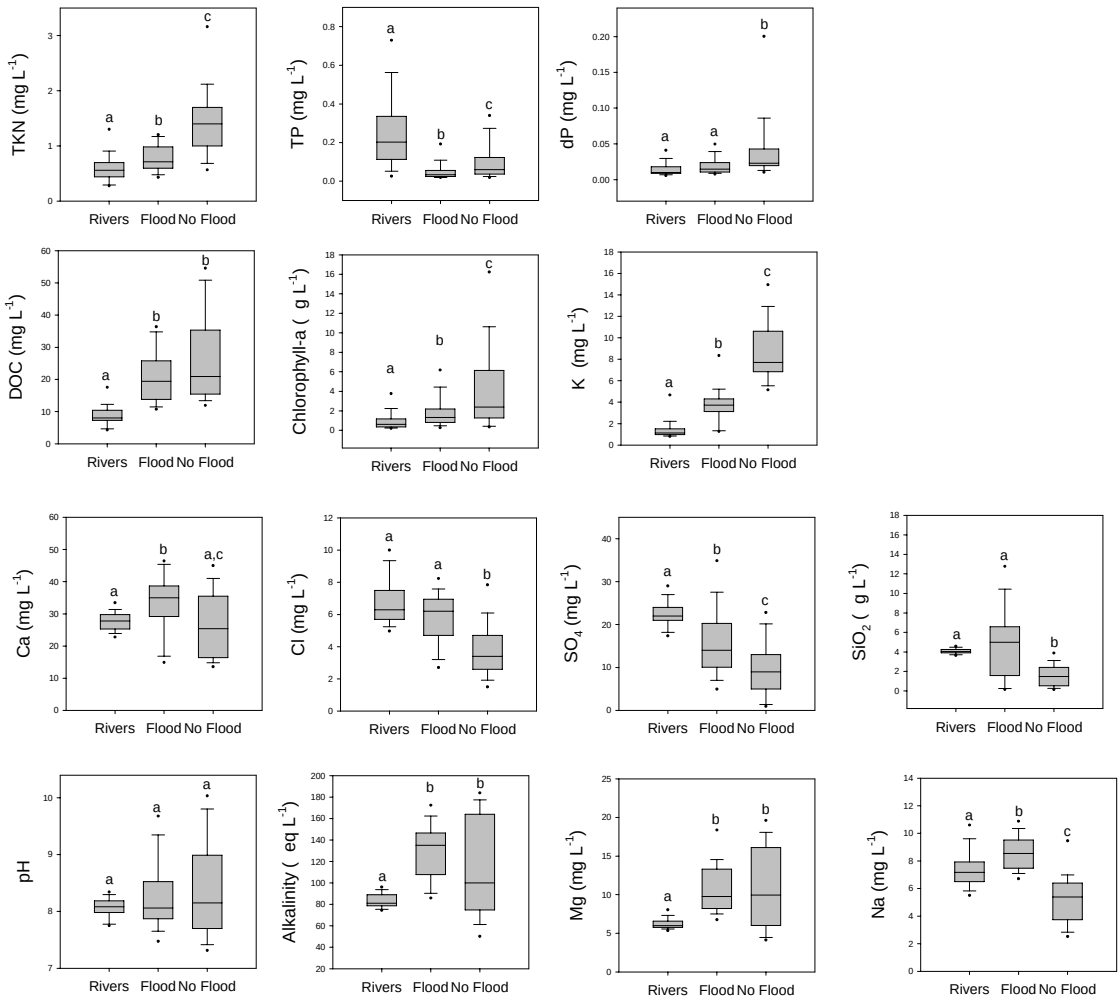

Figure 3.4 Box plots of selected physical and chemical variables for river sites (includes Slave River distributaries and Great Slave Lake) (Rivers; n=51), lakes that received flood waters (Flood; n=46) and lakes that did not receive flood waters (No Flood; n=47) from 2003–2005. Outliers (solid dots) are samples outside the 5th and 95th percentiles. Small case letters (a,b,c) are used to identify limnological variables with statistically significant differences ($p < 0.05$) in mean values between the hydrological categories based on ANOVA tests.

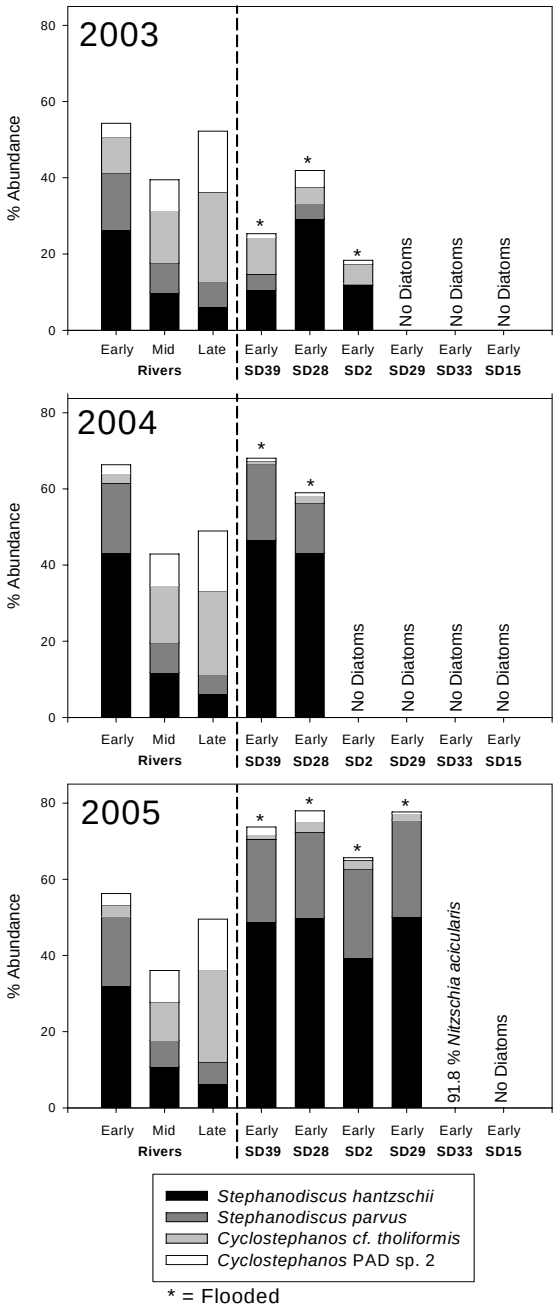

Figure 3.5 Seasonal relative abundance (%) of the most common planktonic diatom taxa (≥15%) from river sites (includes Slave River distributaries and Great Slave Lake) and lakes that received flooding in 2003–2005. Flooded lakes did not contain planktonic diatom taxa later in the season and lakes that did not receive floodwaters did not contain planktonic diatom taxa. Early, mid and late labels represent early-spring (May), mid-summer (July) and late-summer (August 2003)/late-autumn (September 2004, 2005) samples, respectively.

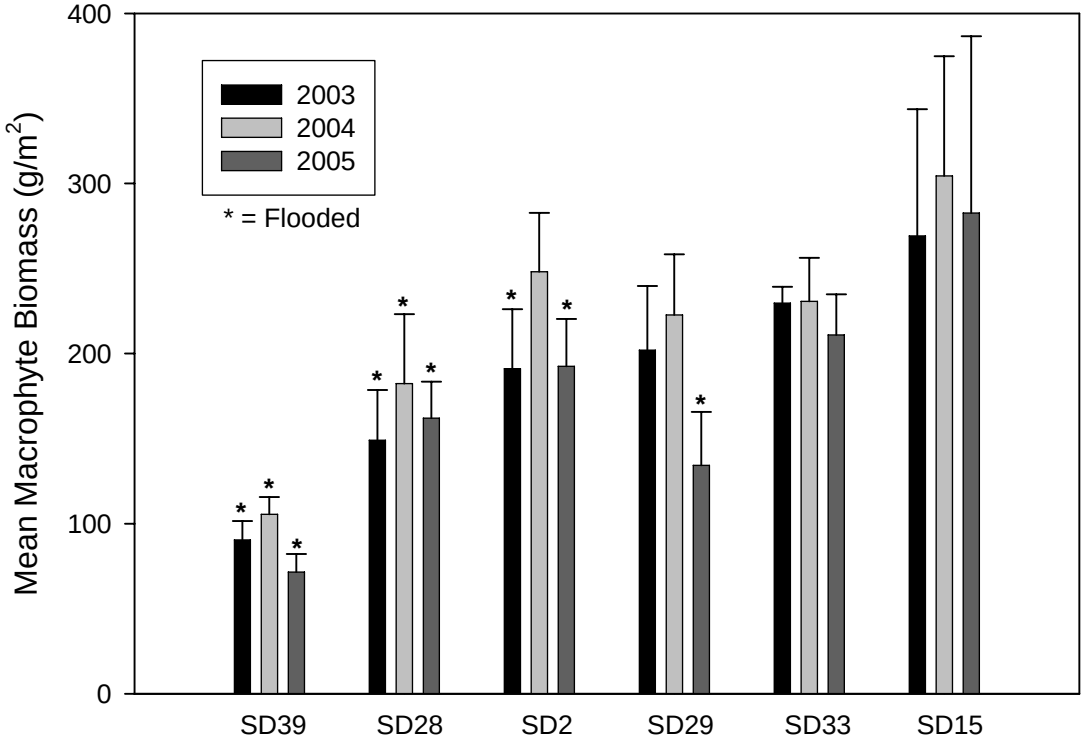

Figure 3.6 Mean aboveground macrophyte biomass from all 6 study lakes during the years 2003–2005. Asterisk indicates years when lakes received flood inputs. Error bars indicate one standard deviation unit.

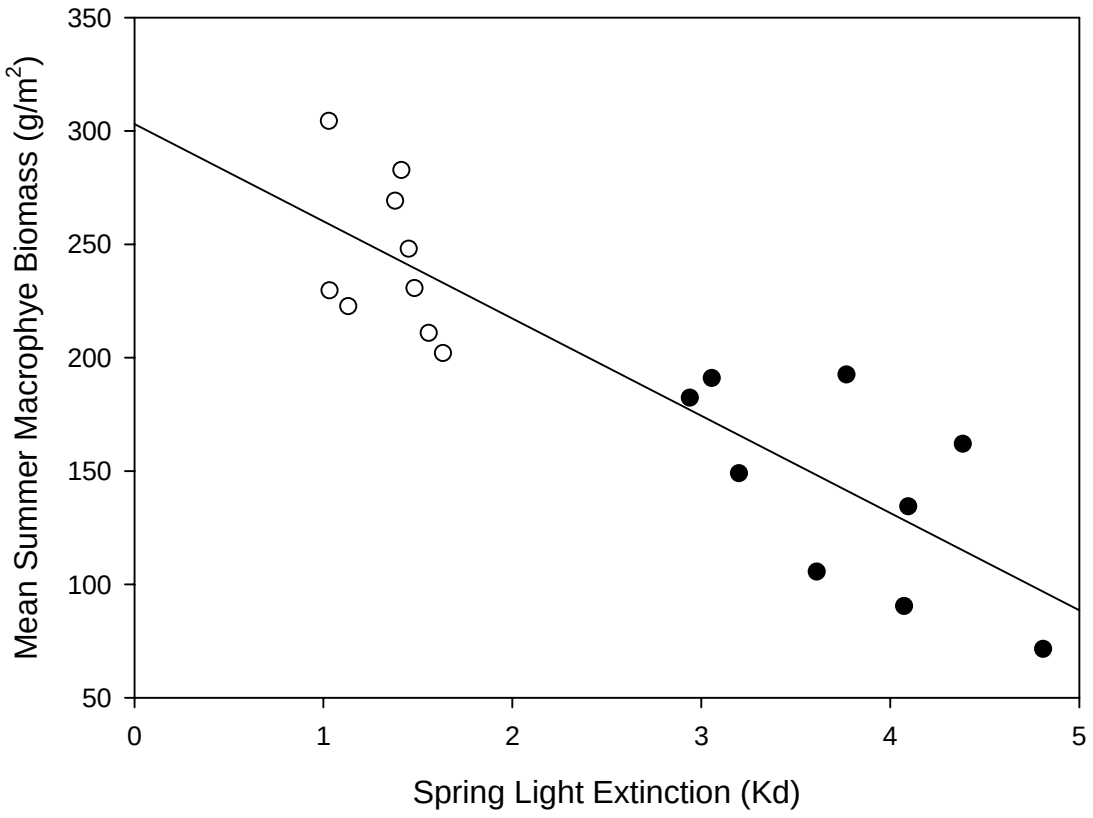

Figure 3.7 Comparison of the relations between mean aboveground macrophyte biomass and mean spring light extinction among lakes that flooded (closed circles) and lakes that did not flood (open circles). Regression line $R^2 = 0.76$.

3.10 Tables

Table 3.1 Comparison of hydrological settings and the severity of spring flooding conditions in 6 Slave River Delta lakes from 2003–2005 (Brock et al. in review).

Lake	Hydrological Category	Spring Flooding Conditions		
		2003	2004	2005
SD39	Exchange-dominated	Moderate Flood	Small Flood	Large Flood
SD28	Exchange-dominated	Moderate Flood	Small Flood	Large Flood
SD2	Flood-dominated	Moderate Flood	No Flood	Large Flood
SD29	Evaporation-dominated	No Flood	No Flood	Large Flood
SD33	Evaporation-dominated	No Flood	No Flood	No Flood
SD15	Evaporation-dominated	No Flood	No Flood	No Flood

Table 3.2 Summary of the effects of flooding on Slave River Delta lake conditions.

	Flood	No Flood
Physical and Chemical Parameters	↓ nutrients ↓ chl-*a* & K ↑ ions & SiO_2 ↑ alkalinity ↓ spring light environment	↑ nutrients ↑ chl-*a* & K ↓ ions & SiO_2 ↓ alkalinity ↑ spring light environment
Phytoplankton Diatom Communities	- Abundance of diatoms in spring phytoplankton samples - No diatoms present in mid- and late-season phytoplankton samples	- No diatoms present in spring phytoplankton samples - No diatoms present in mid- and late-season phytoplankton samples
Macrophyte Biomass	↓ mean aboveground macrophyte biomass	↑ mean aboveground macrophyte biomass

Chapter 4
Effects of flooding on epiphytic diatom communities in two floodplain lakes of the Slave River Delta (Northwest Territories, Canada)

4.1 Abstract

To improve understanding of the role of river flooding and other hydrological factors on epiphytic diatom communities, a natural experiment was conducted to compare diatom communities in two hydrologically distinct lakes in the Slave River Delta (Northwest Territories, Canada) over two years (2004 and 2005) of varying spring flood magnitude of the Slave River. Magnitude and spatial extent of flooding was low in 2004 and high in 2005. Replicate samples were collected from three dominant macrophyte species (Lake SD28: *Potamogeton friesii*, *Myriophyllum exalbescens* and a species of *Equisetum*; and, Lake SD29: *Potamogeton friesii*, *Ceratophyllum demersum*, and a species of floating filamentous green algae) in three separate basins from each lake. Multivariate analyses (PCA, analysis of similarities) of the common macrophyte in both lakes (*Potamogeton friesii*) revealed that yearly differences due to frequency and intensity of flooding account for the greatest differences in epiphytic diatom community composition (PCA axis 1 = 0.302 and ANOSIM SD29 – 2004 versus 2005 Global R value = 0.982, $p < 0.001$ and d.f. = 23), followed by hydrolimnological differences between the two study lakes (PCA axis 2 = 0.262 and ANOSIM SD28 versus SD29 – 2004 and 2005 Global R value = 0.814, $p < 0.001$ and d.f. = 47), and by spatial variability within lakes (variation along both PCA axes and ANOSIM from both lakes in both years Global R value = 0.940-1.000, $p < 0.001$ and d.f. = 47). Epiphytic diatom community composition differed significantly ($p < 0.001$) at all levels of comparison. Observed patterns of epiphytic diatom composition between years and lakes indicated that hydrological effects on the limnological conditions, coupled with changes in the light environment, exert the strongest control on epiphytic diatom community composition,

whereas spatial variability of limnological conditions within lakes and host-macrophyte specificity appear to play statistically significant but less important roles. Epiphytic diatom community composition is a sensitive indicator of hydrological change and knowledge gained concerning the roles of hydrological factors, limnological conditions and macrophyte host species on epiphytic diatom communities is important to inform interpretations of hydroecological changes from analyses of sedimentary diatom assemblages, which are often dominated by epiphytic taxa, in ongoing monitoring and paleolimnological studies in the Slave River Delta and other floodplain environments.

4.2 Introduction

Epiphytic algae are often the major primary producers in small, shallow lakes and provide an important supply of autochthonous carbon and energy to higher trophic levels (Cattaneo and Kalff 1980; Lalonde and Downing 1991; Sand-Jensen and Borum 1991; Hecky and Hesslein 1995; Wetzel 1996; Robinson et al. 1997). The importance of epiphytic algae to aquatic ecosystems is due, at least in part, to their ability to maintain high rates of photosynthesis, which is facilitated by the higher efficiency of nutrient retention and recycling in algal-microbial-substratum communities compared to planktonic communities (Wetzel 1996). Despite their ecological importance, however, studies on epiphytic algae remain overshadowed by the large number of studies devoted to phytoplankton, even in small and shallow lakes where relative biomass of macrophytes and epiphytes is highest (Stevenson 1996).

Studies have shown that light, temperature, nutrient supply, wave action, water-level fluctuations and plant architecture affect the quantity and productivity of epiphyton (Boston and Hill 1991; Lalonde and Downing 1991; Cattaneo et al. 1998; Romo and Galanti 1998; Gross et al. 2003), but there is uncertainty concerning the relative importance of these factors on community structure. Interestingly, Eminson and Moss (1980) demonstrated that epiphytic algal community structure is not specific to individual host macrophyte species in eutrophic lakes and rivers, but

that epiphyte-host relationships are much stronger in oligotrophic waters. Thus, with progressive enrichment, water chemistry may exert greater relative influence upon epiphytic community structure than does the substratum (Shamess et al. 1985). Invertebrate grazing can also affect epiphytic algal community structure by decreasing epiphyton cover and altering species composition by selective feeding (Cattaneo 1983; Marks and Lowe 1989). Müller (1999) and Sultana et al. (2004) found that under different light intensities, even small-scale changes, can have a large effect on species composition and abundance of epiphytic algae, while Comte and Cazaubon (2002) have suggested that epiphyte distribution is affected more by the morphology of the plant than by the light environment. Blindow (1987) demonstrated that microhabitat structure exerts strong control over community composition because many species of epiphytes were strongly associated with either the upper leaves, lower stems or lower leaves, and affected to a lesser extent by different species of host macrophyte or sampling sites. Still, other studies suggest that a combination of factors such as gradients of light, turbulence and nutrient availability control the development of epiphyte community composition (Lalonde and Downing 1991). In floodplain environments, hydrological factors may play an additional role in regulating epiphyte communities. River flooding and hydrological variability strongly influence submergent macrophytes, phytoplankton and benthic algal communities in flooded lentic systems (Van den Brink et al. 1993, 1994; Squires and Lesack 2001, 2002, 2003; Squires et al. 2002; Chapter 3), but very few studies have investigated the effects of hydrological factors on epiphytic algal community structure in floodplain lakes (Engle and Melack 1993; Tesolin and Tell 1996).

Epiphytic communities are composed of a variety of algal classes, but diatoms (Class Bacillariophyceae) are often dominant in shallow lakes and wetlands, including tropical South American floodplain lakes (Tesolin and Tell 1996), Scandinavian lakes (Kairesalo 1980, 1984), shallow marsh wetlands in central North America (Goldsborough and Robinson 1985), and in floodplain lakes of the Mackenzie Delta in northern Canada (Squires and Lesack 2001). Diatoms are an important food source for a variety of organisms (Cattaneo 1983) and are important players

in biogeochemical cycles of nutrients and other elements (e.g., Si). Diatoms are also sensitive environmental indicators and excellent biomonitors of changes in limnological systems. Their short life cycles, rapid dispersal, high taxonomic richness and narrow ecological tolerances promote quick and sensitive responses to environmental changes (Stoermer and Smol 1999). Shifts in the taxonomic composition of diatom communities are usually amongst the most sensitive indicators of ecosystem stress and change (Schindler 1987). Additionally, diatoms often provide an important source of information about past ecological changes for paleolimnological studies (Stoermer and Smol 1999). Consequently, improved understanding of the factors that regulate epiphytic diatoms will help inform interpretations arising from these studies.

In the Slave River Delta, Northwest Territories, diatom assemblages in the surface sediments of most lakes are dominated by epiphytic taxa, reflecting the large habitat space (macrophyte surface area) available in these shallow deltaic lakes that support prolific macrophyte growth (Chapter 2). As part of ongoing hydroecological monitoring studies and multi-proxy paleolimnological investigations of the Slave River Delta (see Wolfe et al. 2007), epiphytic diatom communities were compared in two small lakes (Lakes 'SD28' and 'SD29', unofficial names) which differ markedly in their hydrological setting. The Slave River floods into lake SD28 every spring and at various times throughout the ice-free season. In contrast, SD29 is geographically removed from the influence of the Slave River, except during the most extreme spring flood events. Data collection spanned two years (2004 and 2005) of varying spring flood magnitude (very little flooding in 2004 and extensive delta-wide flooding in 2005). Lake SD28 flooded in both years, whereas SD29 flooded only in 2005. Replicate epiphyte samples were collected from three dominant macrophyte species (SD28: *Potamogeton friesii* Ruprecht, *Myriophyllum exalbescens* Fernald, *Equisetum* sp.; and, SD29: *Potamogeton friesii*, *Ceratophylum demersum* Linnaeus, floating filamentous green algae) in three separate basins from each lake. The objective of this study was to determine the relative importance of differences in hydrolimnological conditions (between lakes and between study years), spatial

variability of limnological conditions within each lake and macrophyte host species in regulating the community composition of epiphytic diatoms in lakes of the Slave River Delta.

4.3 Study area and site descriptions

The Slave River Delta is located at the mouth of the Slave River in the Northwest Territories (61°15' N; 113°30' W) (Figure 4.1). The entire delta covers an area of 8,300 km^2 beginning at the Slave River Rapids at Fort Smith, NWT, but most of it is no longer active (Vanderburgh and Smith 1988). The active part of the delta is arcuate, spans an area approximately 400 km^2, and is prograding into Great Slave Lake through a system of active distributaries (Prowse et al. 2002). It is an important delta in northern Canada that is strongly influenced by climatic, hydrological and geomorphic variability (English et al. 1997). As a result of high biological productivity and high diversity of plant species, this delta is an important feeding, staging, and breeding habitat for a large number of waterfowl, muskrat, and other wildlife and is important economically and culturally to local First Nation communities who depend on it for traditional lifestyle occupations (English et al. 1997). The delta is a large wetland complex comprising numerous river channels, marshes, fens, bogs, swamps and forests. Scattered throughout this landscape are hundreds of small (<3 km^2), shallow (<5m) lakes spanning a wide hydrological gradient, and are characterized by extensive macrophyte growth throughout all or most of their basins.

There are three distinct hydrological lake categories in the Slave River Delta with varying degrees of hydrological association with the Slave River and its distributaries, defined as flood-dominated, evaporation-dominated and exchange-dominated (Brock et al. 2007). The water balance of flood-dominated lakes, located in the active part of the delta, is strongly influenced by Slave River floodwater during the spring melt. In contrast, evaporation-dominated lakes, located in the older inactive part of the delta, receive precipitation (spring snowmelt and summer rainfall) and, after snow melt in spring, evaporation becomes the over-riding process controlling lake water balances during the remainder of the ice-free season. Exchange-dominated lakes, located

along the Slave River and delta front adjacent to Great Slave Lake, receive inputs from channel connections with the Slave River or from Great Slave Lake water via seiche events, which result in variable water balances depending on the strength and frequency of these connections.

Lake SD28 (unofficial name; 61°14' N; 113°23' W) is a small (~1.9 km^2), shallow (~4.0 m maximum water depth), exchange-dominated basin located along the Slave River floodplain, upstream of the active delta (Figure 4.1). SD28 flooded in the spring of both years of this study (small flood in 2004 and large flood in 2005) when Slave River water entered the lake during high river levels via a small channel. During the ice-free season, this connection can serve as an inlet or outlet depending on relative levels of the river and lake. The basin is surrounded by dense stands of the emergent macrophyte *Equisetum*, and the bottom is dominated by dense stands of *Potamogeton* species and *Myriophyllum exalbescens*.

Lake SD29 (unofficial name; 61°14' N; 113°12' W) is a small (~1.0 km^2), shallow, evaporation-dominated basin located within a large meander loop of the Slave River (Figure 4.1). There are no inflows or outflows and following successive years without flooding (including 2004), maximum lake water levels declined to ~0.6 m, while water depth more than doubled (~1.5 m) after a large ice-jam flood entered the basin in spring of 2005. The basin is surrounded by a sedge marsh with mature spruce forest on higher elevations and is a highly productive system dominated by submergent macrophytes (*Potamogeton* species and *Ceratophyllum demersum*) and extensive growth of floating filamentous green algae.

4.4 Materials and methods

4.4.1 Fieldwork methods

Macrophyte samples and associated epiphytic algae were collected from lakes SD28 and SD29 in mid-July of 2004 and 2005, when macrophyte biomass was near its annual peak. The three most common macrophytes were sampled in each lake. In both lakes, *Potamogeton friesii* was sampled because it is very common throughout lakes in the Slave River Delta and it is a dominant

submergent macrophyte in both study sites. The macrophytes *Myriophyllum exalbescens* and *Ceratophyllum demersum*, were sampled from SD28 and SD29, respectively, because they were the next most abundant submergent macrophyte in each lake. Finally, two very different but abundant epiphyte habitats were sampled from each lake. A species of *Equisetum* was sampled in SD28 as it completely surrounds the lake and is the most dominant emergent macrophyte, while in SD29, a species of floating filamentous algae (hereafter referred to as a macrophyte) was sampled, as it dominates the surface of the lake throughout the majority of the ice-free season. It was important to study diatoms on these different macrophytes to determine if the host plants act as neutral substrates for epiphyte attachment or if some other feature (e.g. morphology or habitat) is controlling epiphytic diatom community composition. Four individual plants of each macrophyte species were cut at the sediment surface, carefully removed from the water and placed in separate Whirl-pak® bags and frozen until subsequent analyses. Plants were collected from central locations (except *Equisetum* in SD28, which were collected at the basin margins, ~0.5 m water depth) in three basins (SD28: western [Basin 1], central [Basin 2] and eastern [Basin 3], SD29: western [Basin 1], central [Basin 2] and eastern [Basin 3]; Figure 4.2) to assess the spatial variability of epiphytic diatom assemblages on macrophytes. Physical and chemical limnological data (see below) at each basin were also collected to determine if spatial variations, as a result of site-specific limnological conditions, affect epiphytic diatom community composition. Although three distinct basins exist in SD28, lake SD29 has only a single basin and as a result, three separate sampling sites (western, central and eastern) were chosen (hereafter referred to as basins) to assess spatial variability within SD29. Bathymetric maps (Figure 4.2) were determined by taken multiple depth measurements and corresponding GPS coordinates along multiple transects throughout the entire basin. Bathymetry data was subsequently used to create bathymetric maps in SURFER version 8.

In situ limnological measurements (water depth, temperature, pH, conductivity, and light extinction of photosynthetically active radiation [PAR; 400-700 nm] through the water column

[as k_d] measured with an irradiance sensor [Apogee Instruments Model QMSS-SUN. Logan, Utah]) were recorded at each sampling site. Water samples were collected from 10 cm below the water surface at each site for chlorophyll and chemical analyses (dissolved phosphorus [dP], total phosphorus [TP], total nitrogen [TKN], dissolved organic carbon [DOC], major ions [Ca^{2+}, Mg^{2+}, K^+, Na^+, Cl^- and SO_4^{2-}], dissolved silica [SiO_2], and alkalinity; Environment Canada (1996)). Zooplankton and other large particles were removed prior to analyses of water chemistry and chlorophyll by passing water through a 650 µm screen. The water was then filtered and the particles retained by a 0.7 µm GF/C filter (Whatman) were frozen and analyzed for chlorophyll-a (chl-*a*) using standard spectrophotometric methods (Jeffrey et al. 1997). Water samples (1 L) for chemical analyses were kept at 4ºC and sent to Taiga Environmental Laboratory, Yellowknife (July 2004) and the Environment Canada National Laboratory for Environmental Testing, Burlington (July 2005) for analysis within 3–7 days of collection.

4.4.2 Laboratory analyses

After thawing, macrophyte samples were placed in individual beakers, and sample bags were rinsed with deionized water into the same beakers to collect all epiphytes which may have become detached from the host macrophyte. Concentrated HNO_3/H_2SO_4 acid (1:1 ratio by volume) was added to each beaker and heated in a water bath at 90°C until most of the macrophyte tissue was digested. Further digestion was completed by adding 10 mL of 30% H_2O_2 to each sample and heating at 90°C for another two hours. A 12 mL aliquot of each sample (total sample volume = 200 mL) was centrifuged at 9000 rpm for 15 minutes. The acid residue was removed from the cleaned diatom slurries through repeated washings with deionized water and centrifugation (~6 times) until the diatom slurry attained a neutral pH. The resulting diatom slurries were dried onto coverslips and mounted onto microscope slides with Naphrax© mounting medium. For each sample, at least 400 diatom valves were identified and enumerated along transects using a Zeiss Axioskop 2_{plus} compound microscope with differential interference

contrast optics (1000X magnification, numerical aperture = 1.30). Diatom taxonomy followed Krammer and Lange-Bertalot (1986-1991). Diatom data were expressed as taxon relative abundances (%) of the total sum of diatom frustules in each sample.

4.4.3 Numerical analyses

Prior to numerical analyses, all diatom species that were encountered in fewer than three samples and with a maximum abundance <1% were classified as rare taxa and were omitted from numerical analyses to avoid the influence of taxa whose distributions were poorly characterized by the samples. Diatom percent abundance data were square-root transformed to reduce the influence of dominant taxa.

Principal Components Analysis (PCA), an indirect gradient, multivariate ordination technique, was used to assess the main limnological differences between lakes, between years and among basins within each lake.

Detrended Correspondence Analysis (DCA) was performed on various subsets of the diatom data to quantify the gradient length (in SD units) of the first axis, which was used to determine if linear or unimodal based ordination methods were most appropriate for analyzing the diatom data using criteria outlined in Birks (1995). Gradient length for the global dataset (all samples, n = 144) was >2 standard deviation units, therefore, a unimodal ordination technique (Correspondence Analysis [CA]) was employed. CA was used to illustrate variability of all epiphytic diatom communities between the two study lakes, between the two years of varying flood magnitude (2004 and 2005), among the different sampling sites and among the different macrophyte species. While ordination of the global dataset provides a useful approach to summarize the main patterns of variation in epiphytic diatom community composition among samples, different host macrophyte species were analyzed from the two study lakes – a feature that makes it difficult to assess the relative importance of between-lake versus between-year differences in hydrological conditions. Thus, several subsets of the global dataset were

subsequently analyzed to assess the relative importance of the possible factors regulating epiphytic diatom community composition. First, a PCA was performed (DCA gradient length <2, therefore linear ordination) using all epiphytic diatoms samples collected from specimens of *Potamogeton friesii* (n = 48), which is the only species common to both lakes, to determine the relative importance of hydrological differences between years (2004, 2005) and between lakes (SD28, SD29), and spatial variability within each lake (among three basins). Second, a series of indirect gradient ordinations were performed on data collected from each lake and year to determine the roles of spatial variability within each lake and differences in host macrophyte species on epiphytic diatom community composition. Here, preliminary DCA ordinations revealed gradient lengths <2 for diatom data from SD28 in 2004, SD28 in 2005 and SD29 in 2004 (therefore linear ordination [PCA]), but >2 for diatom data from SD29 in 2005 (therefore unimodal ordination [CA]). The PCAs and CA were performed using samples from all macrophyte species, in all basins within each lake from each year (n = 36). Sample scores (or epiphytic diatom assemblages) in the ordination diagrams were coded *a priori* according to the lake, year, basin and macrophyte host to visualize relationships among epiphytic diatom community composition and the various possible explanatory variables.

Direct gradient ordination by RDA was used to identify relationships between the epiphytic diatom assemblages on samples of *Potamogeton friesii* and the limnological gradients between the lakes in 2004 and 2005. RDA was performed using forward selection (and Monte Carlo tests with 999 random permutations) to determine a subset of limnological variables that explained significant ($p \leq 0.05$) and independent amounts of variation in the diatom data (ter Braak and Šmilauer 2002). Sample scores (or epiphytic diatom communities) in the RDA ordination diagram were coded *a priori* according to the lake, year and basins to visualize their roles on variation in limnological conditions and diatom community composition. All ordinations by CA, PCA and RDA were performed using CANOCO version 4.5 (ter Braak and Šmilauer 2002).

Analysis of Similarities (ANOSIM), a non-parametric multivariate test that is analogous to a one-factor ANOVA (Clarke and Warwick 2006), was used to determine if differences in epiphytic diatom communities between the two lakes, between years, among the different sample sites within the lakes and among the macrophyte species are statistically significant ($p \leq 0.05$). The sample statistic (Global R value) reflects the observed difference among groups of samples contrasted with the difference among replicates within each group of samples. A Global R value of zero indicates that the similarity between and within groups of samples is the same on average. A value of one, on the other hand, indicates that all the replicates within a group of samples are more similar to each other than with any replicates from different groups of samples (Clarke and Warwick 2006). Within- and across-group rank Bray-Curtis dissimilarities were computed (5000 permutations) and the distribution of these values was compared to the initial rank dissimilarity and reported as the Global R value (Clarke and Warwick 2006). A series of one-way ANOSIM tests ($\alpha = 0.05$) were performed on various subsets of the diatom data to test for the effects of differences between lakes, years, sample sites and host macrophyte species on epiphytic community composition. First, comparisons of epiphytic diatom community composition between the two lakes (in both study years combined as well as during individual years (2004 and 2005)) were performed using all samples from the macrophyte common to both lakes (*Potamogeton friesii*). These tests evaluated the differences in epiphytic diatom communities due to hydrolimnological differences between lakes SD28 and SD29 without the possible confounding influence of differences in host macrophyte species. Second, comparisons of epiphytic diatom community composition between 2004 and 2005 at each lake were performed using samples from each macrophyte species individually (SD28: *P. friesii*, *Myriophyllum exalbescens*, *Equisetum* sp. and SD29: *P. friesii*, *Ceratophylum demersum*, floating filamentous algae). These tests evaluated the differences in epiphytic diatom communities due to hydrolimnological differences between years at each lake. Third, comparisons of epiphytic diatom community composition among basins in each lake, from each year were performed using

samples from each macrophyte species individually, from all three lake basins. These tests evaluated the spatial variability of epiphytic diatom community composition within each lake. Fourth, comparisons of epiphytic diatom community composition among macrophyte host species in each lake, from each year were performed using samples of all macrophyte species from each lake basin individually. These tests evaluated the variability of epiphytic diatom community composition due to differences among macrophyte host species. Similarity Percentage (SIMPER) tests were also performed on the various levels of comparison to determine the contributions of each diatom taxon to the dissimilarity between lakes, between years, among basins and among macrophyte species. ANOSIM and SIMPER analyses were performed using the program PRIMER version 6.1.5 (Clarke and Warwick 2006).

4.5 Results

4.5.1 Comparison of physical and chemical limnological differences between and within lakes

Principal Components Analysis of the water chemistry data showed that samples from the two lakes and both years differed mainly along gradients of concentrations of ions, alkalinity, conductivity, light (as K_d) and pH (Figure 4.3). Eigenvalues for the first and second PCA axes were 0.968 and 0.014 respectively, and explained 98.3% of the variation in the data set. Alkalinity, conductivity, SiO_2, Ca Mg, Na, light and pH were all strongly correlated to axis 1, while TKN, TP, dP, DOC, K, Cl and SO_4 were closely associated with axis 2. The main gradient of variation among samples (axis 1) separates samples from flooded lakes (SD28 in 2004 and 2005, and SD29 in 2005; associated with high concentrations of most ions, alkalinity, conductivity and light) from the non-flooded lake (SD29 in 2004; associated with low concentrations of most ions, alkalinity, conductivity, light and high pH). PCA axis 2 separates samples from lake SD28 (associated with low concentrations of nutrients and high SO_4) and lake SD29 (associated with high concentrations of nutrients and K). Limnological conditions at SD29

after flooding in 2005 remained distinct from conditions at SD28 in both years, though values are more similar to those in SD28 in 2004 than in 2005.

Physical and chemical conditions differed between lakes and between the two years of different flood magnitude. Generally, lake SD28 had higher concentrations of Na, Mg, SO_4 and SiO_2, higher conductivity and higher alkalinity, while lake SD29 had higher concentrations of nutrients (DOC, TKN, TP and dP), K and Cl, and higher pH (Table 4.1; Figure 4.3). Although the magnitude of flooding in SD28 differed between the years 2004 (small flood) and 2005 (large flood), limnological conditions did not vary considerably, although greater among-basin variability occurred in SD28 in the high-magnitude flood year of 2005 compared to 2004 (i.e. variation of sample scores along axis 1 of the PCA ordination shown in Figure 4.3). In contrast, the limnological conditions at lake SD29 differed markedly between years. After spring flooding in 2005, concentrations of TP, dP, Na, Mg, Ca, SiO_2 and conductivity and alkalinity were all markedly higher in SD29 compared to values in 2004 when the lake did not flood (Table 4.1). The underwater light environment also differed between lakes and years. Due to periodic inputs of sediment-laden river water via a channel connection with the Slave River, lake SD28 has high extinction co-efficients throughout the ice-free season (Chapter 3), but extinction coefficients were higher in 2005 as a result of a large magnitude spring flood in 2005 (compared to minor flooding in 2004). Lake SD29 had clear water in the absence of flooding in 2004 (and low extinction coefficients), but extinction coefficients were very high in 2005 following the large ice-jam flood (Table 4.1). Chemical variables that declined on average between years in SD29 include pH and concentrations of K, DOC and TKN, while concentrations of Cl and SO_4 remained relatively stable from year to year (Table 4.1).

4.5.2 Epiphytic diatom community composition

A total of 64 diatom taxa were found in the epiphyte samples collected from both lakes in 2004 and 2005 (Table 4.2). All samples contained sufficient numbers of diatom valves (300-400

valves) to provide accurate estimates of percent composition. Most of the diatom taxa identified are common epiphytes that have been reported in a variety of other studies on epiphytic algae (Goldsborough and Robinson 1985; Müller 1995, 1999; Tesolin and Tell 1996; Cattaneo et al. 1998; Romo and Galanti 1998; Comte and Cauzaubon 2002; Sultana et al. 2004).

Community composition of epiphytic diatoms reveals variability at all levels of comparison – between lakes, between years, among sampling sites and among host macrophyte species (Figure 4.4). The most common taxon is in this study is *Achnanthes minutissima* Kützing, which is present in all samples from both lakes but attains higher relative abundance in SD28. Other common epiphytes include *Cocconeis placentula* var. *placentula* Ehrenberg and *Epithemia adnata* (Kützing) Brébisson, which are present in the majority of samples from both lakes. Each lake also has a unique common diatom taxon that is not present in the other lake. *Cymbella microcephala* Grunow was found only in lake SD28, while *Nitzschia amphibia* Grunow was only present in lake SD29 (see Figure 4.4). Taxa that were relatively more abundant in SD28 include *Rhopalodia gibba* (Ehrenberg) O. Müller, *Gomphonema angustum* Agardh, *Gomphonema parvulum* (Kützing) Kützing and *Achnanthes minutissima*, while taxa with higher relative abundance in SD29 include *Fragilaria tenera* (W. Smith) Lange-Bertalot, *Eunotia bilunaris* (Ehrenberg) Mills, *Nitzschia palea* (Kützing) W. Smith, *Fragilaria capucina* var. *mesolepta* (Rabenhorst) Rabenhorst and *Cocconeis placentula* var. *placentula*. There are minor differences in diatom community composition between years in SD28 (e.g. *Cocconeis placentula* var. *placentula* was more abundant in 2004 than 2005), but there are large differences between non-flood (2004) and flood (2005) years in SD29. For example, *Gomphonema gracile* Ehrenberg, *Eunotia bilunaris* and *Fragilaria tenera* were not observed at all in 2004, but occurred in high relative abundance in 2005 (Figure 4.4). Also, diatom community composition on floating algae in SD29 in 2005 (dominated by *Nitzschia palea* and *Fragilaria tenera*) was very different compared to the same floating algae in SD29 in 2004 (Figure 4.4).

Analysis of the complete epiphytic diatom data set by CA illustrates that differences between the two lakes account for the largest amount of variation in community composition, as indicated by clear separation of samples from SD28 (positioned to the left) and SD29 (positioned to the right) along axis 1 (Figure 4.5a). Community composition was most distinct between lakes in 2004, and greater similarity was observed between lakes in 2005 when they flooded as shown by overlap of some sample scores from SD28 (both years) with those from SD29 (2005 only). Differences between years appear to account for the second largest amount of variation in epiphytic diatom community composition, as indicated by separation of sample scores along axis 2 (2004 positioned lower and 2005 positioned higher; Figure 4.5a). Interestingly, epiphytic diatom communities show greater variation between years at lake SD29 (flooded in 2005 but not in 2004) compared to SD28 which flooded in both years. Epiphytic diatom community composition also differs among the three basins within each lake and among macrophyte host species. The differences are generally less obvious than differences between lakes and years although variability of epiphytic community composition on floating algae in SD29 is pronounced between years and among basins (Figure 4.4, 4.5). The abundance of *Rhopalodia gibba* and *Cymbella microcephala* in SD28 are highest in basin 1 and lowest in basin 3 in 2004, and the opposite pattern occurs in samples from 2005. Also, *Nitzschia palea* is consistently more abundant in basin 3 at SD29 than in the other two basins. Comparisons of the community composition among macrophyte species reveal some associations between diatoms and host macrophyte species (Figure 4.4). In lake SD28, for example, *Gomphonema angustum* attains higher relative abundance on *Equisetum* compared to *P. friesii* and *M. exalbescens*. In SD29, relative abundance of *Gomphonema gracile*, *Cocconeis placentula* var. *placentula* and *Eunotia bilunaris* are higher on *C. demersum* and *P. friesii* than on floating algae, while *Fragilaria tenera* is much more abundant on floating algae.

Multivariate analyses of the global dataset show that differences between lakes have the largest effect on epiphyte community composition (Figure 4.5). However, these differences are

due in part to the fact that different macrophyte species were analyzed in the two lakes and are not only due to differences in hydrolimnological features between lakes. Consequently, analyses were standardized to compare epiphytic diatom community composition between lakes, years and basins on a common macrophyte host species (*Potamogeton friesii*). Overall, results indicate that differences between flood years are the strongest controlling factor of epiphytic diatom community composition followed by differences between lakes, and among basins within each lake (Figure 4.6, Table 4.3). Specifically, analysis of the epiphytic diatom data by PCA revealed that axis 1 captured 30.2% of the variation in epiphytic diatom communities on samples of *Potamogeton friesii* (Figure 4.6). Samples scores are clearly separated from flooded lakes (SD28 in both years and SD29 in 2005, positioned to the right) from the site that did not flood (SD29 in 2004, positioned to the left), indicating differences between flood years and non-flood years are most important in determining epiphytic diatom communities. Differences between years were larger at SD29 (no flood in 2004 and large flood in 2005) than at SD28 (flooded both years), as indicated by a larger separation of sample scores between years for SD29 along PCA axis 1 (Figure 4.6) and higher global R values for between-year comparisons of epiphytic diatom communities on all macrophyte taxa (0.982-1.000 at SD29 versus 0.422-0.644 at SD28; Table 4.3). Analysis by SIMPER identified *Cocconeis placentula* var. *placentula*, *Cymbella microcephala*, *Epithemia adnata*, *Gomphonema gracile* (greater abundances in 2004), and *Achnanthes minutissima* (greater abundances in 2005) as the taxa which contributed most to the dissimilarity between years in SD28. For lake SD29, SIMPER analyses identified *Fragilaria capucina* var. *mesolepta*, *Epithemia adnata, Epithemia turgida* (Ehrenberg) Kützing, *Nitzschia amphibia*, *Achnanthes minutissima* (more abundant in 2004), and *Gomphonema parvulum* and *Nitzschia palea* (greatest relative abundance in 2005), as the taxa contributing most to the dissimilarity between 2004 and 2005.

PCA axis 2 explained 26.2% of the variation in epiphytic diatom communities and indicated that hydrolimnological differences between the two lakes accounted for the next largest

difference in community composition, as indicated by separation between epiphytic diatom communities in SD28 (low on axis 2) and SD29 (higher on axis 2) in both years (Figure 4.6). Analysis by SIMPER identified *Cymbella microcephala* and *Nitzschia amphibia* as the taxa which contributed most to the dissimilarity between the two lakes, because they were only present in samples from SD28 and SD29, respectively (Figure 4.4). Separation of sample scores among lake basins is also evident. Interestingly, the spatial distribution of epiphytic diatom assemblages on *P. friesii* appears to play a lesser role in SD29 when compared to differences between years, while variability among sample sites in SD28 is greater than variation between years (Figure 4.6). However, among-basin variability of epiphytic diatom community composition is higher in SD29 in the year it flooded (2005) compared to when it did not flood (2004). In contrast, among-basin variability at SD28 is greater in the low-magnitude flood year (2004) compared to the high magnitude flood year (2005), as shown by the spread of sample scores along PCA axis 1 (Figure 4.6).

To remove the influence of between-lake and between-year variability, separate analyses were performed on epiphytic diatom communities from all basins and all macrophyte species within each lake in 2004 and 2005. ANOSIM tests revealed the composition of epiphytic diatom communities differed significantly among all lake basins ($p < 0.001$; Table 4.3) and among all macrophyte species ($p < 0.001$; Table 4.3) within each lake in 2004 and 2005. PCA axis 1 for SD28 in 2004 and 2005 captured 32.1% and 28.7% of the variation in epiphytic diatom communities, and PCA axis 2 captured 21.3% and 18.3%, respectively (Figure 4.7a,b). In both years, sample scores from each lake basin were separated mainly along axis 1, with lesser amounts of variation occurring along axis 2. In contrast, separation of epiphytic diatom communities according to macrophyte host species occurred mainly along axis 2 and to a lesser extent along axis 1, indicating that in lake SD28 spatial variability of epiphytic community composition exceeds that due to differences in macrophyte host species. For SD29 in 2004, eigenvalues for PCA axes 1 and 2 are similar (0.357, 0.327) and variability of sample scores

according to sample location and macrophyte host species are roughly similar along both axes, indicating that spatial variability and host plant species exerted comparable influence (Figure 4.7c). Interestingly, this pattern was noticeably different at SD29 in 2005. Eigenvalues of the first two axes differed markedly (0.383, 0.174) and axis one separated epiphytic diatom community composition according to host macrophyte species with much less variability due to difference among sample sites (Figure 4.7d).

Ordination by RDA performed on all samples from *Potamogeton friesii* identified six variables (dP, K, SO_4, SiO_2, pH and conductivity) that explained significant and independent amounts of variation in the epiphytic diatom communities between lakes, between years and among basins (Figure 4.8). The eigenvalues of the first two RDA axes ($\lambda_1 = 0.295$, $\lambda_2 = 0.254$) were both significant ($p \leq 0.05$) and captured 99.5% and 96.5% of the variation in the species-environment relationships, respectively. Conductivity, pH and concentrations of SiO_2 are highly correlated with the first RDA axis (intraset correlations = 0.743, 0.909 and 0.778, respectively) and concentrations of dP, K and SO_4 show strong correlation with the second axis (intraset correlation = 0.839, 0.815 and 0.750). The first RDA axis mainly separated epiphytic diatom communities typical of flooded lakes (with lower pH, higher conductivity and higher concentrations of SiO_2 and dominated by taxa of the genera *Gomphonema*, *Eunotia* and *Fragilaria*) from communities of lake SD29 in 2004 when it did not flood (with higher concentrations of nutrients and K and dominated by taxa of the genera *Cocconeis* and *Nitzschia*). The second RDA axis separated the diatom communities of lake SD28 (with lower concentrations of dP and K, and higher concentrations of SO_4 and dominated by *Cymbella microcephala*, *Rhopalodia gibba* and *Gomphonema* taxa) from those of lake SD29 (higher concentrations of dP and K and lower concentrations of SO_4 and dominated by *Cymbella microcephala*, *Rhopalodia gibba* and *Gomphonema* taxa). Importantly, there is a large separation between samples collected in 2004 and 2005 from lake SD29. This lake did not flood in 2004 and epiphytic diatom communities for this year are positioned in the lower left quadrant, associated with relatively low

concentrations of SiO_2, low conductivity and relatively abundant *Nitzschia amphibia, Fragilaria capucina* var. *mesolepta* and *Epithemia* taxa. In contrast, SD29 was inundated by a large flood in 2005 and diatom communities moved to a unique location in the lower right quadrant of the RDA plot, associated with higher concentrations of SiO_2, higher conductivity and abundant *Eunotia bilunari*s and taxa of the genera *Navicula* and *Gomphonema*. Epiphytic diatom communities from SD28, which flooded in both years and received periodic flood waters via a channel connection to the Slave River throughout the season, are positioned high in the RDA, associated with moderate concentrations of SiO_2 and conductivity values. The light environment (k_d PAR) of the two lakes was not identified as a significant variable ($p>0.05$) in the RDA due, at least in part, to the strong correlation of k_d with conductivity (positive) and pH (negative), although river flooding has been shown to dramatically decrease the amount of light in delta lakes (due to increased minerogenic turbidity) and affect benthic algae (Squires and Lesack 2001).

4.6 Discussion

A major focus of limnological studies continues to be on the identification of factors that exert important control on biological communities, and many studies have attempted to assess factors regulating the composition, distribution, biomass and diversity of epiphytic algal communities (Stevenson 1996). However, the majority of studies of epiphytic algae have been conducted at a single study site and many of these also utilize artificial substrates, while relatively few studies have compared epiphytic algal communities on living macrophytes among lakes as a way to assess possible control factors. Most of the studies that have included comparisons among multiple sites have focused primarily on the roles of nutrients (e.g., Eminson and Moss 1980; Shamess et al. 1985; Lalonde and Downing 1991). This study demonstrates a strong role of hydrologic processes in regulating epiphytic diatom communities in lakes by comparing aquatic systems in a fluvial-deltaic environment that differ primarily in susceptibility to river flooding.

As a result of hydrolimnological differences between SD28 and SD29, mainly due to variability in frequency and intensity of flooding, significant differences in the composition of epiphytic diatom communities occurred between lakes and years and these differences exert strong control of epiphytic community composition. Based on analyses of epiphytic diatom communities growing on *Potamogeton friesii* (the common macrophyte in both lakes), between-year differences in flood activity accounted for the greatest amount of variation in epiphytic diatom community composition, followed by between-lake differences. Results from PCA of epiphytic diatom communities indicate a clear separation of samples from flooded lakes (SD28 in both years and SD29 in 2005) and SD29 in 2004 which received no flooding along (PCA axis 1 = 0.302; Figure 4.6). However, differences between years were larger at SD29 (no flood in 2004 and large flood in 2005) than at SD28 (flooded both years), as indicated by a larger separation of sample scores between years for SD29 along PCA axis 1 (Figure 4.6) and higher global R values for between-year comparisons of epiphytic diatom communities on all macrophyte taxa (0.982-1.000 at SD29 versus 0.422-0.644 at SD28; Table 4.3). Since lake SD29 is an evaporation-dominated lake, it is removed from the influence of the Slave River except during high-magnitude flood events (Chapter 3). The large ice-jam flood that occurred at SD29 in the spring of 2005 altered the physical and chemical conditions of this lake by decreasing nutrients and increasing alkalinity, conductivity and concentrations of most ions (Figure 4.3), resulting in strongly contrasting epiphytic diatom communities between years. Results are also consistent with findings by Engle and Melack (1993) and Tesolin and Tell (1996) who found that yearly changes in epiphyte community structure in floodplain lakes are often associated with changes in nutrient supply as a result of flooding. In contrast, lake SD28 is frequently flooded (generally once or more per year), and has little variation in epiphytic diatom composition between years. Although variability between 2004 and 2005 was lower in SD28 than in SD29, statistically significant differences in composition of epiphytic diatom communities were observed between years in SD28. The observed differences are likely the result of the different spring flood magnitude

between study years (small flood in 2004 and large flood in 2005). Flood-induced limnological changes were less in 2004, but ice-jam flooding in the spring of 2005 dramatically raised water levels (approximately 2 m above summer levels), decreased concentrations of most nutrients and changed the underwater light environment by increasing extinction coefficients.

Hydrolimnological differences between lakes accounted for the second largest amount of variation among epiphytic diatom communities as indicated by a separation of epiphytic diatom communities from SD28 and SD29 (PCA axis 2 = 0.262; Figure 4.6). The hydrological settings of lakes in the Slave River Delta are associated with distinctly different limnological conditions and composition of diatom assemblages in surface sediments (Chapter 2). Differences are most pronounced between exchange-dominated lakes that are influenced by the Slave River (e.g. SD28) and evaporation-dominated lakes that are removed from the influence of the river (e.g. SD29). Lake SD28 was classified as having flood-dominated hydrology based on water stable isotope tracers and surface sediment diatom assemblage (Brock et al. 2007, Chapter 2). It is highly susceptible to spring flooding and can be influenced by high river levels throughout the ice-free season due to a channel connection with the Slave River (Brock et al. 2007). The chemical conditions of SD28 are strongly influenced by flood waters and, as a result, the lake has high concentrations of most ions, high alkalinity and low concentrations of nutrients with low inter-annual variability (Chapter 3). In contrast, lake SD29 generally does not flood and has much higher concentrations of nutrients, K, pH and lower concentrations of most ions, and has a high degree of inter-annual variability (Chapter 3). Furthermore, the underwater light environment differed markedly between the two study lakes due to supply of suspended sediment from the Slave River. Light (as K_d) was not identified as a significant control variable in the RDA (Figure 4.8), because it was strongly correlated with conductivity. When analyzed as the sole explanatory variable, K_d was significant ($p < 0.05$) and as a result, it may be considered a controlling variable. Results are consistent with Squires and Lesack (2001) who found that light availability is a strong controlling factor of benthic algae in floodplain lakes of the Mackenzie Delta, and Sultana et al.

(2004) found that even small-scale changes in light intensities, can have a large effect on species composition of epiphytic algae.

Within-lake and among-macrophyte host species variability both account for statistically significant ($p < 0.05$) amounts of variation in epiphytic diatom community composition, but the relative importance of these two factors appears to vary depending on the year and lake. Differences in epiphytic diatom communities among basins in SD28 are captured mainly by PCA axis 1 (2004 $\lambda_1 = 0.321$ and 2005 $\lambda_1 = 0.287$), whereas among-macrophyte variability is captured mainly by PCA axis 2 (2004 $\lambda_2 = 0.213$ and 2005 $\lambda_2 = 0.183$; Figure 4.7). In contrast, both within-lake and among-macrophyte host species variability have comparable influence on epiphyte community composition (PCA $\lambda_1 = 0.357$ and $\lambda_2 = 0.327$) at SD29 in 2004, but differences due to macrophyte variability is much greater than among basin variability in 2005 (PCA $\lambda_1 = 0.383$ and $\lambda_2 = 0.174$; Figure 4.7). Greater relative influence of within-lake differences than among-macrophyte host species differences at SD28 may be due, at least in part, to the channel connection that can create physical and chemical gradients within the lake. Throughout the ice-free season the limnological conditions in lake SD28 are variably influenced by river water due to a channel connection with the Slave River that serves as an inlet and outlet (Chapter 3), and this channelized inflow likely can establish a more marked gradient of limnological conditions compared with SD29. This finding is consistent with evidence presented by Squires and Lesack (2002) that nutrient concentrations within a flood-prone lake in the Mackenzie Delta changed considerably depending on the distance from the inlet channel. Furthermore, the strong role of nutrients and water chemistry on periphyton is well acknowledged (Borchard 1996) and even modest changes in the chemical parameters among lake basins may alter algal community composition (Marks and Lowe 1993; Müller 1999).

Significant differences in epiphytic diatom community composition are also evident on different macrophytes, suggesting that varying plant architecture or different aquatic habitats (e.g.

floating and submergent) is likely important in regulating epiphytic community composition. Studies such as those by Blindow (1987) and Comte and Cazaubon (2002) have suggested that epiphytic diatom taxa are not randomly distributed among macrophyte hosts, but instead show specificity for particular macrophyte species. Selection by diatoms for macrophyte hosts may be due, at least in part, to differences among diatom taxa in their mode of attachment which leads to selection of certain attributes of plant morphology or microhabitat structure. Additionally, the chemical environment and supply of nutrients to epiphytes may differ among macrophyte species. Grazing pressures and selective feeding by consumers of epiphytes may also differ among macrophyte taxa, and could account for some of the observed differences in diatom community composition among host plant species (Brönmark 1989). While macrophyte-epiphyte associations have been demonstrated by some studies, researchers often agree that environmental and physicochemical factors exert a greater influence on community composition than macrophyte structure does (Eminson 1978; Eminson and Moss 1980; Lalonde and Downing 1991). There has also been evidence to suggest that macrophytes act as a neutral substrate for epiphyte attachment (Cattaneo and Kalff 1979; Stevenson 1988). In this study, however, we demonstrate that community composition of epiphytic diatoms differed significantly among macrophyte species and as such, macrophytes do not appear to act simply as neutral sites for attachment.

Thomaz et al. (2007) found that flooding increases similarity among aquatic habitats in river-floodplain systems. They suggest that river flooding homogenizes hydrolimnological characteristics of lakes and, as a result, ecological processes and biological communities tend to be more similar. Our data are inconsistent with these findings as flooding at SD28 and SD29 in 2005 did not make epiphytic diatom communities and limnological conditions the same in both lakes. Although flooding altered the physical and chemical conditions and significantly influenced epiphytic diatom community composition in SD29, conditions between lakes remained distinct. Since SD29 had not flooded for at least three years prior to 2005, we postulate that hydrolimnological conditions after flooding in 2005 resulted in conditions that are unique among

delta lakes. It is likely that it would take successive years of high-magnitude flooding before limnological conditions and epiphyte communities became more similar to exchange- or flood-dominated lakes.

4.7 Conclusions

Although there are a variety of factors that regulate epiphytic diatom community composition, we demonstrate the overriding influence of flooding and hydrolimnological variability on diatom communities compared to spatial differences of limnological conditions within lakes or differences in host macrophyte species. The examination of such driving forces behind changes in epiphytic diatom communities improves knowledge of factors regulating epiphytic diatoms and will provide a scientific basis for effective long-term monitoring and for accurate paleolimnological interpretations of hydrological variation in the Slave River Delta from analyses of sedimentary diatom assemblages. Since the influence of hydrology on the limnological characteristics of delta lakes appears to play a more important role than macrophyte-host species, marked shifts in sedimentary assemblages of epiphytic diatoms can be more appropriately interpreted as a result of changes in flood dynamics as opposed to a result of changes in composition of macrophyte communities. Ongoing and future studies of epiphytic diatom communities from a wide variety of macrophytes in a broad range of hydrologically diverse lakes may further refine our understanding of factors influencing epiphytic diatom communities in water bodies of the Slave River Delta.

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4.9 References

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4.10 Figures

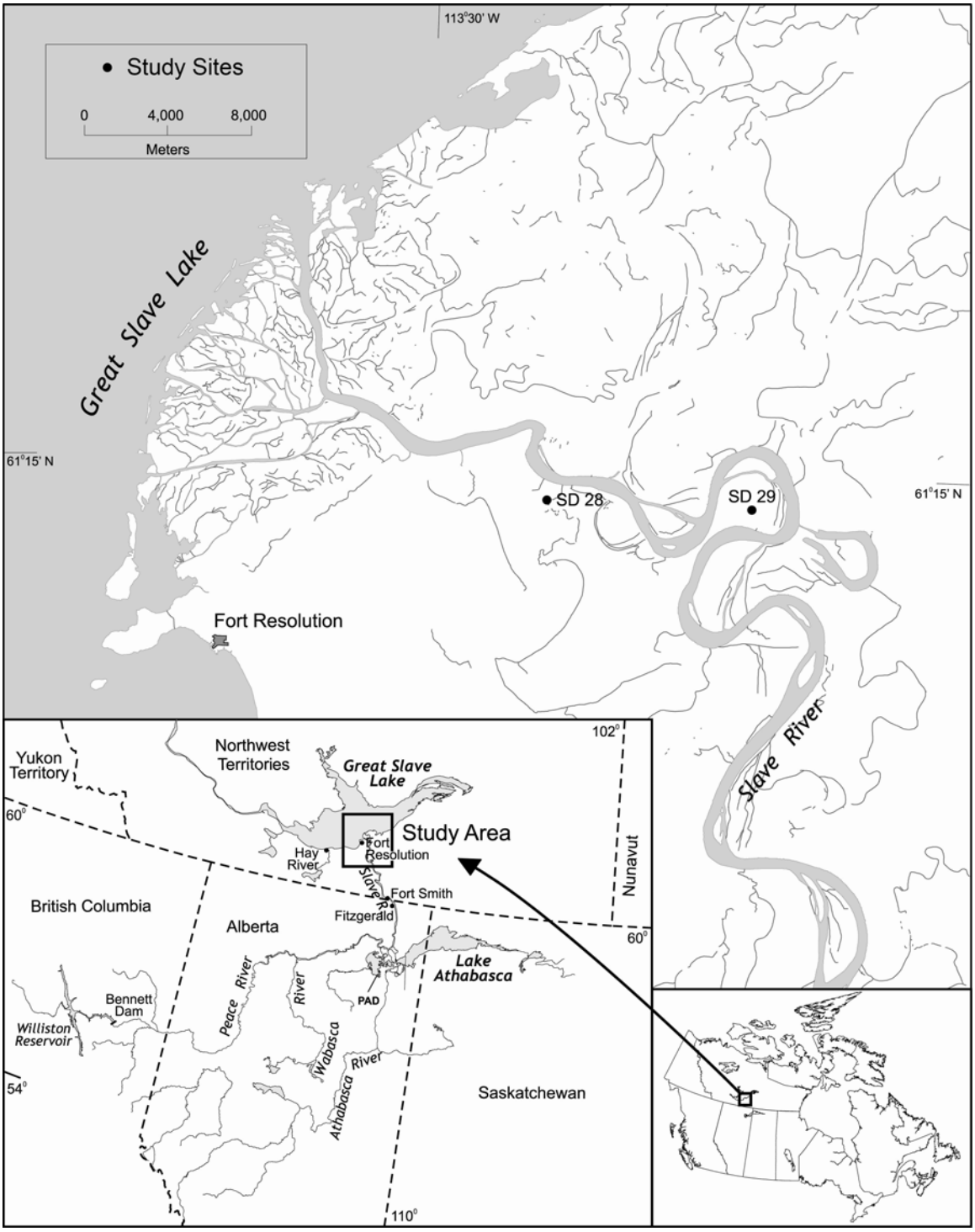

Figure 4.1 Location map showing the Slave River Delta (NWT) and the study lakes SD28 and SD29.

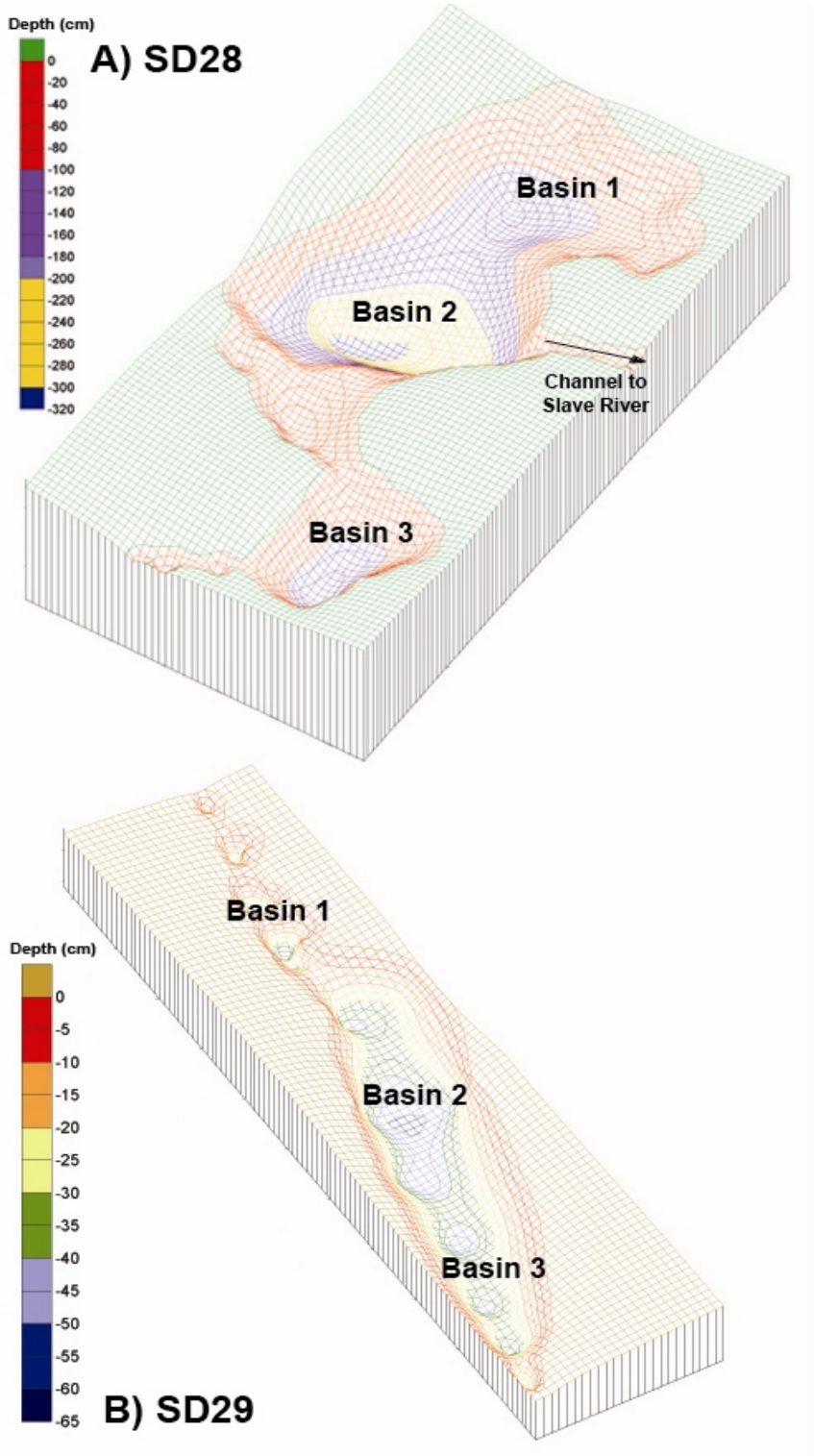

Figure 4.2 Bathymetric maps for lake SD28 (A) and lake SD29 (B), showing the approximate locations of the sample sites.

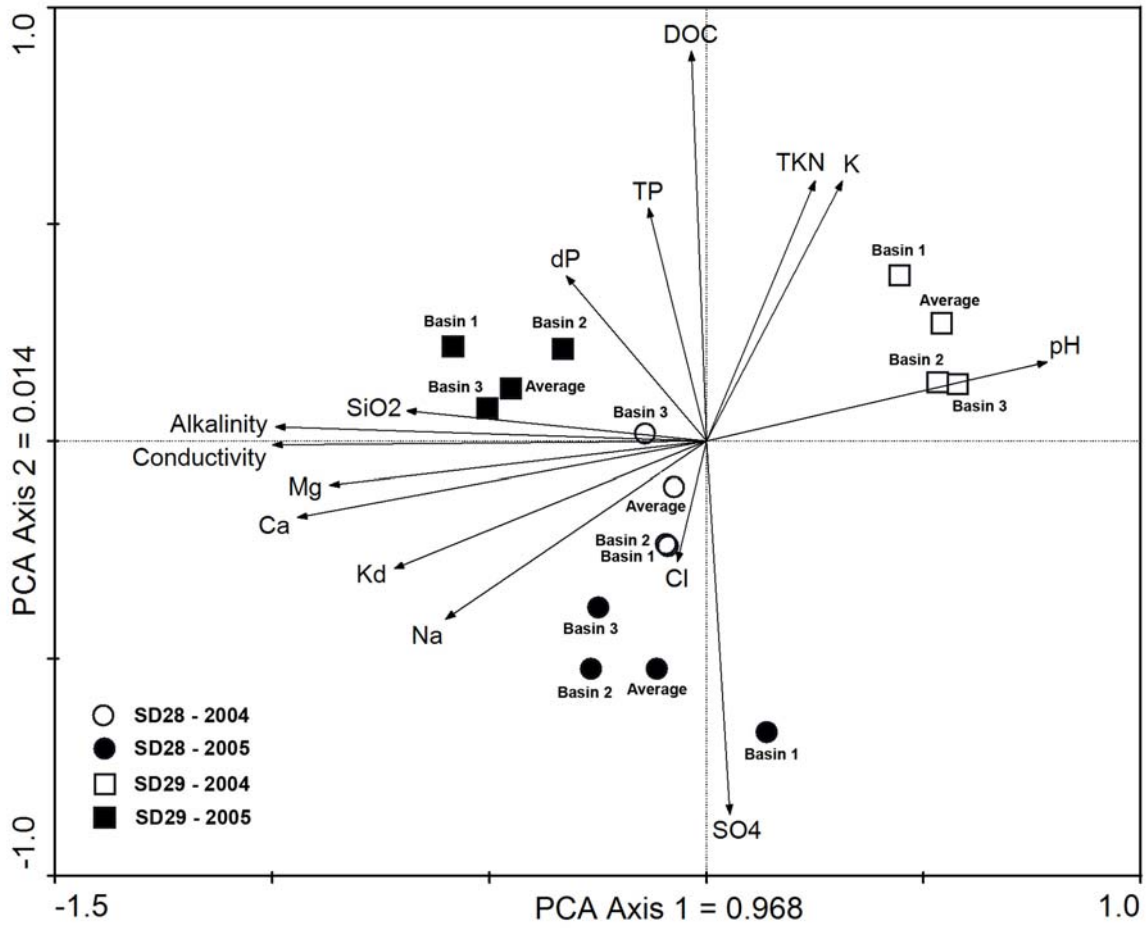

Figure 4.3 Principal components analysis (PCA) ordination diagram illustrating the relative position of samples from basins within lakes SD28 and SD29 in 2004 and 2005 with respect to 15 physical/chemical variables.

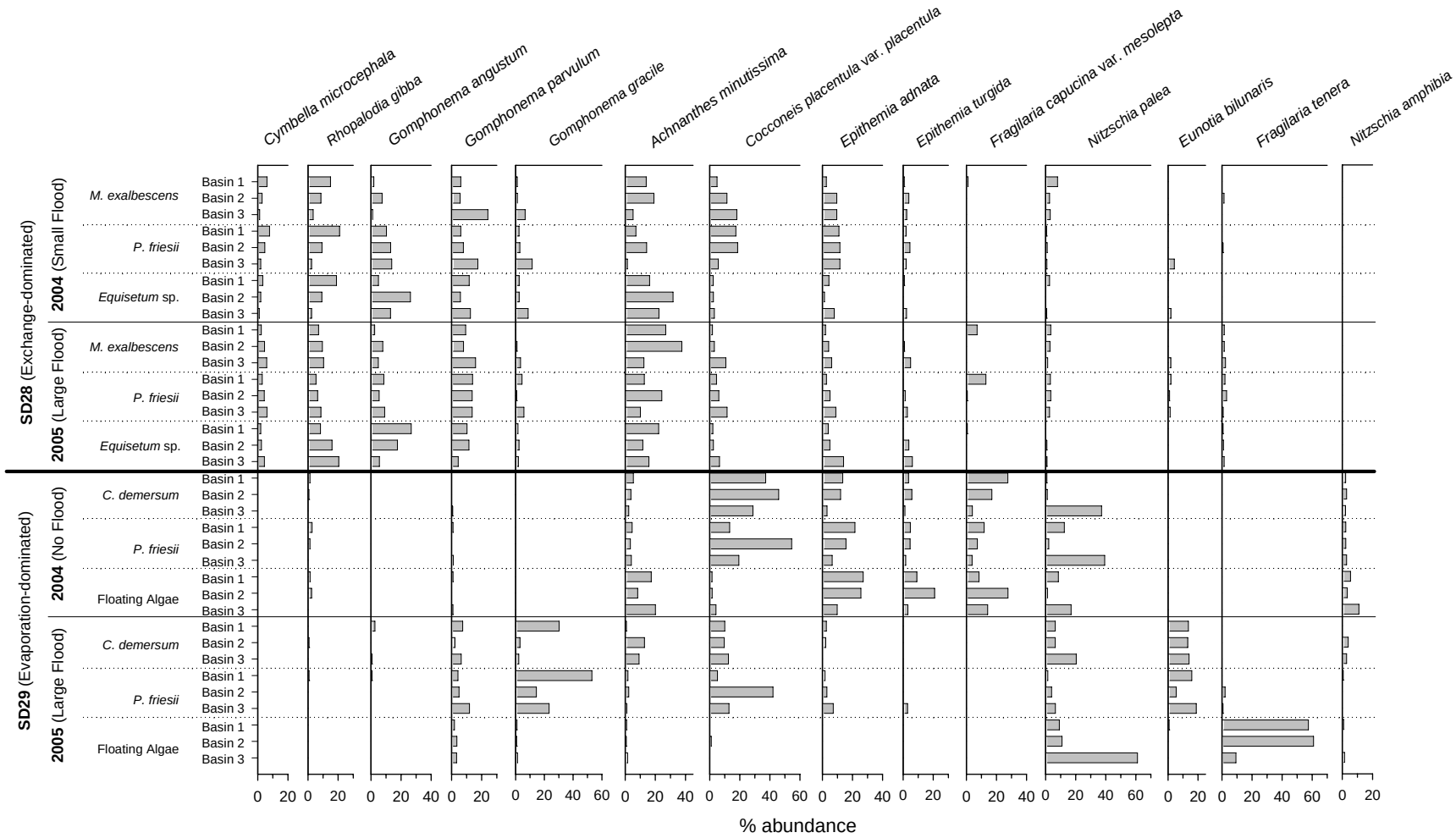

Figure 4.4 Average percent abundance of the most abundant diatom taxa (10% in at least one sample) on 4 specimens of three different macrophyte species at three different sample sites at lakes SD28 and SD29 in the years 2004 and 2005.

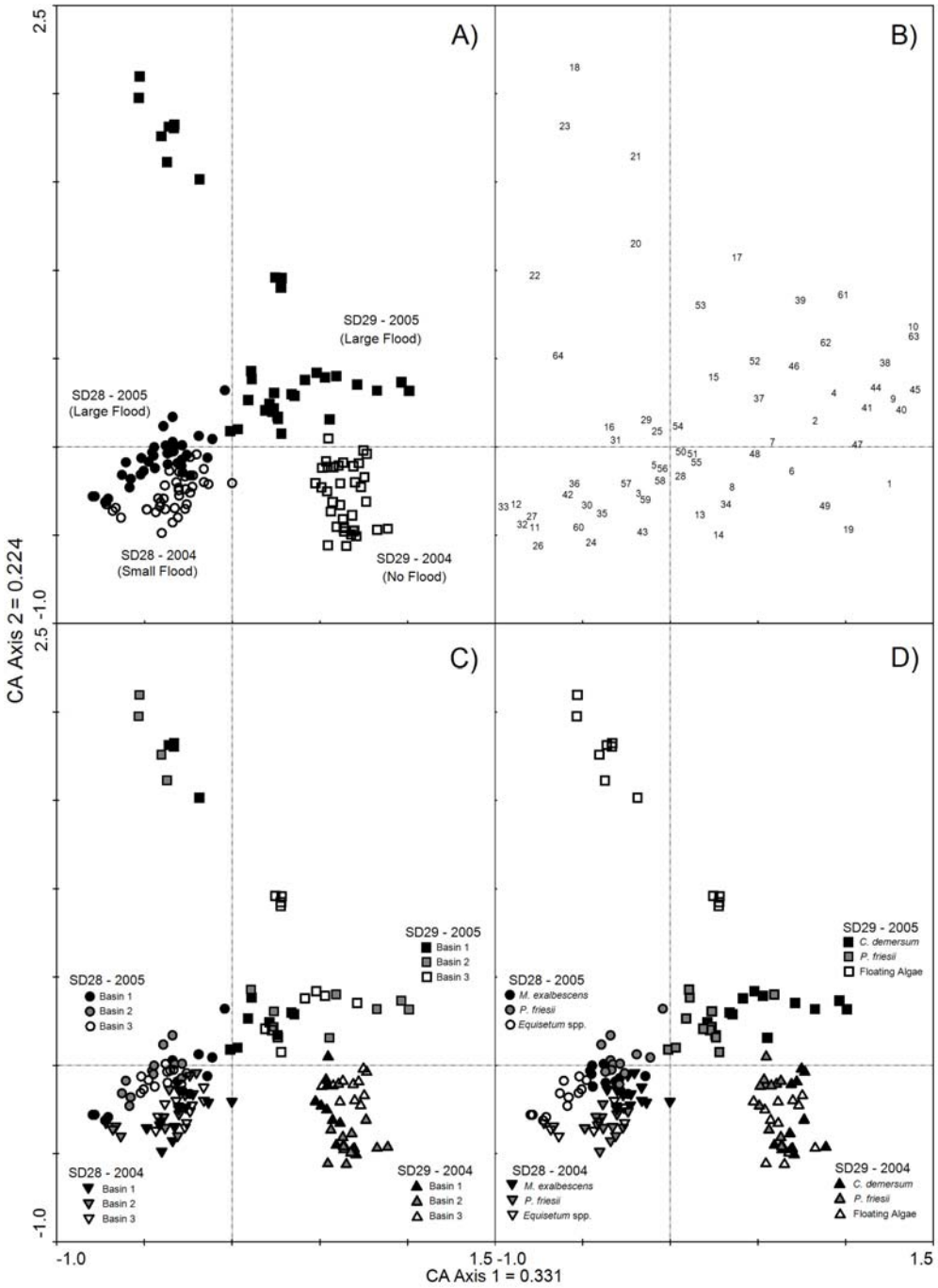

Figure 4.5 Correspondence analysis (CA) of diatom taxa (n = 64) on all macrophyte species sampled from lakes SD28 and SD29 in 2004 and 2005. Panel A compares sample scores (epiphytic diatom community composition) between lakes SD28 and SD29 and years 2004 and 2005. Panel B includes diatom taxa scores (numbers correspond with taxon names provided in Table 2). Panel C codes samples to assess spatial variability among sample sites within each lake. Panel D codes sample scores to allow comparisons among macrophyte-host species.

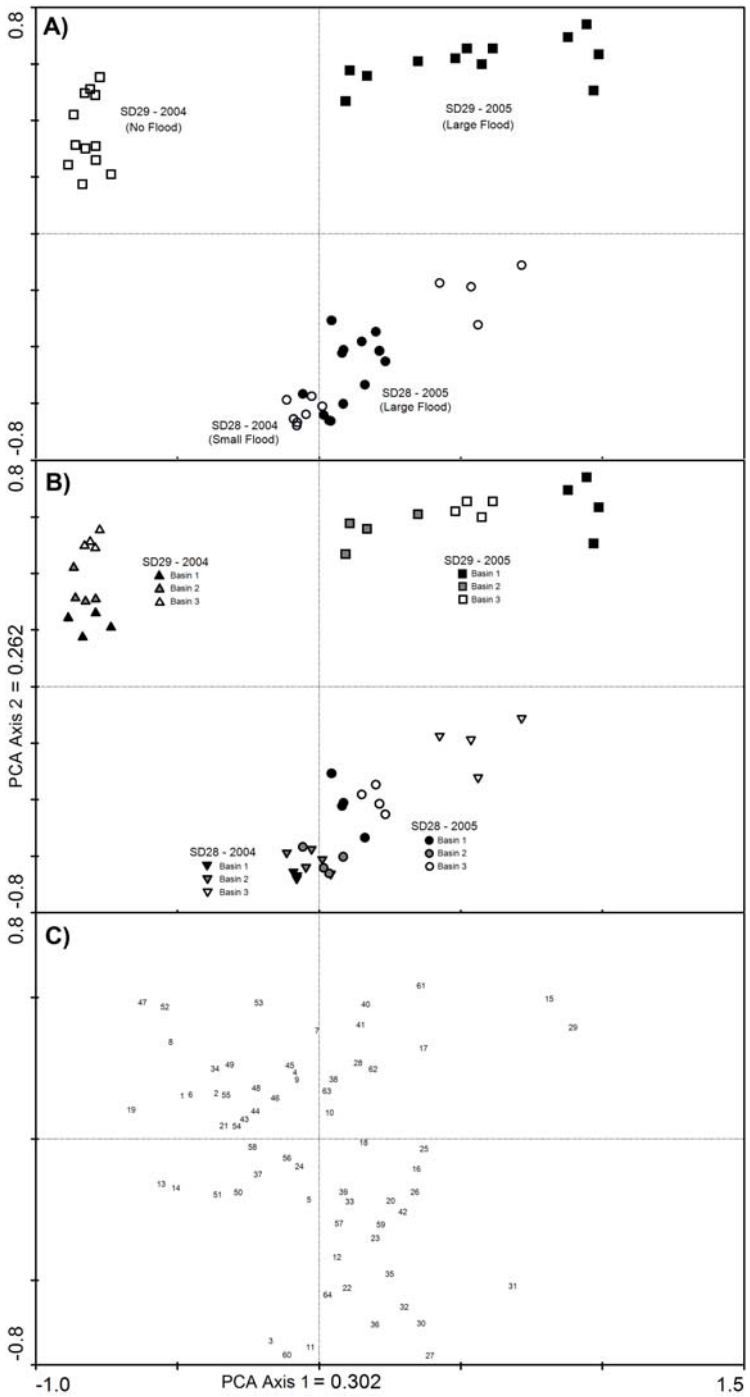

Figure 4.6 Principle components analysis (PCA) of diatom taxa (n = 64) from samples of *Potamogeton friesii* from lakes SD28 and SD29 in 2004 and 2005. Panel A compares sample scores between lakes SD28 and SD29 and years 2004 and 2005. Panel B codes samples to allow comparisons among lake basins. Panel C includes diatom taxon scores (numbers correspond with taxon names provided in Table 2).

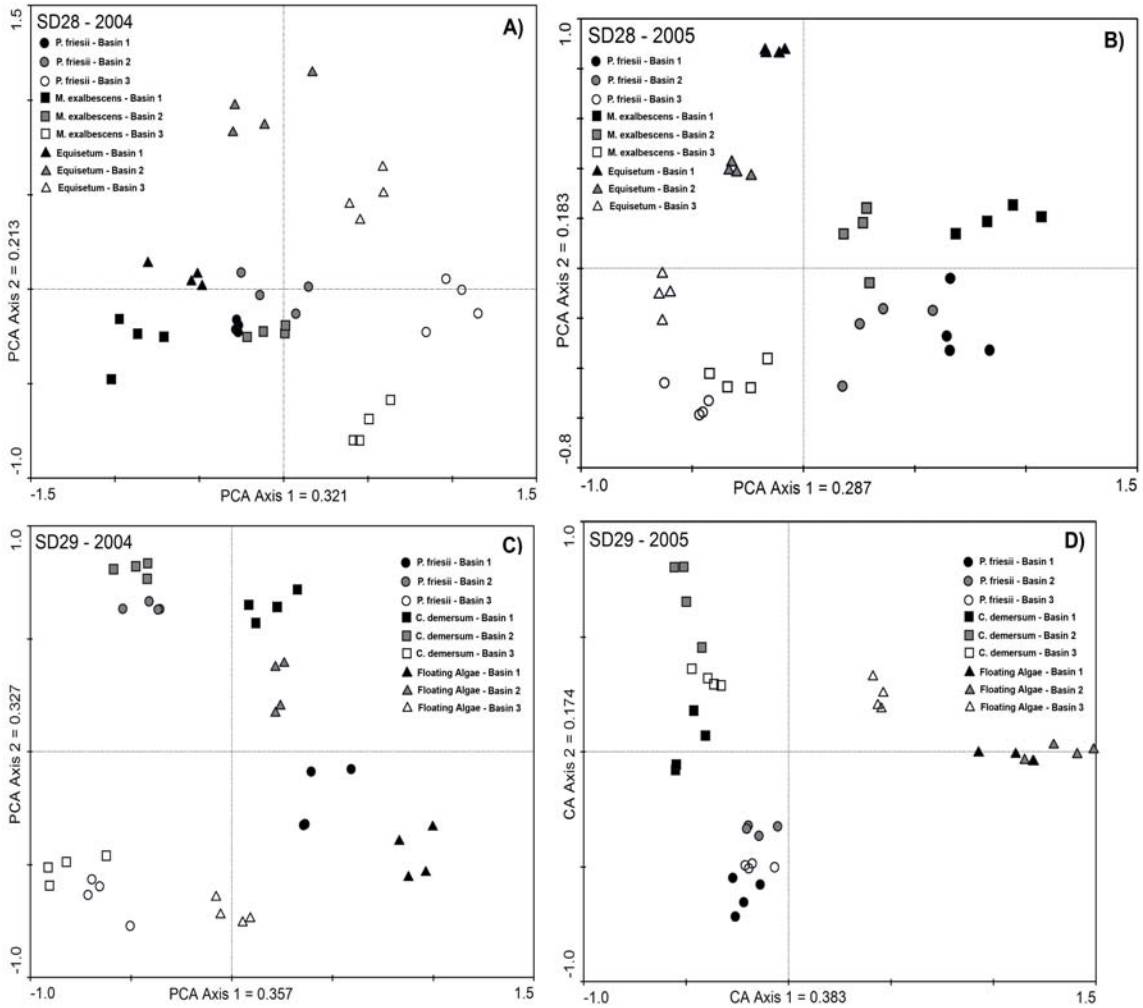

Figure 4.7 Principle components analysis (PCA) and Correspondence analysis (CA) of diatom taxa (n = 64) on all macrophyte species from all basins within lakes SD28 and SD29 in 2004 and 2005 (SD28: *Potamogeton friesii*, *Myriophyllum exalbescens*, *Equisetum* and SD29: *Potamogeton friesii*, *Ceratophylum demersum*, floating filamentous algae). Panel A (PCA) compares sample scores among lake basins and macrophyte species from SD28 in 2004. Panel B (PCA) compares sample scores among lake basins and macrophyte species from SD28 in 2005. Panel C (PCA) compares sample scores among lake basins and macrophyte species from SD29 in 2004. Panel D (CA) compares sample scores among lake basins and macrophyte species.

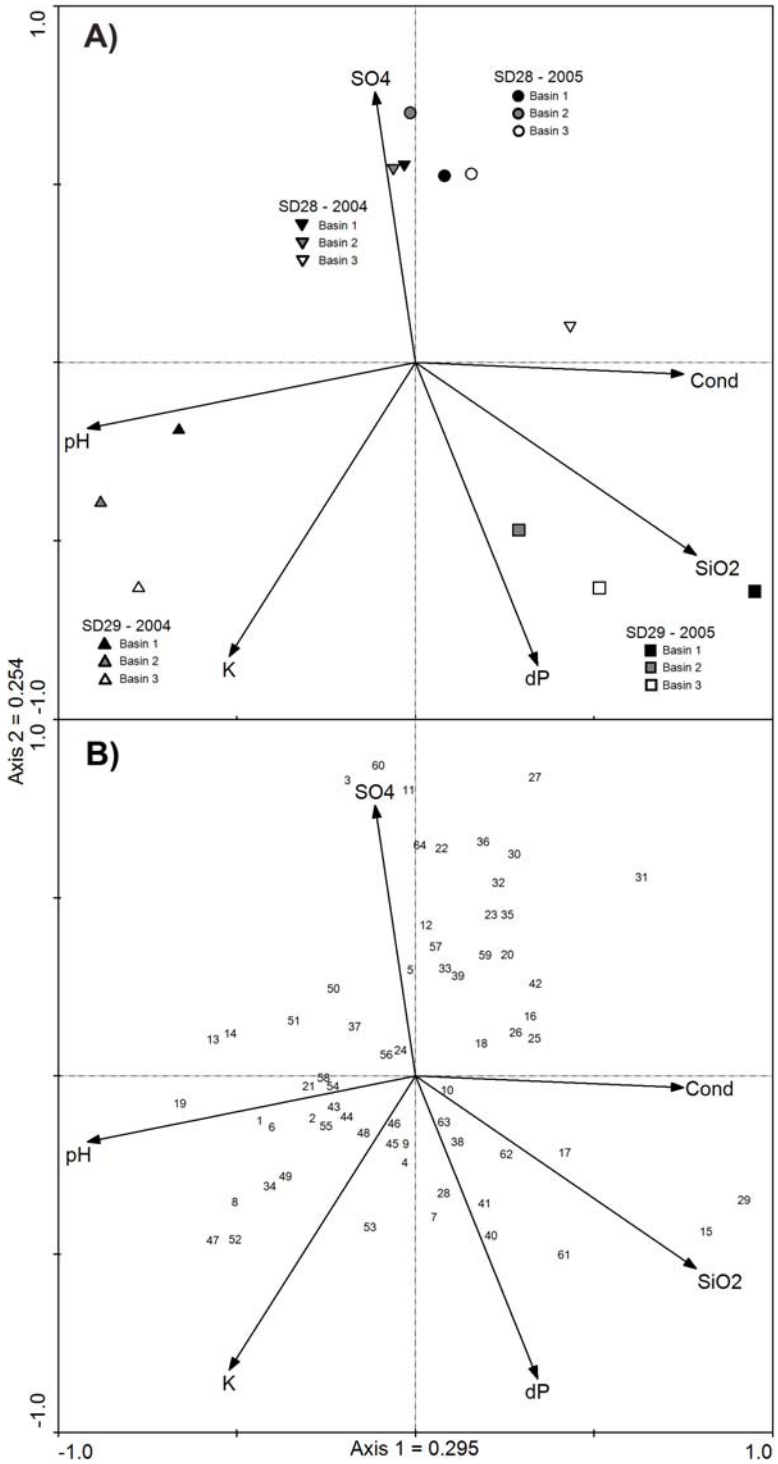

Figure 4.8 Redundancy analysis (RDA) of diatom taxa (n = 64) from samples of *Potamogeton friesii* and forward-selected environmental variables from the three basins at lakes SD28 and SD29 in 2004 and 2005. Sample scores are located in panel A and diatom taxon scores are located in panel B. Numbers correspond with taxon names provided in Table 2.

4.11 Tables

Table 4.1 Values of selected physical and chemical limnological variables obtained from water samples collected from SD28 and SD29 in July 2004 and 2005 at the time of sampling.

		SD28 (2004)				SD28 (2005)			
Variable	**Units**	Basin 1	Basin 2	Basin 3	Average	Basin 1	Basin 2	Basin 3	Average
pH		8.89	8.98	8.40	8.76	8.89	8.90	8.39	8.73
Cond	$\mu S\ cm^{-2}$	313.33	313.00	325.00	317.11	188.00	307.00	362.00	285.67
Alkalinity	$\mu eq\ L^{-1}$	138.00	137.00	162.00	145.67	70.90	134.00	176.00	126.97
Na	$mg\ L^{-1}$	10.80	10.90	11.20	10.97	6.90	10.40	11.60	9.63
K	$mg\ L^{-1}$	4.47	4.62	3.69	4.26	2.60	4.14	4.38	3.71
Mg	$mg\ L^{-1}$	18.40	18.60	20.60	19.20	8.98	15.40	19.10	14.49
Ca	$mg\ L^{-1}$	29.20	29.20	30.70	29.70	19.10	34.60	41.60	31.77
Cl	$mg\ L^{-1}$	5.40	5.10	3.10	4.53	4.17	4.66	4.19	4.34
SO_4	$mg\ L^{-1}$	19.90	19.90	7.90	15.90	16.30	26.66	17.2	20.05
SiO_2	$mg\ L^{-1}$	3.76	3.70	8.01	5.16	4.43	4.52	3.82	4.26
DOC	$mg\ L^{-1}$	24.30	24.30	32.00	26.87	10.90	18.00	21.6	16.83
TKN	$mg\ L^{-1}$	1.00	1.10	1.40	1.17	0.78	0.77	0.95	0.83
TP	$mg\ L^{-1}$	0.03	0.03	0.03	0.03	0.02	0.02	0.03	0.02
dP	$mg\ L^{-1}$	0.01	0.01	0.02	0.01	0.01	0.01	0.02	0.01
K_d (PAR)		2.05	2.18	1.90	2.04	2.23	2.38	2.65	2.42
		SD 29 (2004)				**SD 29 (2005)**			
Variable	**Units**	Basin 1	Basin 2	Basin 3	Average	Basin 1	Basin 2	Basin 3	Average
pH		9.30	10.12	9.80	9.74	7.96	9.16	8.49	8.54
Cond	$\mu S\ cm^{-2}$	247.00	233.00	215.00	231.67	371.00	327.00	363.00	353.67
Alkalinity	$\mu eq\ L^{-1}$	100.00	82.40	95.20	92.53	188.00	163.00	178.00	176.33
Na	$mg\ L^{-1}$	6.00	6.27	7.09	6.45	8.03	8.27	8.39	8.23
K	$mg\ L^{-1}$	10.70	13.20	14.40	12.77	8.96	8.26	8.89	8.70
Mg	$mg\ L^{-1}$	10.80	8.30	9.70	9.60	16.50	16.70	17.20	16.80
Ca	$mg\ L^{-1}$	18.00	16.30	19.70	18.00	47.60	38.80	43.60	43.33
Cl	$mg\ L^{-1}$	3.40	5.30	5.50	4.73	5.23	4.70	5.15	5.03
SO_4	$mg\ L^{-1}$	7.30	11.00	13.70	10.67	6.94	12.30	11.10	10.11
SiO_2	$mg\ L^{-1}$	0.61	1.77	4.90	2.43	13.70	12.80	14.50	13.67
DOC	$mg\ L^{-1}$	42.00	24.00	22.50	29.50	23.40	22.90	23.10	23.13
TKN	$mg\ L^{-1}$	1.10	1.70	1.80	1.53	1.19	1.06	1.29	1.18
TP	$mg\ L^{-1}$	0.08	0.10	0.12	0.10	0.16	0.09	0.12	0.12
dP	$mg\ L^{-1}$	0.03	0.06	0.08	0.06	0.16	0.07	0.09	0.11
K_d (PAR)		1.23	1.80	0.95	1.33	3.49	3.65	2.56	3.23

Table 4.2 Diatom taxa (n = 64) found in ≥3 samples (n = 144) at ≥1% abundance in at least one sample. Taxon numbers correspond to numbers presented in Figures 4.5 and 4.6.

	Taxon Name
1	*Achnanthes conspicua* Mayer
2	*Achnanthes lanceolata* var. *frequentissima* Lange-Bertalot
3	*Achnanthes minutissima* Kützing
4	*Amphora libyca* Ehrenberg
5	*Caloneis bacillum* (Grunow) Cleve
6	*Cocconeis placentula* var. *euglypta* Ehrenberg
7	*Cocconeis placentula* var. *lineata* Ehrenberg
8	*Cocconeis placentula* var. *placentula* Ehrenberg
9	*Craticula halophila* (Grunow) Cleve
10	*Cyclostephanos* PAD sp.2 Hall et al. 2004
11	*Cymbella microcephala* Grunow
12	*Cymbella proxima* Reimer
13	*Epithemia adnata* (Kützing) Brébisson
14	*Epithemia turgida* (Ehrenberg) Kützing
15	*Eunotia bilunaris* (Ehrenberg) Mills
16	*Eunotia minor* (Kützing) Grunow
17	*Fragilaria capucina* var. *capucina* Demazières
18	*Fragilaria capucina* var. *gracilis* (Oestrup) Hustedt
19	*Fragilaria capucina* var. *mesolepta* (Rabenhorst) Rabenhorst
20	*Fragilaria capucina* var. *rumpens* (Kützing) Lange-Bertalot
21	*Fragilaria capucina* var. *vaucheriae* (Kützing) Lange-Bertalot
22	*Fragilaria nanana* Lange-Bertalot
23	*Fragilaria tenera* (W. Smith) Lange-Bertalot
24	*Gyrosigma attenuatum* (Kützing) Rabenhorst
25	*Gomphonema acuminatum* Ehrenberg
26	*Gomphonema angustatum* (Kützing) Rabenhorst
27	*Gomphonema angustum* Agardh
28	*Gomphonema clavatum* Ehrenberg
29	*Gomphonema gracile* Ehrenberg
30	*Gomphonema minutum* (Agardh) Agardh
31	*Gomphonema parvulum* (Kützing) Kützing
32	*Gomphonema pseudotenellum* Lange-Bertalot
33	*Gomphonema subtile* Ehrenberg
34	*Gomphonema truncatum* Ehrenberg
35	*Navicula cryptocephala* Kützing
36	*Navicula cryptotenella* Lange-Bertalot
37	*Navicula libonensis* Schoeman

38	*Navicula minima* Grunow
39	*Navicula minuscula* var. *muralis* (Grunow in Van Heurck) Lange-Beralot in Lange-Bertalot & Rumrich
40	*Navicula menisculus* Schumann
41	*Navicula pupula* Kützing
42	*Navicula radiosa* Kützing
43	*Navicula trivialis* Lange-Bertalot
44	*Navicula seminulum* Grunow
45	*Neidium ampliatum* (Ehrenburg) Krammer
46	*Nitzschia acicularis* (Kützing) W. Smith
47	*Nitzschia amphibia* Grunow
48	*Nitzschia fonticola* Grunow
49	*Nitzschia hungarica* Grunow
50	*Nitzschia liebetruthii* Rabenhorst
51	*Nitzschia linearis* (Agardh) W. Smith
52	*Nitzschia palea* (Kützing) W. Smith
53	*Nitzschia paleacea* Grunow
54	*Nitzschia perminuta* (Grunow) M. Peragallo
55	*Nitzschia radicula* Hustedt
56	*Nitzschia recta* Hantzsch
57	*Nitzschia sigmoidia* (Ehrenburg) W. Smith
58	*Nitzschia sublinearis* Hustedt
59	*Rhoicosphenia abbreviata* (Kützing) Lange-Bertalot
60	*Rhopalodia gibba* (Ehrenberg) O. Möller
61	*Stauroneis phoenicenteron* (Nitzsch) Ehrenburg
62	*Stephanodiscus minutulus* (Kützing) Cleve & Möller
63	*Surirella angusta* Kützing
64	*Synedra ulna* var. *acus* Ehrenberg

Table 4.3 Results from Analysis of Similarities (ANOSIM) tests on percent abundance data of epiphytic diatoms collected from different macrophytes in two lakes (SD28, SD29) of the Slave River Delta, NWT. Values presented are the Global R (and associated *p*-values and degrees of freedom) for comparisons of epiphytic diatom community composition among samples collected in the two lakes in two years (2004 and 2005) of differing flood magnitude and spatial extent.

Epiphytic diatom community composition - differences between lakes on *P. friesii*

Dataset - diatom epiphytes on:	**SD28 versus SD29 – 2004 and 2005**	
P. friesii	0.814 ($p < 0.001$, d.f = 47)	
	SD28 versus SD29 – 2004	**SD28 versus SD29 – 2005**
P. friesii	0.996 ($p < 0.001$, d.f. = 23)	0.962 ($p < 0.001$, d.f. = 23)

Epiphytic diatom community composition - differences between years on *P. friesii*

Dataset - diatom epiphytes on:	**SD28 – 2004 versus 2005**	**SD29 – 2004 versus 2005**
P. friesii	0.644 ($p < 0.001$, d.f. = 23)	0.982 ($p < 0.001$, d.f. = 23)

Epiphytic diatom community composition - differences between years on other macrophyte species

Dataset - diatom epiphytes on:	**SD28 – 2004 versus 2005**	**SD29 – 2004 versus 2005**
M. exalbescens (SD28)/ *C. demersum* (SD29)	0.422 ($p < 0.001$, d.f. = 23)	0.992 ($p < 0.001$, d.f. = 23)
Equisetum (SD28)/ Floating Algae (SD29)	0.568 ($p < 0.001$, d.f. = 23)	1.000 ($p < 0.001$, d.f. = 23)

Differences in spatial variability of diatom epiphytic community composition among basins

Dataset - diatom epiphytes on:	**SD28 – 2004**	**SD28 – 2005**
P. friesii from all basins	0.940 ($p < 0.001$, d.f. = 11)	0.965 ($p < 0.001$, d.f. = 11)
M. exalbescens from all basins	0.993 ($p < 0.001$, d.f. = 11)	0.994 ($p < 0.001$, d.f. = 11)
Equisetum from all basins	1.000 ($p < 0.001$, d.f. = 11)	0.999 ($p < 0.001$, d.f. = 11)
	SD29 – 2004	**SD29 – 2005**
P. friesii from all basins	1.000 ($p < 0.001$, d.f. = 11)	0.944 ($p < 0.001$, d.f. = 11)
C. demersum from all basins	0.850 ($p < 0.001$, d.f. = 11)	0.961 ($p < 0.001$, d.f. = 11)
Floating algae from all basins	0.995 ($p < 0.001$, d.f. = 11)	1.000 ($p < 0.001$, d.f. = 11)

Differences in epiphytic diatom community composition among macrophyte host species

Dataset - diatom epiphytes on:	**SD28 – 2004**	**SD28 – 2005**
All macrophytes from Basin 1	0.914 ($p < 0.001$, d.f. = 11)	1.000 ($p < 0.001$, d.f. = 11)
All macrophytes from Basin 2	0.905 ($p < 0.001$, d.f. = 11)	0.986 ($p < 0.001$, d.f. = 11)
All macrophytes from Basin 3	0.975 ($p < 0.001$, d.f. = 11)	0.981 ($p < 0.001$, d.f. = 11)
	SD29 – 2004	**SD29 – 2005**
All macrophytes from Basin 1	0.979 ($p < 0.001$, d.f. = 11)	0.984 ($p < 0.001$, d.f. = 11)
All macrophytes from Basin 2	0.892 ($p < 0.001$, d.f. = 11)	0.993 ($p < 0.001$, d.f. = 11)
All macrophytes from Basin 3	0.896 ($p < 0.001$, d.f. = 11)	1.000 ($p < 0.001$, d.f. = 11)

Chapter 5
An assessment of sedimentary diatom assemblages for paleohydrological reconstructions in a complex floodplain environment

5.1 Abstract

Sediment cores were collected from a lake in each of the three hydrological lake categories (flood-, exchange- and evaporation-dominated) that exist in the Slave River Delta, NWT, to evaluate the ability of diatom assemblages to accurately classify the hydrological state of a lake and to assess temporal variability of hydroecological conditions within individual lakes in a complex deltaic environment. Results indicate that diatoms provide sensitive records of environmental change and important information on past changes in hydrological conditions such as river flooding. The composition and temporal variation of diatom assemblages differed among lakes of different hydrological categories in consistent and predictable ways. The flood-dominated lake (SD2) provided a high resolution record of hydroecological variability and changes in flood-frequency over time. Sedimentary diatom assemblages repeatedly shifted in dominance from taxa indicative of low river influence to taxa indicative of high river influence, consistent with evidence from other paleolimnological proxies (stable isotopes, plant macrofossils) and a 46-year long record of spring discharge on the Slave River. Sedimentary diatom assemblages from the exchange-dominated lake (SD28) were dominated by taxa indicative of high river influence and were relatively static during the past ~100 years, but the total sum of planktonic diatoms (% abundance) can provide robust records of large, spatially extensive flood events in the Slave River Delta. Sedimentary diatom records from both the flood- and exchange-dominated lakes show marked correspondence with gauged Slave River peak

discharge levels over the past 46 years indicating an ability of diatoms to track periods of higher and lower flood frequency and high magnitude flood events. Sedimentary diatom assemblages from the evaporation-dominated lake (SD20) in this study were poorly preserved below 6 cm depth, but assemblages from above 6 cm had distinct community composition similar to assemblages in surface sediments of evaporation-dominated lakes of the Slave River Delta. These diatoms correctly identify this lake as having evaporation-dominated hydrology. Overall, the sediment records provide no evidence for reduced flood frequency or a decrease in high-magnitude flood events to indicate that upstream river regulation or another driver of change may be causing perceived changes of lower flood frequency and low water levels throughout the delta.

5.2 Introduction

The Slave River Delta, Northwest Territories (Figure 5.1) is a floodplain landscape that consists of hundreds of wetlands and lakes with variable hydrological connectivity and flood susceptibility and possesses a wide range of hydrological lake settings. These productive aquatic basins provide extensive shoreline habitat and support highly diverse populations of migratory waterfowl, fish, mammals and vegetation communities (English et al. 1997). The ecological resources of the delta are also of central importance to the livelihood and socio-cultural integrity of the residents of the nearby town of Fort Resolution, NWT (Wolfe et al. 2007). There is a perception among local residents and land users that flood frequency has declined and water levels have dropped throughout much of the delta in recent decades (Wesche 2007). There is also increasing concern over the effects of climate change, consumptive use of river water (e.g. Alberta Oil Sands industry), and upstream regulation of the Peace River on the hydroecological conditions of the Slave River Delta (Prowse and Conly 2001; Schindler and Smol 2006). Natural processes can also play a role in shaping this deltaic landscape, as geomorphological changes (e.g. levee formation and channel avulsion) have been documented in the Slave River Delta during the past

~60 years (English et al. 1997), but have been attributed to natural deltaic processes (Gardner et al. 2006).

Since deltas are extremely dynamic systems that are often affected by multiple stressors, it is important to distinguish changes due to natural variability from those induced by anthropogenic changes. In the absence of long-term monitoring data and direct records of environmental change, we must often rely on paleoecological proxy-data to quantify past variability within these ecosystems. As a result of the dynamic nature of deltaic sediments, interpretation of paleolimnological records can be challenging (e.g. Michelutti et al. 2001), but a variety of successful studies have provided long-term records of environmental change (Espinosa 1994; Zalat and Servant Vildary 2007) and important information about past flood events and the dynamic hydroecological responses to such events in deltaic environments (Hay et al. 1997, 2000; Hall et al. 2004; Wolfe et al. 2005, 2006). In complex depositional environments such as the Slave River Delta, a multi-proxy paleolimnological approach can provide key insights into hydroecological dynamics of this ecologically sensitive northern delta. Paleolimnological proxy analyses (plant macrofossils and isotopes) have provided varying degrees of sensitivity to assessments of hydroecological change in the Slave River Delta (Adam 2007; Mongeon 2007), and the use of sedimentary diatom assemblages may also provide important information on past hydroecological conditions in the delta.

Contemporary regional studies of 41 lakes in the Slave River Delta in Chapter 2 have identified distinct relationships between hydrological and limnological conditions of delta lakes. Lakes with evaporation-dominated hydrology are removed from the influence of Slave River flooding and their water balance is influenced mainly by precipitation and evaporation (Brock et al. 2007). Correspondingly, in Chapter 2 we found that the limnological conditions of these lakes are characterized by high alkalinity and high concentrations of nutrients and ions as a result of

evaporative enrichment. In contrast, flood-dominated lakes commonly receive a pulse of turbid floodwater from the Slave River during the spring thaw, and have low alkalinity and low concentrations of most nutrients and ions. Exchange-dominated lakes are variably influenced by floodwaters from the Slave River and seiche events from Great Slave Lake and are characterized by a broad array of limnological conditions depending on the strength of the connection to these other surface waters.

In Chapter 2, we also analyzed surface sediment samples from these lakes and found that surface sediment diatom assemblages in most Slave River Delta lakes are dominated by epiphytic taxa, reflecting the large habitat space (macrophyte surface area) available in these shallow delta lakes that support prolific macrophyte growth. Many of these epiphytic diatom taxa are distributed broadly among lakes of more than one hydrological category and, as a result, these taxa are likely unable to distinguish past hydroecological changes in paleoecological studies in the Slave River Delta. Importantly, however, they identified specific 'indicator' taxa that can discriminate among the three hydrological lake categories and distinguish periods of high and low river influence. Two common epiphytic diatoms (*Navicula minima* Grunow and *Nitzschia amphibia* Grunow) are associated with evaporation-dominated lakes, and are rare in surficial sediments of flood- or exchange-dominated lakes. Thus, they appear to be useful indicators of low river influence. Diatoms indicative of flood- and exchange-dominated lakes (high river influence) span a much wider range of habitat types including epiphytic, planktonic, tychoplanktonic and motile benthic taxa. Planktonic 'indicator' taxa (*Cyclostephanos* cf. *tholiformis* Stoermer, Håkansson & Theriot, *Stephanodiscus minutulus* (Kützing) Cleve & Möller and *Cyclostephanos* PAD sp.2 Hall et al. 2004) are not found in evaporation-dominated lakes and are important indicators of connectivity to rivers and Great Slave Lake. In fact, we found that in the absence of flooding, there is a complete lack of planktonic diatoms in the water column, while

lakes that flood in the spring contain similar planktonic diatom communities to those occurring in the rivers that flood them (Chapter 3). Thus, occurrence of these taxa in lake sediment profiles appears to provide sensitive indicators for identifying past flood events and assessing changes in flood frequency in paleolimnological studies.

Although diatom assemblages found in lakes across wide hydroecological gradients in the Slave River Delta can discriminate among hydrological lake categories in a modern setting, it remains uncertain as to whether they can track these changes over time and accurately assess shifts in hydrological conditions within a lake. Here, we use paleolimnological techniques to evaluate the ability of diatom assemblages to consistently detect differences in the hydrological state between lakes, as well as to detect changes in hydroecological conditions over time within individual lakes in a complex deltaic environment. We collected sediment cores from a lake in each of the three hydrological lake categories in the Slave River Delta (flood-, exchange- and evaporation-dominated). Lake SD2 (flood-dominated) has shown variable flooding from 2003-2005, and was chosen to assess if diatom assemblages track changes of flood frequency over time. Lake SD28 (exchange-dominated) is a flood-prone lake that has flooded every year since 2003 and even when spring floods are unusually small (2004), and was chosen to assess if diatoms consistently characterize the lake as river-influenced. Lake SD20 (evaporation-dominated), which has few routes for flood waters to enter the lake (far removed from the rivers) and did not flood in any years when we have studied the system (2002-2005; even in 2005 when large spatially extensive flooding occurred), was chosen to assess past hydroecological variability in the delta in the absence of flooding. This study is part of a large multidisciplinary research project in the Slave River Delta which aims to address concerns about the impacts of natural and anthropogenic variations in climate and river discharge on the hydrology and hydroecology of this northern ecosystem (Wolfe et al. 2007).

5.3 Study area and site descriptions

The Slave River Delta is located at the mouth of the Slave River in the Northwest Territories (61°15' N; 113°30' W) where it enters Great Slave Lake (Figure 5.1). The entire delta covers an area of 8,300 km^2 beginning at the Slave River Rapids at Fort Smith, NWT, but most of it is no longer active (Vanderburgh and Smith 1988). The active part of the delta is arcuate, spans an area approximately 400 km^2, and is prograding into Great Slave Lake through a system of active distributaries (Prowse et al. 2002). The delta consists of a large wetland complex with numerous river channels, marshes, fens, bogs, swamps and forests. Scattered throughout this landscape are a multitude of small, shallow (<5 m) water bodies (hereafter referred to collectively as lakes) that span broad hydrological gradients and support extensive macrophyte growth.

Lake SD2 (unofficial name; 61°16' N; 113°34' W) is a small (~1.2 km^2), shallow (~1.5 m maximum water depth), flood-dominated basin located beside Resdelta Channel (natural levee height = ~1.5 m) at the margin of the active outer delta and the older inactive portion of the delta where the Slave River bifurcates into numerous distributary channels (Figure 5.1). There are no active inflow or outflow channels, and flooding can be variable (flooded in 2003 and 2005, no flooding in 2004; Chapter 3). The lake is surrounded by dense willow stands and highly productive conditions have been observed, characterized by extensive emergent (*Equisetum* spp., *Typha* spp. and *Carex* spp.) and submergent (dominated by *Potamogeton* spp. and *Myriophyllum exalbescens* Fernald) macrophyte communities.

Adam (2007) conducted high-resolution paleolimnological analyses (plant macrofossils) from lake SD2 and provided a comprehensive 90-year record of hydroecological variability. Adam (2007) found decadal-scale oscillations in Slave River influence on the active delta, with periods of high frequency, variable intensity flooding as well as at least three multi-year intervals of low-river influence. Beginning in ~1943, an 18-year period of particularly low river influence

is reflected by low C/N ratios, low mineral matter and high $\delta^{15}N$ values. Plant macrofossil remains revealed a distinct response of the vegetation at SD2 to this period of low river influence. The presence of a unique macrofossil assemblage, dominated by *Saggittaria cuneata* Sheldon, suggests greatly reduced water levels at SD2 between 1943 and 1961, likely in response to evaporative draw-down associated with many consecutive years of low Slave River influence.

Lake SD28 (unofficial name; 61°14' N; 113°23' W) is a small (~1.9 km^2), exchange-dominated basin with maximum water depth of ~4.0 m and is located within the more elevated area of the Slave River floodplain upstream of the active delta (Figure 5.1). Based on monitoring from 2003-2005, lake SD28 frequently floods when Slave River water enters the lake during high river levels via a single narrow channel. During the ice-free season, this connection can serve as an inlet or outlet depending on relative levels of the river and lake. The basin is surrounded by the emergent macrophytes *Equisetum* spp. and *Carex* spp., and the lake bottom is covered by dense stands of various *Potamogeton* species, while shallow areas have dense growth of the floating-leaved macrophyte *Nuphar variegatum* Engelman.

Multi-proxy paleohydrological analyses by Mongeon (2007) indicated that ^{210}Pb values are the best indicator of flood influence in the basin, as geochemical records show very little variation as a result of annual floodwater inputs diluting the signals. Overall, the $\delta^{18}O_{lw}$ record from aquatic plant cellulose indicates that the water balance of SD28 has shifted from a positive water balance (I>E) to a more positive water balance (I>>E) during the last ~30 years. The SD28 sediment record of nitrogen isotope values show more variability from the top to the bottom of the core in comparison to organic content, bulk organic carbon and nitrogen (C and N) content, carbon and nitrogen ratios, and organic carbon isotope records, which show very little variability between 1901 to 1973, and then become slightly more variable from 1974 to 2002.

Lake SD20 (unofficial name; 61°18' N; 113°19' W) is a small (~2.4 km^2), shallow (~1.5 m maximum water depth), evaporation-dominated basin located upstream of the outer delta in an older relict floodplain. There are no active inflow or outflow channels, and the lake did not flood during a three-year monitoring period. The basin is surrounded by a thin band of *Salix* spp., *Typha* spp. and *Carex* spp. marsh, with a much larger wetland to the south and mature spruce forest on higher elevations.

Mongeon (2007) conducted multi-proxy paleohydrological analyses from Lake SD20 and concluded that hydrological conditions have varied over the last ~230 years in the absence of river flooding. Multi-decadal dry and wet periods follow the same general trend as a perched basin (Spruce Island Lake) in the Peace-Athabasca Delta whose water balance is regulated mainly by local climatic conditions, indicating that information preserved in the sediments from lake SD20 represent a regional climate signal (Wolfe et al. 2005). Similar climatic regimes have influenced the water balance of upland basins in both the Slave River Delta and Peace-Athabasca Delta over the last 300 years, as the paleohydrological trends from these two basins closely align with paleoclimate records reconstructed from tree-ring sequences upstream near the headwaters of the Athabasca River (Hall et al. 2004).

5.4 Materials and methods

5.4.1 Sample collection and laboratory analyses

Sediment cores (27.5 cm and 33.0 cm in length) were collected near the center of lakes SD20 and SD28, respectively, in September 2002. A 49.5 cm sediment core was collected from the northwest region of SD2 in July 2004. This site is distal to the known point of entry of flood waters, and was chosen to maximize the length of time captured. All sediment cores were collected using a Glew gravity corer (Glew 1989), transported by boat (SD2) and helicopter

(SD28) and sectioned into 0.5 cm intervals (Glew 1988) at the field base in Fort Resolution. All samples were stored at 4ºC prior to analyses.

Microscope slides for diatom analysis were prepared from wet sediment samples by acid digestion following standard methods (Hall and Smol 1996). All consecutive samples were analyzed to determine diatom percent abundance of the total sum of diatom valves. For each sample, at least 400 diatom valves were identified and enumerated along transects using a Zeiss Axioskop II_{Plus} compound microscope with differential interference contrast optics (1000X magnification, numerical aperture = 1.30). Diatom taxonomy followed Krammer and Lange-Bertalot (1986-1991).

5.4.2 Core chronologies

Sediments were analyzed for radioactive isotopes (^{210}Pb and ^{137}Cs) using an Ortec GWL Series HPGe coaxial well gamma spectroscopy system maintained at the WATER Lab, University of Waterloo, Waterloo ON, Canada. One to 2 g samples of dry sediment were analyzed from every 0.5 cm sediment interval. Chronologies were developed by Adam (2007; SD2), and Mongeon (2007; SD20 and SD28) based on the ^{210}Pb activity profile using the Constant Rate of Supply (CRS) model, which assumes a constant flux of ^{210}Pb supply to the sediment and allows for changing sedimentation rates (Oldfield and Appleby 1984).

5.4.3 Numerical methods

In Chapter 2, we used direct gradient ordination by RDA to identify relationships between the surface sediment diatom assemblages and the limnological gradients among 41 lakes in the Slave River Delta. We performed RDA using the same methods and data as in Chapter 2 but with diatom assemblages in the sediment samples of cores from SD2, SD20 and SD28 also added as passive samples, as a method to help determine past changes in hydrologic connectivity in

relation to hydrological lake categories. Briefly, RDA was performed on the 41-lake data set using forward selection (and Monte Carlo tests with 999 permutations) to identify a subset of environmental variables that explained significant ($p \leq 0.05$) and independent amounts of variation in the diatom data. Sample scores for the surface sediment diatom assemblages in the 41 lakes of the spatial survey in Chapter 2 were coded *a priori* in the ordination diagrams according to the three hydrological lake categories (flood-, exchange- and evaporation-dominated) to visualize variation in limnological conditions and diatom assemblage composition among the categories. All ordinations were performed using CANOCO version 4.5 (ter Braak and Šmilauer 2002).

In Chapter 2, we used Similarity Percentage tests (SIMPER; Clarke and Warwick 2006) to identify specific diatom taxa that accounted for the greatest observed differences between hydrological categories (flood-, exchange- and evaporation-dominated). Taxa contributing >2% of the average Bray-Curtis similarity within a hydrological category were considered 'indicator' taxa that are most representative of that hydrological category. Using methods from Chapter 2, we group diatom taxa according to relative river influence. The 'low river influence' category is the sum of the diatom taxa that were identified as indicators of evaporation-dominated lakes, and the 'high river influence' category is the sum of the diatom taxa that were identified as indicators of flood- and exchange-dominated lakes.

5.5 Results

5.5.1 Core chronologies

Dating by ^{210}Pb and ^{137}Cs identified that the cores from SD2 (basal date is ~AD1914), SD28 (~AD1903) and SD20 (~AD1771) encompass ~90, ~100, and ~231 years, respectively (Appendix C). Results for core chronologies are briefly summarized below.

The chronology of the SD2 core was developed using the CRS model, which assumes a constant rate of supply of unsupported ^{210}Pb to the sediment, and constraining this model to the 1963 ^{137}Cs peak (Adam 2007). The CRS model was used because the propensity for flooding at SD2 and evidence of flood deposits in the sediments suggests that the sedimentation rates are likely to be highly variable. Fluctuations in the total ^{210}Pb activity likely reflect dilution by rapid sedimentation during flood events. To circumvent the limitations of an atypical ^{210}Pb decay curve, the definitive 1963 peak in ^{137}Cs activity was used to constrain the CRS modeled age-depth profile. Unsupported ^{210}Pb does not reach background values (defined by ^{214}Bi), however in keeping with the standard shape of the exponential curve, it is likely that unsupported ^{210}Pb reached background shortly after 36.75cm. In the approach towards establishing a chronology, ^{210}Pb dates were determined down-core to 36.75 cm, providing a date of 1935 at this horizon. However, to account for the missing unsupported ^{210}Pb inventory below 36.75cm, calculation of the inventory (by extrapolation based on the regression line of CRS ^{210}Pb dates and cumulative dry mass) continued down core until the age-depth curve passed through the 1963 ^{137}Cs peak.

The SD28 chronology was developed using the CRS model (Mongeon 2007). The linear ^{210}Pb model cannot be applied to this basin as variable flooding at this basin will result in variable sedimentation rates. Analysis of the ^{210}Pb profile for the sediment core from SD28 revealed that background levels of ^{210}Pb were not reached and measured ^{210}Pb values do not follow the typical exponential decay curve. CRS dates were interpolated using modeled ^{210}Pb CRS dates from 0-29.25 cm, resulting in a date of 1917 at the 29.25 cm interval. CRS dates from the basal portion of the core (29.75-33.0 cm) were extrapolated using the average sedimentation rate of 0.231 (g/cm^2/year), which was calculated by taking the average sedimentation rate from the sediment intervals 24.75to 28.75 cm.

The chronology of the SD20 core was developed using the CRS model (Mongeon 2007). Total ^{210}Pb activity for this core generally declines exponentially with depth and reaches supported ^{210}Pb levels at approximately 15.25 cm, resulting in a CRS modeled ^{210}Pb date of 1907. Measured total ^{210}Pb activity from 15.75 cm down-core does not follow the exponential decay curve. Dates for 15.75 cm and to the bottom of the sediment core were extrapolated using an average sedimentation rate calculation, which was based on the average sedimentation rate of 0.052 g/cm^2/year calculated from sediment increments 14.75 cm (0.059 g/cm^2/yr) and 15.25 cm (0.045 g/cm^2/yr), resulting in a basal date of 1771 for the bottom of the sediment core.

5.5.2 Sedimentary diatom assemblages

A total of 140, 188 and 94 diatom taxa were identified in sediments from SD2, SD28 and SD20, respectively. Of these, 12, 12 and 9 taxa were common in the assemblages from SD2 (Figure 5.2), SD28 (Figure 5.3) and SD20 (Figure 5.4), respectively, with relative abundances greater than 5% in at least one sample. The common taxa are mostly epiphytic forms (e.g. *Achnanthes minutissima* Kützing, *Achnanthes lanceolata* var. *frequentissima* Lange-Bertalot, *Cocconeis placentula* var. *placentula* Ehrenberg, *Fragilaria capucina* var. *mesolepta* (Rabenhorst) Rabenhorst, *Navicula libonensis* Schoeman) plus the large, benthic *Rhopalodia gibba* (Ehrenberg) O. Müller, and were well represented in the surficial sediments of 41 shallow lakes of the Slave River Delta (Chapter 2). Planktonic taxa, indicative of river flooding (Chapter 3), were found in the two river-influenced lakes (SD2 and SD28), but not in the evaporation-dominated lake (SD20). The predominance of epiphytic and benthic taxa in the sedimentary diatom assemblages suggests that all three lakes have been shallow and have supported extensive macrophyte communities during the periods represented by the cores.

The sediment cores from all three lakes have distinctive composition of sedimentary diatom assemblages and distinctive patterns of temporal variability of assemblages that are consistent

with contrasting hydrological settings of the lakes today (Figures 5.2, 5.3 and 5.4). The sediment record from lake SD2 (flood-dominated) contains highly variable diatom assemblages during the past ~90 years, with alternating dominance of assemblages by taxa indicative of low river influence and those indicative of high river influence (Figure 5.2). Shifts in sedimentary diatom assemblages throughout the length of the core from SD2 are consistent with fluctuations in the frequency and intensity of spring flood events that alter inputs of nutrients and ions, light environment and aquatic plant communities. Diatom assemblages in the basal portion of the core (~1914-1925) imply that flood frequency was low, based on the highest relative abundance of taxa indicative of low river influence, notably *Nitzschia amphibia* Grunow and two common epiphytes *Navicula pupula* Kützing and *Achanthes lanceolata* var. *frequentissima*. Following this period, taxa indicative of high river influence increased considerably between ~1926 and 1947, particularly *Navicula libonensis*. The abundance of planktonic diatoms also increased during this time period, consistent with increased frequency of river flooding (Chapter 3). Low river connectivity and low flood-frequency occurred between ~1948 and 1962, based on a rapid decline in taxa indicative of high river influence (from more than 20% to less than 5% abundance) and planktonic taxa, along with an increase in taxa indicative of low river influence and a peak in *Achnanthes minutissima* (27% abundance). Although *A. minutissima* was not found to be an indicator of low river influence in Chapter 2, it is a very common epiphyte throughout the Slave River Delta and can often be the dominant taxon growing on a variety of macrophytes in evaporation-dominated lakes (Chapter 3). Between ~1963 and 1979, flooding frequency increased, as implied by a steady rise in relative abundance of taxa indicative of high river influence. Relative abundance of these taxa peaked in the mid-1970s (30% abundance). The diatom assemblages in the uppermost sediments in the core (~1980-2004) suggest moderate flood activity, as indicated by increased but relatively stable composition of taxa indicative of high river

influence. The only exception is the upper-most sediment sample, which has high abundance of *Achnanthes minutissima*, *A. lanceolata* var *frequentissima* and other taxa indicative of low river influence, corresponding with the absence of flooding at SD2 in 2004 when the core was collected.

Lake SD28 (exchange-dominated) has a direct channel connection to the Slave River and is one of the most flood-prone lakes in the Slave River Delta (Brock et al. 2007). SD28 flooded each year during three years (2003-2005) of monitoring, even in 2004 when the majority of delta lakes did not flood. High susceptibility to flooding is reflected in the sedimentary diatom assemblages during the past ~100 years (Figure 5.3). Throughout the entire length of the sediment core, diatom taxa indicative of high river influence (including planktonic taxa) remain elevated, while taxa indicative of low river influence occur at only very low percent, suggesting sustained channel connection to the Slave River with direct in-flow to the lake. Although flooding occurs annually, the continued presence of epiphytic taxa suggests that suspended sediments supplied by river flood water must settle out quickly allowing sufficient light penetration for the development of extensive macrophyte beds, which provide habitat for epiphytic diatom taxa. There is little detectable change in the sedimentary diatom assemblages throughout the past ~100 years, with the exception of increased percent abundance of *Achnanthes minutissima* and *Fragilaria capucina* var. *mesolepta* in the uppermost samples of the core. A notable exception is the pronounced oscillation in the total percent abundance of planktonic diatom taxa, which often double within a span of one or two years (Figure 5.3). The presence of planktonic diatoms throughout the sediment core is also consistent with continued connection with the Slave River, but large peaks in the total sum of planktonic taxa may indicate high-magnitude flood events.

Lake SD20 (evaporation-dominated) is removed from the influence of rivers and does not flood easily. In fact, SD20 did not flood in 2005 when ice-jam flooding was spatially extensive

and inundated many delta lakes (Brock et al. in review). Lake water-balance in SD20 is controlled by precipitation and snowmelt (Brock et al. 2007), suggesting the water balance is strongly regulated by climatic factors and less influenced by flood waters compared to many lakes in the delta. The sedimentary diatom record is extremely short (~18 years) due to inadequate preservation of diatoms in sediments below 6 cm in the core (Figure 5.4). However, the available data suggest that the lake has remained in a clear-water, macrophyte-dominated state with no river influence, based on the consistently high abundance of epiphytic taxa (e.g. *Achnanthes minutissima* and *Cocconeis placentula* var. *placentula*) and a complete lack of planktonic taxa (Figure 5.4). Diatom preservation was poor between ~1975 and 1983, with evidence of dissolution on many of the valves and no preserved diatoms were found throughout the remainder of the sediment core.

Ordination of sedimentary diatom assemblages from the three study lakes as passive samples within RDA space of a spatial survey of surficial sediments (Chapter 2), further indicates distinctive diatom assemblages, hydrological conditions and hydroecological variability among lakes SD2, SD28 and SD20 (Figure 5.5). The first RDA axis mainly separates surficial sediment diatom assemblages typical of evaporation-dominated lakes from assemblages typical of river-influenced (flood- and exchange-dominated) lakes. To a lesser degree, the second RDA axis separated the diatom assemblages of flood-dominated lakes from those of exchange-dominated lakes. Diatom assemblages in the sediment core from lake SD2 reflect a very dynamic flooding regime as implied by marked fluctuations in diatom assemblages between those that are characteristic of river-influenced and evaporation-dominated lakes. Most of the assemblages in the sediment core from SD2 have affinity to flood- and exchange-dominated lakes, but distinct periods with assemblages typical of evaporation-dominated lakes (characterized by low river influence and more nutrient-rich conditions) did occur, indicating reduced river influence

between ~1914 to mid-1920s and ~mid-1940s to early-1960s. In contrast, diatom assemblages from lakes SD28 and SD20 exhibited very little temporal variability or change in hydroecological status throughout the cores. Sedimentary diatom assemblages from lake SD28 consistently cluster near the surface sediment assemblages from flood-dominated lakes, illustrating relatively consistent and strong river influence throughout the past ~100 years. Although the record from SD20 is very brief, the sedimentary diatom assemblages cluster near surface sediment diatom assemblages from evaporation-dominated lakes, reflecting a lake that is removed from the influence of the Slave River and is consistent with strong influence of evaporation on the water balance and ecological conditions.

5.6 Discussion

Results from analyses of temporal patterns of change in diatom assemblages in sediment cores from lakes of the Slave River Delta indicate that diatoms provide sensitive records of environmental change and important information on past changes in hydrological conditions including the frequency of river flooding. Sediment cores from the three study lakes revealed distinctive diatom assemblages that were indicative of their different hydrological settings (flood-, exchange- and evaporation-dominated). Each lake tracked changes in flood frequency, or the absence of changes, and are consistent with information provided by other proxies as well as with long-term monitoring records of spring discharge records on the Slave River.

Diatom taxa indicative of low and high river influence from SD2 and total sum of planktonic diatoms from SD28 show marked correspondence with gauged Slave River peak discharge levels over the past 46 years (1960-2005, Water Survey of Canada gauging station at Fitzgerald, AB; Figure 5.6). Slave River discharge plays a significant role in dictating the extent of flooding throughout the delta during spring melt (Brock et al. in review). In 2005, ice-jam flooding in the Slave River Delta resulted in substantial, wide-spread flooding that inundated

many lakes in both the active and relict portions of the delta. In the discharge record, this flood event is consistent with greater than average discharge during spring thaw. In contrast, thermal melt of river ice in the spring 2004 thaw season resulted in very little flooding except for lakes with a direct channel connection to the Slave River (e.g. SD28) and lakes in the outer-most fringes of the outer delta (Brock et al. in review). The spatial extent of flooding in 2004 was very low and corresponded with below average Slave River discharge when compared to the 46 years of gauge data. Moreover, in spring 2003, moderate flooding in the delta corresponded with roughly average discharge levels of the past 46 years.

Using 2003, 2004 and 2005 Slave River discharge levels as a framework, relationships between elevated Slave River discharge during spring thaw and periods of high relative abundance of diatom taxa indicative of high-river influence at SD2 becomes apparent (Figure 5.6). For example, between ~1963 and 1981 a steady rise in diatom taxa indicative of high river influence implies a period of increased flood frequency at lake SD2. During this period, Slave River discharge matched or exceeded 2003 levels for thirteen of eighteen years. Additionally, relative abundance of taxa indicative of high river influence peaked in the mid-1970s, which also corresponds with the highest recorded Slave River discharge levels since records began in 1960 (Brock et al. in review), and with widespread ice-jam flooding at the Peace-Athabasca Delta in 1974 (Pietroniro et al. 1999). Between ~1982 and 1990 there was an increase in taxa indicative of low river influence, which coincides with a period when Slave River peak discharge was at or below 2004 levels in six of eight years. Furthermore, between 1996 and 1999, four consecutive years of discharge at or above 2003 levels correspond with greater abundance of high river influence diatoms.

In lake SD28, one of the most flood-prone lakes in the delta which floods in most years, sedimentary diatom assemblages exhibited little temporal variability compared to the other study

lakes. However, the total sum of planktonic diatoms appears to provide useful information about flood frequency and magnitude. Comparison of total planktonic diatoms in SD28 and gauged Slave River discharge since 1960 reveal marked correspondence between elevated Slave River discharge during spring thaw and elevated percent abundance of total planktonic diatoms. Similarly, low percent abundance of planktonic taxa correspond with low discharge levels (e.g. 1983, 1995 and 2000; Figure 5.6). Additionally, the highest percent abundance in 1974 corresponds with highest Slave River discharge in over 40 years, which resulted in wide-spread flooding (Pietroniro et al. 1999). Slave River discharge at or above the 2005 level can be considered major flood events causing widespread flooding (Figure 5.6). Comparison with peaks in total sum of planktonic taxa (in %) indicates that there may have been at least 10 major floods at SD28 prior to Slave River discharge gauge measurements and possibly one very large flood event (~1904) that was larger than the massive 1974 flood (as indicated by the highest percent abundance of total planktonic taxa). The patterns of change (and peaks) of the total sum of planktonic taxa and the sum of high river influence indicator taxa do not always agree completely in the sediment record from SD28 (Figure 5.3). The total sum of planktonic taxa might provide more accurate or sensitive information about changes in river influence because these taxa only originate from the river whereas taxa included in the high river influence indicator-category also can grow in the lake in the absence of flooding. Since planktonic diatoms originate from the river and are indicative of flooding (Chapter 3), the total percent abundance of planktonic taxa appears to be a sensitive measure of the magnitude of flooding in the Slave River Delta, even in lakes that flood rather consistently every year.

The profiles of sedimentary diatoms from each of the lakes in this study exhibit distinctive assemblage composition and patterns of temporal variability that are related to their individual hydrological setting. Lake SD2 is a flood-prone site with variable flood frequency during the past

~90 years and is sensitive to shifts between periods of frequent and infrequent flooding. Chapter 3 reveals that flood-dominated lakes can exhibit limnological characteristics of both evaporation- and exchange-dominated lakes depending on the relative influence of river connectivity and flooding, which is also evident in the shifts of sedimentary diatom assemblages from those typical of more river influenced lakes to less river influenced lakes (Figure 5.5). Similarly, some restricted-drainage lakes in the Peace-Athabasca Delta (analogous to flood-dominated in the Slave River Delta) provide sensitive records of temporal flooding variability and shifts in hydrological conditions (Hall et al. 2004). Conversely, exchange-dominated lakes exhibit very little inter-annual variability in their physical and chemical conditions (Chapter 3). Thus, it is not surprising that sedimentary diatom assemblages from lake SD28 are dominated by taxa indicative of high river influence and are relatively static in the past ~100 years (Figures 5.3 and 5.5). Isotopic analyses by Mongeon (2007) are also consistent with the diatom data, suggesting that very little change has occurred at lake SD28. Findings by Hall et al. (2004) reveal that sedimentary diatom assemblages in a lake in the Peace-Athabasca Delta (Lake PAD8) are also relatively unresponsive over time. Lake PAD8 similarly has a single narrow channel connection with a river that serves both as an inlet and an outlet, and composition of diatom assemblages indicated frequent and relatively consistent river flooding. Paleolimnological studies in the Mackenzie Delta have also shown little variability in sedimentary diatom assemblages, leading the researchers to conclude that paleolimnological analyses of past flood regimes were unsuccessful in this system (e.g. Michelutti et al. 2001). The study by Michelutti et al. (2001), however, may have encountered a similar limitation as we observed in the diatom profiles from lake SD28 – namely that the lakes selected in their study were frequently flooded (i.e., exchange-dominated hydrology) and diatom assemblages are therefore relatively unresponsive to hydrological variability.

Lake SD20 (evaporation-dominated) is very different from the other two river-influenced lakes in this study and was selected for paleolimnological analysis to assess past hydroecological variability in the delta in the absence of flooding, but due to poor diatom preservation, this was not possible. Although the record is very short, sedimentary diatom assemblages reveal that SD20 has been a shallow, clear-water, macrophyte-dominated lake with no apparent change in hydrological connectivity in the past ~18 years, which corresponds well with isotopic analyses performed on the same sediment core (Mongeon 2007). Dissolution of diatom valves is consistent with very shallow, alkaline waters in SD20 and under such highly alkaline conditions, preservation of siliceous algal remains is likely hindered due to the dissociation of silicic acid at elevated pH values (Barker et al. 1994). Moreover, silica availability may have been poor without the inputs of silica-rich river flood waters (Chapter 2). Closed-drainage lakes in the Peace-Athabasca delta are analogous to evaporation-dominated lakes in the Slave River Delta and interpretation of diatom assemblages in sediment cores from these lakes have associated high abundance of epiphytic taxa with low flood frequency (Hall et al. 2004; Wolfe et al. 2005). Although we were unsuccessful at obtaining a long hydroecological record from lake SD20, other evaporation-dominated lakes may prove to be more successful in future studies.

The three lakes in this study have strongly contrasting hydrological settings and are representative of a wide variety of lakes throughout the delta. None of these lakes demonstrate (or were able to detect) any recent or fundamental change in hydrological conditions. Although the records are brief, there is no evidence of any directional shifts in sedimentary diatom assemblages and no obvious hydrological thresholds have been crossed over the time frames represented by the three records. These results are particularly important in light of recent concerns and observations regarding water level changes in the delta (Wesche 2007), as there is no compelling

evidence for reduction in flood frequency or a decrease in high magnitude flood events that can be linked to upstream river regulation or other drivers of hydroecological change.

5.7 Conclusions

Results obtained in this study demonstrate that sedimentary diatom assemblages in sediment cores from lakes in the Slave River Delta sensitively and accurately track changes in hydrological connectivity and flooding. The composition and temporal patterns of variation in diatom assemblages differs among lakes from different hydrological categories (flood-, exchange- and evaporation-dominated) in consistent and predictable ways. Lake SD2 (flood-dominated) floods periodically and diatom assemblages provided a high resolution record of flooding variability during the past ~90 years. At lake SD28 (exchange-dominated), which floods almost every spring, sedimentary diatom assemblages have remained relatively static during the past ~100 years, but the total sum of planktonic diatoms appears to provide a robust record of large, spatially extensive flood events at this lake. Sedimentary diatom assemblages from lake SD20 were distinct from those of the other lakes and accurately classified the lake as having evaporation-dominated hydrology, but diatoms were poorly preserved in this site. Successful paleolimnological studies of evaporation-dominated lakes in the nearby Peace-Athabasca Delta suggest that other lakes in this hydrological category do not necessarily suffer problems of poor diatom preservation and can provide high-quality records of past hydroecological variability in the delta in the absence of flooding.

The paleolimnological records in this study provide excellent records of changes in environmental conditions and flooding regimes. However, these short records (<100 years) may be too brief to illustrate the true natural variability within this system because longer paleolimnological records obtained at the upstream Peace-Athabasca Delta show there have been more marked hydrological changes during the past 300-1000 years compared to the past 100

years (Hall et al. 2004). Extending the sediment records of both river-influenced sites (SD2 and SD28) in future studies may be able to identify multi-centennial patterns of changes in hydrological conditions of the Slave River Delta. Given the likelihood of continued climatic warming and increasing consumptive use of river water (Schindler and Donahue 2006; Schindler and Smol 2006), understanding past changes in the hydroecology of the Slave River Delta will be important to anticipate and manage future changes to this ecosystem.

5.8 Acknowledgements

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5.10 Figures

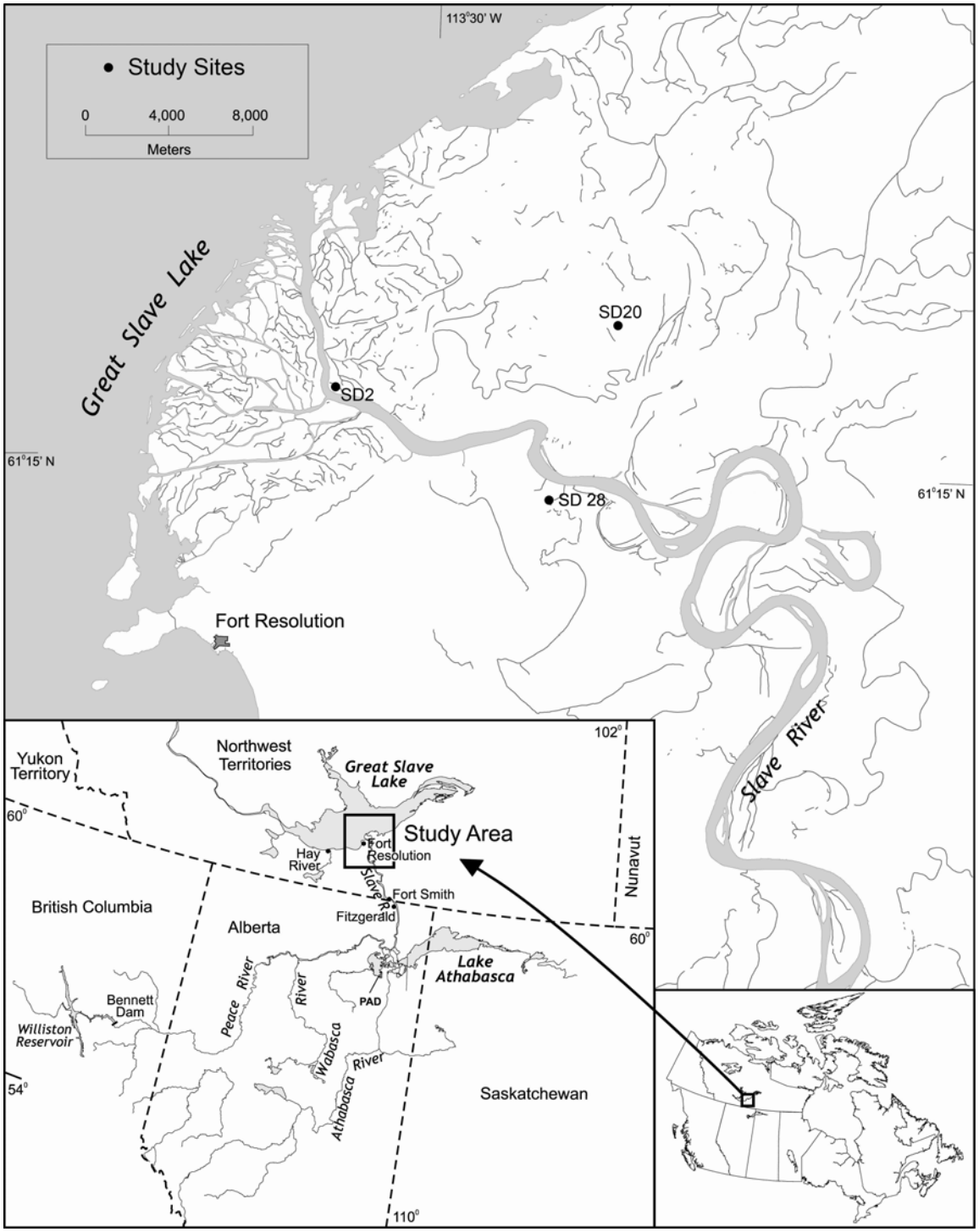

Figure 5.1 Location of the Slave River Delta and sampling sites SD2 (a lake with flood-dominated hydrology), SD28 (exchange-dominated) and SD20 (evaporation-dominated).

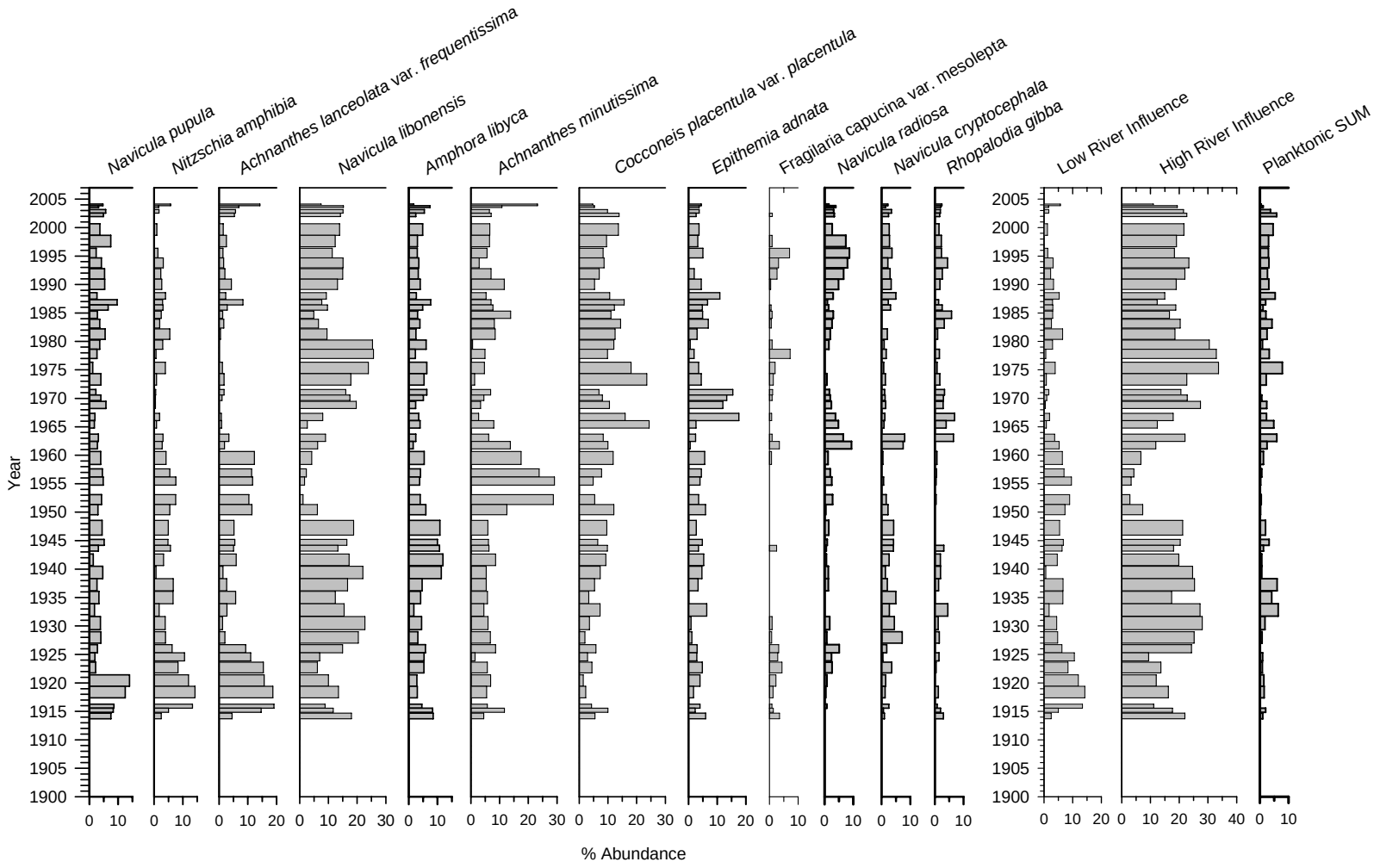

Figure 5.2 Relative abundance profiles of the dominant diatom taxa (with relative abundances of ≥5% in at least one sediment interval) from a sediment core from lake SD2.

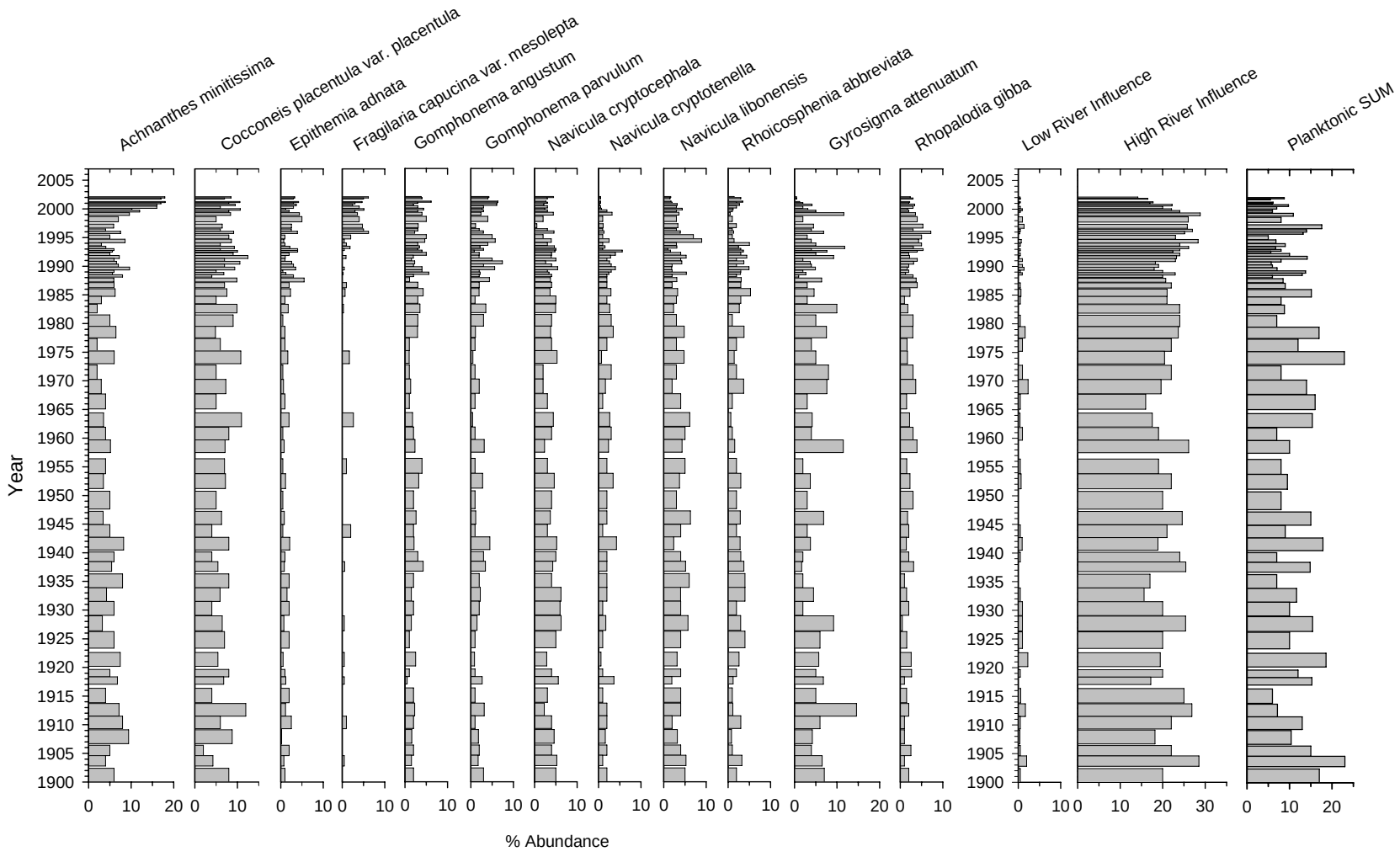

Figure 5.3 Relative abundance profiles of the dominant diatom taxa (with relative abundances of ≥5% in at least one sediment interval) from a sediment core from lake SD28.

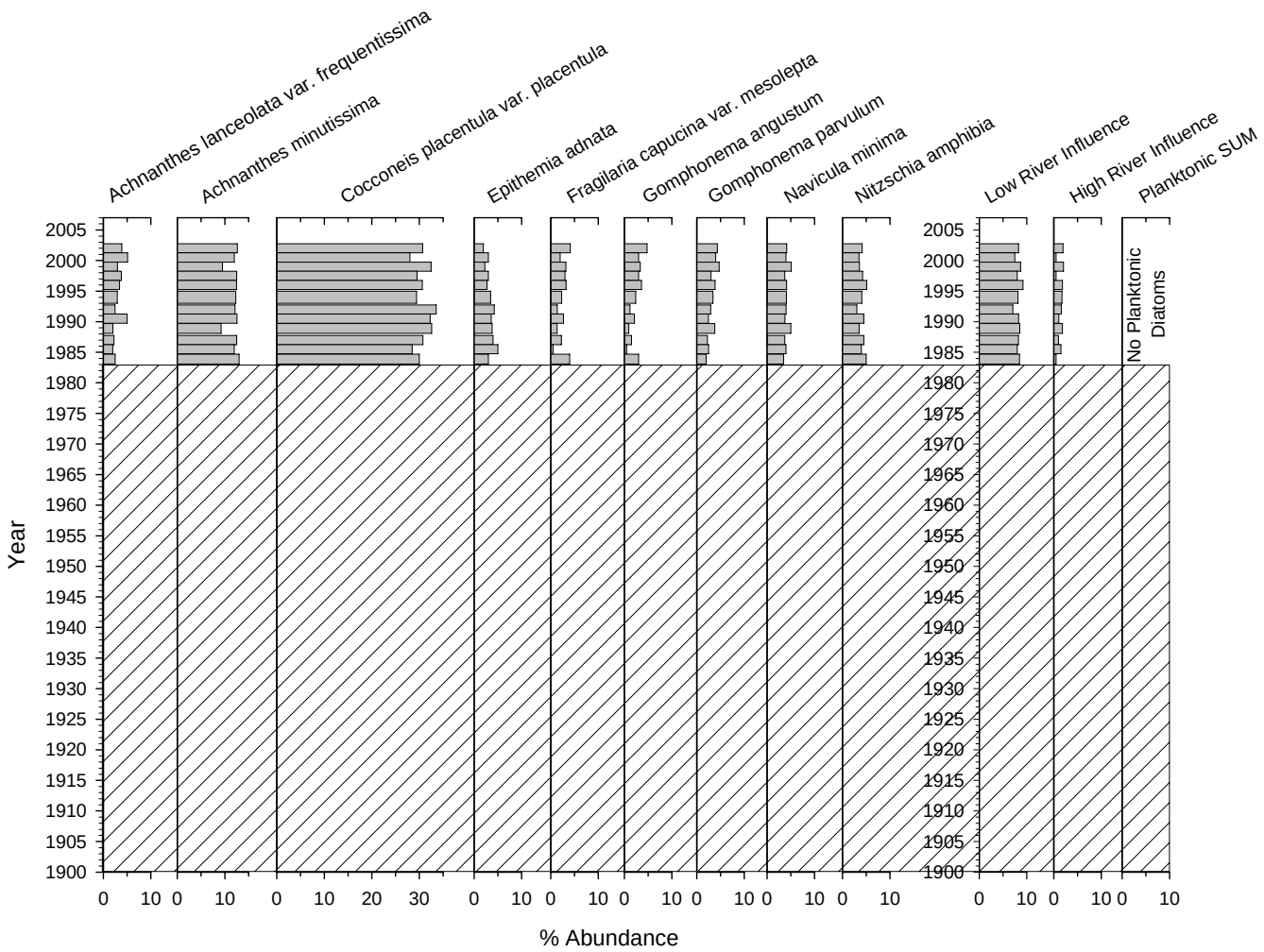

Figure 5.4 Relative abundance profiles of the dominant diatom taxa (with relative abundances of ≥5% in at least one sediment interval) from a sediment core from lake SD20. The hatched bar indicates sediment intervals with poor diatom preservation due to dissolution.

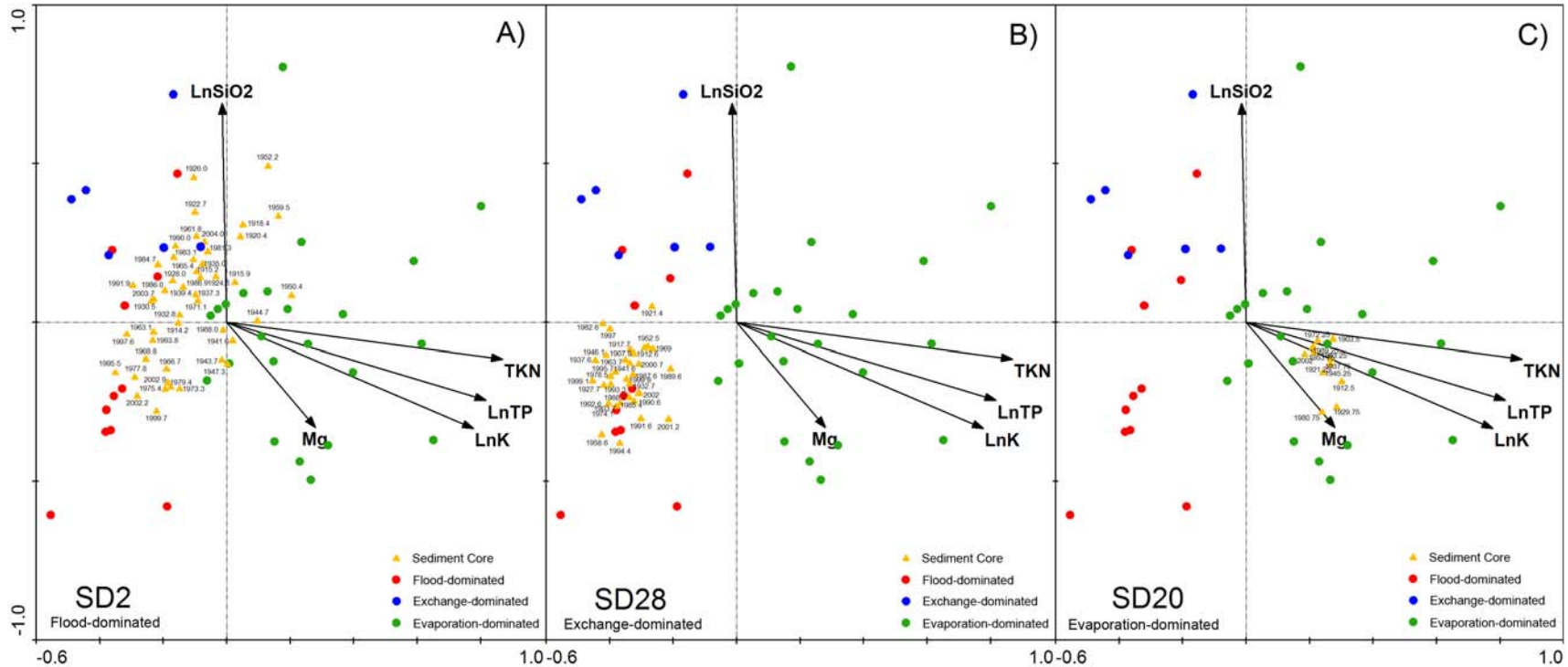

Figure 5.5 Redundancy analysis (RDA) of surface sediment diatom assemblages (n = 88) and forward-selected environmental variables from a spatial survey of 41 lakes in the Slave River Delta situated along broad hydroecological gradients (see Chapter 2). Sedimentary diatom assemblages from SD2 (A), SD28 (B) and SD20 (C) sediment cores are plotted as passive samples within ordination space of the 41 lake dataset to compare and illustrate past changes in hydroecological conditions and diatom community composition at each of the study lakes.

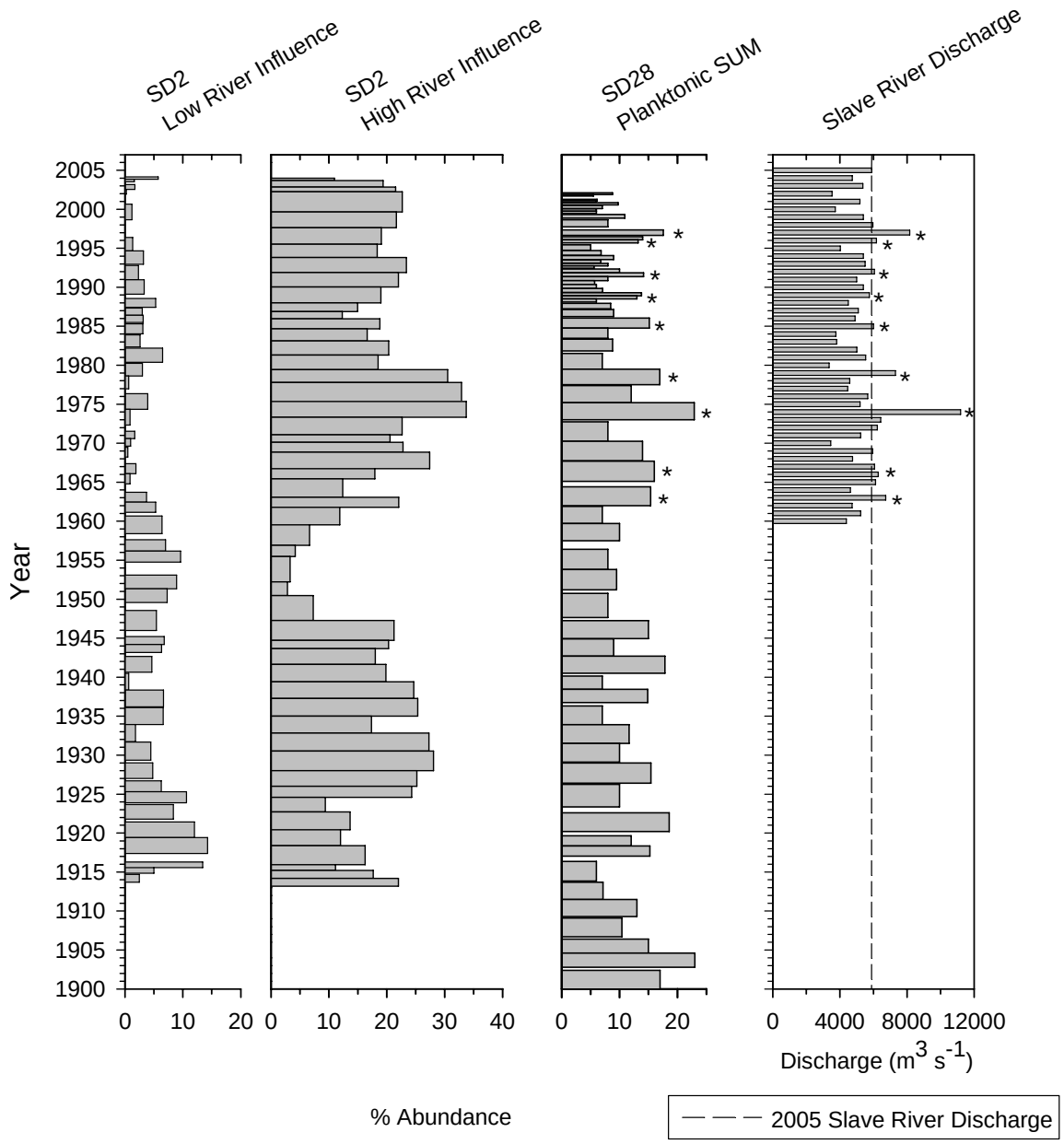

Figure 5.6 Summary profiles of diatom relative abundance from cores from SD2 (low and high river influence taxa) and SD28 (total sum of planktonic taxa), and Slave River discharge levels (1960-2005, Water Survey of Canada gauging station at Fitzgerald, AB). The asterisks indicate correspondence between high relative abundance of total sum of planktonic taxa and high Slave River discharge levels. The dashed line indicates 2005 Slave River peak discharge level, which resulted in widespread flooding across the Slave River Delta.

Chapter 6
Summary and overall conclusions

6.1 General comments

The preceding chapters have described my research on the relationships between hydrology, limnology and ecology of Slave River Delta water bodies. In this chapter, I summarize the objectives and major conclusions of each of the preceding data chapters (Chapters 2-5), and implications for ecosystem management and future research recommendations.

The research in this thesis was undertaken to understand the hydroecology of an important northern floodplain environment, and how it functions in the face of multiple stressors over various time-scales. Overall, I found that:

1. Hydrology is closely linked with the limnological and ecological characteristics of Slave River Delta lakes.
2. River Flooding is a key factor in controlling the physical, chemical and biological conditions of lakes in the delta.
3. The physical and chemical characteristics, biomass of macrophytes, and diatom community structure of delta lakes will respond predictably to future changes in hydrologic conditions.
4. Diatom communities can be successfully used as bioindicators of hydrological change in floodplain lakes.
5. Diatoms provide sensitive records of environmental change and important information on past changes in hydrological conditions.
6. Analyzing multiple time-scales gives the temporal perspective needed to understand the hydroecology of such a variable environment

6.2 Chapter 2 conclusions

Chapter 2 reported results from analyses of water chemistry and surface sediments collected from 41 shallow lakes in the Slave River Delta to determine if hydrological differences among lakes in the Slave River Delta result in predictable differences in physical and chemical characteristics of lakes, and if these differences are related to the composition of diatom assemblages in recently-deposited surficial lake sediments. My approach was to: 1) quantify relationships between basin hydrology and limnological conditions, and determine if limnological conditions differ among the three hydrological lake categories (flood-dominated, exchange-dominated and evaporation-dominated), 2) identify the main environmental gradients associated with the composition of diatom assemblages contained in surface sediments and determine whether diatom assemblage composition differs among the hydrological lake categories and 3) identify the diatom taxa that best discriminate among the hydrological lake categories. The main conclusions of Chapter 2 were as follows:

1. The hydrological settings of lakes in the Slave River Delta are associated with distinctly different limnological conditions and composition of diatom assemblages in surface sediments. Differences are most pronounced between lakes that are influenced by the Slave River or Great Slave Lake (flood- and exchange-dominated lakes) and lakes that are removed from the influence of the river (evaporation-dominated lakes).
2. The distinct composition of water chemistry and diatom assemblages among hydrological categories indicates that the lake classification scheme of Brock et al. (2007) based on stable isotope results from the open-water season of 2003 also captures major limnological and ecological differences.
3. In the absence of river flooding, evaporation-dominated lakes have the highest concentrations of several ions and nutrients and these clear water, macrophyte-dominated systems have high relative abundances of common epiphytic diatoms such as *Navicula minima* and *Nitzschia amphibia*. In contrast, flood-dominated lakes have relatively low concentrations of most ions

and nutrients, while exchange-dominated lakes have the lowest average concentrations of most ions and nutrients, but tend to be more variable as a result of varying influence from the Slave River and Great Slave Lake. Sedimentary diatom taxa indicative of flood- and exchange-dominated lakes span a wider range of habitat types when compared to evaporation-dominated lakes, and include the planktonic taxa *Cyclostephanos* cf. *tholiformis*, *Stephanodiscus minutulus* (exchange-dominated) and *Cyclostephanos* PAD sp.2 (flood-dominated) which are important indicators of river connectivity in the Slave River Delta.

4. Our approach has integrated the use of water isotope tracers and chemistry to characterize present hydrolimnological conditions, and has demonstrated the potential of sedimentary diatom assemblages as bioindicators of hydrological changes and as proxy indicators of past hydroecological conditions in the Slave River Delta. Knowledge gained from this formative study is being used in biomonitoring and paleolimnological investigations of the Slave River Delta to further our understanding of the complex interactions among hydrology, limnology, and aquatic ecology in this freshwater ecosystem.

6.3 Chapter 3 conclusions

Chapter 3 reported the responses of limnological conditions, composition of diatom phytoplankton communities and macrophyte biomass to river flooding in six lakes representing the three hydrological categories of lakes in the Slave River Delta. The study spanned three years (2003-2005) of varying spring flood magnitude, which collectively provided a useful experimental design and temporal context to examine the role of river flooding on seasonal and inter-annual dynamics in delta lakes. Two of the six study lakes flooded in all three years, two did not flood in any year and two lakes flooded in one or more years but not in others. Overall, moderate flooding occurred in 2003, flooding was almost entirely absent in 2004, and extensive flooding occurred in 2005. My approach focused on: 1) determining the seasonal and inter-annual effects of river flooding on limnological conditions of Slave River Delta lakes from water

chemistry analyses, 2) comparing the seasonal variability of diatom phytoplankton communities in the Slave River with that of flooded and non-flooded lakes to determine the importance of flooding on an important group of algae, and 3) evaluating the effects of flooding on underwater light environment and macrophyte biomass. It was determined that river flood waters act as a dominant hydrological process controlling limnological and ecological conditions in lakes of the Slave River Delta, and these shallow aquatic systems appear to respond in predictable ways to flooding, as summarized below:

1. Limnological differences between flooded and non-flooded lakes of the Slave River Delta as observed in this study of six lakes over three years are broadly consistent with findings in Chapter 2, which were based on a single, point-in-time water samples collected during a spatial survey of more than 40 lakes in September of 2002. Specifically, lakes that receive river flooding have high concentrations of most ions, SiO_2 and alkalinity, while lakes that do not flood have high concentrations of nutrients, pH and K. Flooded and non-flooded lakes in the delta have consistently distinct limnological conditions, and river flooding plays an important role in determining seasonal and inter-annual patterns of limnological and ecological variability in lakes of the Slave River Delta.
2. In Chapter 2 evaporation-dominated lakes have higher concentrations of several ions, and flood- and exchange-dominated lakes have relatively low concentrations of most ions, while in Chapter 3, ionic concentration is higher in flooded lakes than in non-flooded lakes. I propose that this apparent contradiction is due to differences in sampling strategies between the two studies. Water chemistry from Chapter 2 was collected at the end of the season (late September) from many lakes compared to seasonal samples from six lakes in Chapter 3. The large number of lakes sampled likely represents a much wider gradient of chemical conditions compared to only six lakes. Also, the multiple seasonal samples from Chapter will also affect the water chemistry compared to only one late-season sampling event.

3. River flooding results in predictable changes at the Slave River Delta, but not all lakes flood every year resulting in a broad range of conditions across the entire ecosystem. Lakes dominated by evaporation during the ice-free season show consistent seasonal trends towards evaporative enrichment of lake waters and increased concentrations of nutrients, chl-*a*, pH and K during the summer. Exchange-dominated lakes, however, have limnological conditions that are controlled by the frequency of the exchange of water from the rivers or Great Slave Lake, resulting in highly dynamic conditions throughout any one season. Seasonal limnological conditions in flood-dominated lakes are also controlled by river flooding, but differ between flood and non-flood years.
4. In years when flood-prone lakes do not flood, they can rapidly acquire characteristics of non-flooded lakes. In the absence of flooding, evaporation-dominated lakes (SD15, SD33) have narrow ranges of limnological inter-annual variability, but are distinguished from each other due to different catchment characteristics. Frequently flooded lakes (exchange-dominated: SD28, SD39) also have relatively low limnological variability from year to year but are much more limnologically similar to each other. Frequent river flooding can increase the similarity between floodplain lakes and the rivers that flood them, creating a more homogenized landscape.
5. Lakes with variable flood frequency (SD2, SD29) show strong inter-annual variability, which is largely dependent on whether river floodwaters entered the basins in the spring. During flood years, limnological conditions are similar to the rivers and other flooded lakes but in non-flood years, conditions are more similar to evaporation-dominated lakes. While the temporal duration of the limnological response to flooding in flood-prone lakes can be quite brief, the effects of flooding on evaporation-dominated lakes that do not usually flood appear to persist much longer.
6. Planktonic diatom communities in lakes of the Slave River Delta are strongly controlled by river flooding. In the absence of flooding, there is a complete lack of planktonic diatoms in the

water column, while lakes that flood in the spring contain similar planktonic diatom communities as the rivers that flood them. Diatoms were also absent from phytoplankton samples collected from all lakes in the mid- and late-seasons of 2003 to 2005, suggesting that the diatom plankton communities in flooded lakes are short-lived and appear unable to persist in the absence of flooding.

7. Flooding plays a strong role in the development and productivity of macrophyte communities. The mean aboveground biomass of macrophytes in Slave River Delta lakes decrease with increased flood frequency, and lakes that are closely associated with the river and regularly flood have much lower macrophyte biomass than lakes that did not receive flood waters.
8. There is a strong negative correlation between mean macrophyte biomass and spring light extinction. There is a strong gradient of light penetration among the lakes, which is a function of flood frequency and duration. Flooding reduces lake water transparency as a result of the high concentration of suspended sediments in the Slave River, and isolation from the river results in relatively high transparencies. At the onset of the growing season following a flood, lake water transparency is low and reduces the supply of light during early macrophyte growth, and suggests that macrophyte biomass is limited by water transparency and the availability of light. Alternatively, it is possible that other factors not directly measured in this study, such as sediment nutrient content, may also affect macrophyte biomass.
9. The results suggest that periodic flooding is not required to maintain high biological productivity even though rivers are considered a primary source of nutrients. In the absence of flooding, delta lakes remain nutrient-rich and are highly productive. For example, lake SD33 has among the highest nutrient concentrations and macrophyte biomass of the study lakes but is one of the least flood-prone lakes, whereas lakes that flood more frequently are at the opposite end of the spectrum. Although river water has higher concentrations of TP than lakes, dP is higher in non-flooded lakes indicating most of the TP in rivers and flooded lakes is in the suspended sediment and likely not immediately available to biota. Since infrequently flooded

lakes in the Slave River Delta are very productive aquatic ecosystems, nutrient recycling must play an important role in maintaining high biological productivity.

6.4 Chapter 4 conclusions

Chapter 4 reported results of comparisons of epiphytic diatom communities in two small lakes (Lakes SD28 and SD29) which differ markedly in their hydrological setting. The Slave River floods into lake SD28 (exchange-dominated) every spring and at various times throughout the ice-free season. In contrast, SD29 (evaporation dominated) is geographically removed from the influence of the Slave River, except during the most extreme spring flood events. Data collection spanned two years (2004 and 2005) of varying spring flood magnitude: only SD28 flooded in 2004 (a year of limited flooding) but both lakes flooded in 2005 (a year of extensive flooding). Replicate samples of epiphytes were collected from the three most dominant macrophyte species (SD28: *Potamogeton friesii*, *Myriophyllum exalbescens*, *Equisetum* and SD29: *Potamogeton friesii*, *Ceratophylum demersum*, floating filamentous algae) in three separate basins from each lake. The objective of this chapter was to determine the relative importance of differences in hydrolimnological conditions (between lakes and between study years), spatial variability in limnological conditions within each lake and macrophyte host species in regulating the community composition of epiphytic diatoms in two lakes of the Slave River Delta. The main conclusions of Chapter 4 were as follows:

1. This study demonstrates the overriding influence of flooding and hydrolimnological variability on diatom communities compared to spatial differences of limnological conditions within lakes or differences among host macrophyte species.
2. Lake SD29 did not flood in 2004 and had high concentrations of nutrients, K and high pH, but had low concentrations of most ions. In the spring of 2005 a large ice-jam flood occurred that altered the physical and chemical conditions of this lake. This flood event was associated with marked alteration of epiphytic diatom community composition, as differences between flood

years accounted for the largest difference among diatom communities. In contrast, lake SD28 is frequently flooded and exhibited relatively little limnological variability between years. Still, significant differences in composition of epiphytic diatom communities were observed between years in SD28, likely the result of varying spring flood magnitude (small flood in 2004 and large flood in 2005). Flood-induced limnological changes were lower in 2004, but ice-jam flooding in the spring of 2005 dramatically raised water levels (approximately 2 m above summer levels), increased concentrations of most nutrients and changed the underwater light environment by increasing extinction coefficients.

3. As a result of hydrolimnological differences between SD28 and SD29, due to frequency and intensity of flooding, there are significant differences in the composition of epiphytic diatom communities between lakes, and these differences exert strong control of epiphytic diatom communities.
4. In comparison with lakes in different hydrological settings, chemical differences among sites within lakes are modest, yet significant spatial differences among epiphytic diatom community composition exist in both SD28 and SD29. Different basins within both SD28 and SD29 vary in their limnological conditions and epiphytic diatom community composition, but spatial differences in SD28 are greater than in SD29. Greater spatial differences at SD28 may result from influence of the channel connecting the lake to the Slave River, as it likely act as a point source that can generate chemical gradients within the lake.
5. Significant differences in epiphytic diatom community composition are also evident on different macrophytes, suggesting that varying plant architecture or different aquatic habitats (e.g. floating and submergent) are likely important in regulating epiphytic community composition. This study demonstrates that community composition of epiphytic diatoms differed significantly among macrophyte species and as such, macrophytes do not simply act as neutral sites for attachment.

6. The examination of hydrological factors behind changes in epiphytic diatom communities improves knowledge of factors regulating epiphytic diatoms and will better inform paleolimnological interpretations of hydrological variation in the Slave River Delta. Since the influence of hydrology on the limnological characteristics of delta lakes appears to play a more important role than macrophyte species, marked shifts in sedimentary assemblages of epiphytic diatoms can be more appropriately interpreted as a result of changes in flood dynamics as opposed to a result of changes in macrophyte communities.

6.5 Chapter 5 conclusions

Chapter 5 reported results from a paleolimnological experiment which evaluated the ability of diatom assemblages to consistently detect differences in the hydrological state between lakes, as well as to detect changes in hydroecological conditions over time within individual lakes of the Slave River Delta. Sediment cores were collected from a lake in each of the three hydrological lake categories in the delta (flood-, exchange- and evaporation-dominated). Lake SD2 (flood-dominated) has shown variable flooding from 2003-2005, and was chosen to assess if diatom assemblages track changes of variable hydrological conditions over time. Lake SD28 (exchange-dominated) is a flood-prone lake that has flooded every year since 2003 and even when spring floods are unusually small (2004), and was chosen to assess if diatoms consistently characterize the lake as river-influenced. Lake SD20 (evaporation-dominated) which has few routes for flood waters to enter the lake (far removed from the rivers), and did not flood in any years (even in 2005 when a large, spatially-extensive flood occurred), was chosen to assess past hydroecological variability in the delta in the absence of flooding. The main conclusions of Chapter 5 were as follows:

1. Results from analyses of temporal patterns of change in diatom assemblages in sediment cores from lakes of the Slave River Delta indicate that diatoms provide sensitive records of

environmental change and important information on past changes in hydrological conditions including river flooding.

2. Sediment cores from the three study lakes revealed distinctive diatom assemblages that were indicative of their different hydrological settings (flood-, exchange- and evaporation-dominated). Each lake tracked changes in flood frequency, or the absence of changes, and are consistent with information provided by other proxies as well as with long-term monitoring records of spring discharge records on the Slave River.
3. Diatom taxa indicative of low and high river influence from SD2 show correspondence with gauged Slave River peak discharge levels over the past 46 years (1960-2005, Water Survey of Canada gauging station at Fitzgerald, AB; Figure 6). Between 1963 and 1981 a steady rise in diatom taxa indicative of high river influence indicates a period of increased flood frequency at lake SD2. During this period, Slave River discharge matched or exceeded 2003 levels for thirteen of eighteen years. Relative abundance of taxa indicative of high river influence peaked in the mid-1970s, which also corresponds with the highest recorded Slave River discharge levels since records began in 1960. From 1982 to 1990 there was an increase in taxa indicative of low river influence, which coincided with a period when Slave River discharge was at or below 2004 levels in six of eight years. Furthermore, between 1996 and 1999 four consecutive years of discharge at or above 2003 levels correspond with greater abundance of high river influence diatoms.
4. Comparison of total planktonic diatoms in SD28 and gauged Slave River discharge since 1960 reveal marked correspondence between elevated Slave River discharge during spring thaw and high percent abundance of total planktonic diatoms, providing a record of flood magnitude in the delta. Comparison with peaks in total sum of planktonic taxa (in %) indicates that there may have been at least 10 major floods prior to Slave River discharge gauge measurements and possibly one very large flood event (~1904) that was larger than the massive 1974 flood (as indicated by the highest percent abundance of total planktonic taxa). Since planktonic

diatoms originate from the river and are indicative of flooding, the total percent abundance of planktonic taxa appears to provide a sensitive measure of the magnitude of flooding in the Slave River Delta, even in lakes that flood in most years.

5. The profiles of sedimentary diatoms from each of the lakes in this study exhibit distinctive assemblage composition and patterns of temporal variability that are related to their individual hydrological setting. Lake SD2 is a flood-prone site with variable flood frequency during the past ~90 years and is sensitive to shifts between periods of frequent flooding and periods of very low flooding. Conversely, exchange-dominated lakes such as SD28 exhibit very little inter-annual variability in their physical and chemical conditions and sedimentary diatom assemblages from this lake are dominated by taxa indicative of high river influence and are relatively static during the past ~100 years.
6. Lake SD20 (evaporation-dominated) is very different from the other two river-influenced lakes in this study and was selected for paleolimnological analysis to assess past hydroecological variability in the delta in the absence of flooding, but due to poor diatom preservation this was not possible. Although the record is very short, sedimentary diatom assemblages reveal that SD20 has been a shallow, clear-water, macrophyte dominated lake with no apparent change in hydrological connectivity during the past ~18 years. Obtaining a long hydroecological record from lake SD20 was unsuccessful, however, other evaporation-dominated lakes in the Slave River Delta may prove to be more successful in future studies.
7. The three lakes in this study have strongly contrasting hydrological settings and are representative of a wide variety of lakes throughout the delta. None of these lakes demonstrate (or were able to detect) any recent or fundamental change in hydrological conditions. Although the records are brief, there is no evidence of any directional shifts in sedimentary diatom assemblages and no obvious hydrological thresholds have been crossed over the time frames represented by the three records. These results are particularly important in light of recent concerns and observations regarding water level changes in the delta, as there is no

compelling evidence for reduction in flood frequency or a decrease in high magnitude flood events that can be linked to upstream river regulation or other drivers of hydroecological change.

6.6 Implications for ecosystem and resource management

Knowledge of the modern linkages among hydrology, limnology and ecology, coupled with information about past responses to climatic variability and human activities provides an extremely important basis for predicting future responses of the Slave River Delta to recent and expected trends in river discharge. Climate warming will likely cause reduced river flows, and coupled with human modifications of upstream river systems and decreased ice-jam flooding, may lead to reduced frequency of flooding in northern deltas of the Mackenzie Basin (Marsh and Lesack 1996; Schindler and Smol 2006). Since my results indicate that river flooding is a key factor in controlling physical, chemical and biological conditions of lakes in the Slave River Delta, a reduction in flooding will undoubtedly alter the aquatic ecosystems. In some lakes, for example, a reduction in flood frequency may result in reduced water levels leading to an increasingly terrestrialized system, while in others (previously flood-prone lakes) nutrient concentrations may ultimately increase and these basins may become increasingly more productive systems, although these too will eventually evolve to more terrestrial conditions in the absence of water replenishment from the Slave River.

Paleolimnological analyses reveal no compelling evidence for a reduction in flood frequency or a decrease in high magnitude flood events that can be linked to upstream river regulation initiated in 1968 with construction of the WAC Bennett Dam at the headwaters of the Peace River. However, it appears that Slave River discharge influences flood frequency and magnitude. In light of recent and ongoing transboundary water agreements, it is important to know the hydroecological effects of changing water levels and discharge as a result of upstream resource development, particularly oil sands recovery in northern Alberta. Increased resource development

may also contribute to decreased river discharge and further alter flood patterns and water levels in the Slave River Delta.

6.7 Future research directions and recommendations

The research findings presented in this thesis provide a good contemporary basis for future monitoring studies and the potential for diatoms to be used in reconstructing past changes in flood frequency in the Slave River Delta. To fully understand the implications of multiple stressors on this ecosystem, long-term hydroecological monitoring and paleolimnological studies will be required. A hydroecological monitoring program should be developed for the Slave River Delta to increase the temporal perspective of hydrological and limnological conditions. The results in this thesis capture three years of variable flood conditions, but increasing the sample size (number of lakes) of flood- and exchange-dominated lakes will be able to fully capture the hydroecological gradients in the delta. Further analyses of sediment chemistry from a variety of flooded and non-flooded lakes would also be beneficial to determine sources of nutrients. For example, sampling sediment chemistry and comparing it to water chemistry will help determine if sediment bound phosphorus from river flooding is an important source of nutrients to macrophyte production. Epiphytic diatoms were shown to respond sensitively to differences in hydroecological conditions among and within lakes, and thus a long-term biomonitoring program that employs epiphytic algae can be expected to provide a useful approach to detect changes to multiple stressors. This type of monitoring program and the techniques used in this thesis can also be transferable to other large freshwater deltaic systems around the world.

The research presented in this thesis has shown that shallow, flood-prone lakes contain a decipherable and detailed sedimentary record of hydrological and ecological changes. Consequently, there is reason to be more optimistic about the value of paleolimnological studies in these types of aquatic ecosystems than reported by Michelutti et al. (2001) for the Mackenzie Delta. Even though diatoms provide a useful source of paleolimnological data in The Slave River

Delta, future studies would benefit from multi-proxy analyses to obtain a more complete and comprehensive analysis of past hydroecological change. The paleolimnological records in this study provide excellent records of changes in environmental conditions and flooding regimes. However, these short records (<100 years) may be too brief an illustration of the true natural variability within this system because longer paleolimnological records obtained at the upstream Peace-Athabasca Delta show there have been more marked hydrological changes during the past 300-1000 years compared to the past 100 years (Hall et al. 2004). Extending the sediment records of both river influenced sites (SD2 and SD28) in future studies may be able to identify multi-centennial patterns of changes in hydrological conditions of the Slave River Delta. As a result of poor diatom preservation at SD20, collecting sediment cores from other evaporation-dominated lakes will also be beneficial in determining long-term regional climate variability.

Appendix A

Slave River Delta spatial survey lakes

The following appendix provides the physical, chemical and diatom percent abundance data from 41 lakes, three river sites and Great Slave Lake from a spatial survey conducted in September 2002.

Table A1 Physical data from a spatial survey of Slave River Delta lakes, September 2002.

Lake	Hydrological Category	Latitude (UTM)	Longitude (UTM)	Depth (cm)
SD 1	Flood-dominated	6796450	360900	100
SD 2	Flood-dominated	6796800	361650	60
SD 3	Flood-dominated	6797350	363250	100
SD 4	Flood-dominated	6796760	362150	120
SD 5	Flood-dominated	6795888	365177	240
SD 6	Flood-dominated	6798670	363650	120
SD 7	Flood-dominated	6802929	363807	140
SD 8	Evaporation-dominated	6792549	358400	145
SD 9	Flood-dominated	6797369	359764	125
SD 10	Exchange-dominated	6800325	363078	190
SD 11	Evaporation-dominated	6798140	369545	150
SD 12	Evaporation-dominated	6796301	371053	50
SD 13	Evaporation-dominated	6798099	371918	130
SD 14	Evaporation-dominated	6799258	373304	95
SD 15	Evaporation-dominated	6802209	372375	150
SD 16	Evaporation-dominated	6801021	372195	235
SD 17	Exchange-dominated	6791348	368063	140
SD 18	Evaporation-dominated	6795593	370045	135
SD 19	Evaporation-dominated	6796500	375250	49
SD 20	Evaporation-dominated	6800033	375441	135
SD 21	Evaporation-dominated	6797868	378831	75
SD 22	Evaporation-dominated	6798855	380493	90
SD 23	Evaporation-dominated	6795825	381409	75
SD 24	Evaporation-dominated	6795230	377971	80
SD 25	Evaporation-dominated	6793846	378186	90

Lake	Hydrological Category	Latitude (UTM)	Longitude (UTM)	Depth (cm)
SD 26	Evaporation-dominated	6786563	370914	70
SD 27	Evaporation-dominated	6789184	372615	30
SD 28	Exchange-dominated	6791339	372046	280
SD 29	Evaporation-dominated	6790800	381718	40
SD 30	Exchange-dominated	6787657	387222	1000
SD 31	Evaporation-dominated	6786252	385316	90
SD 32	Evaporation-dominated	6783643	385619	130
SD 33	Evaporation-dominated	6779992	381208	125
SD 34	Evaporation-dominated	6787134	362162	175
SD 35	Evaporation-dominated	6779578	380385	125
SD 36	Evaporation-dominated	6771359	380103	185
SD 37	Evaporation-dominated	6770753	381762	160
SD 38	Flood-dominated	6800416	359957	190
SD 39	Exchange-dominated	6800378	357341	110
SD 40	Flood-dominated	6795784	356331	150
SD 41	Exchange-dominated	6798317	355966	150
SD R1	East Channel	6798437	358872	-
SD R2	Jean River	6803358	373749	-
SD R3	Slave River	6800111	360483	-
SD42	Great Slave Lake	6790567	354976	-

Table A2 Chemical data from a spatial survey of Slave River Delta lakes, September 2002.

Lake	pH	Cond (mS)	TKN (µg/L)	NO3+NO2 (µg/L)	TP (µg/L)	dP (µg/L)	Colour ABS	DOC (mg/L)	SiO2 (µg/L)	Alkalinity (µeq/L)	Na+ (mg/L)	K+ (mg/L)
SD 1	7.97	0.26	589.64	0.45	22.21	11.31	0.04	10.39	364.22	3031.72	9.72	5.01
SD 2	7.80	0.24	866.91	0.00	54.74	12.28	0.03	11.09	304.88	2858.58	11.70	4.62
SD 3	8.31	0.26	983.78	3.84	24.78	10.35	0.05	19.64	1637.78	3039.66	11.65	3.87
SD 4	8.18	0.29	734.94	0.24	26.22	9.23	0.03	13.18	587.23	3539.01	14.37	5.17
SD 5	7.84	0.26	902.29	0.44	32.31	17.40	0.03	12.16	947.28	3101.83	9.89	3.49
SD 6	8.15	0.29	938.03	86.01	19.81	10.83	0.05	16.32	1996.96	2998.75	10.69	4.78
SD 7	8.32	0.24	922.86	0.08	29.90	9.07	0.03	15.20	2256.92	2714.26	11.13	3.71
SD 8	7.94	0.28	1019.63	3.16	25.42	13.08	0.08	23.61	2702.29	3064.90	14.42	5.33
SD 9	8.34	0.32	835.00	0.09	24.78	12.12	0.04	16.38	520.23	4076.08	16.12	4.40
SD 10	8.06	0.25	713.06	3.70	17.24	4.74	0.05	14.36	5681.80	3333.13	9.75	4.41
SD 11	7.47	0.17	953.40	3.50	15.32	5.54	0.10	24.70	2879.59	2034.55	5.12	9.91
SD 12	8.19	0.24	1777.65	0.89	59.39	20.93	0.06	23.53	158.86	2949.70	9.04	12.86
SD 13	7.99	0.30	2003.65	5.66	53.14	27.34	0.13	39.53	1732.82	3916.14	11.66	7.26
SD 14	8.27	0.28	2229.97	79.54	42.72	38.40	0.09	28.81	219.80	3479.36	9.36	13.60
SD 15	7.88	0.29	1642.09	3.62	48.33	21.73	0.13	39.25	3027.22	3755.31	6.51	7.91
SD 16	7.75	0.27	1539.31	7.17	47.85	29.74	0.19	36.75	1931.50	3535.53	7.97	5.63
SD 17	7.46	0.22	1536.20	6.83	58.11	13.24	0.20	36.91	7346.30	3297.10	7.72	3.06
SD 18	7.54	0.22	1190.79	3.56	44.49	13.24	0.10	27.09	2314.17	3285.89	6.99	5.78
SD 19	8.42	0.24	1440.67	3.47	33.91	26.54	0.09	21.61	87.07	3331.99	9.16	27.48
SD 20	7.83	0.26	1902.53	3.54	63.56	32.95	0.09	30.79	1168.58	3786.04	12.26	15.84

Lake	pH	Cond (mS)	TKN (µg/L)	NO3+NO2 (µg/L)	TP (µg/L)	dP (µg/L)	Colour ABS	DOC (mg/L)	SiO2 (µg/L)	Alkalinity (µeq/L)	Na+ (mg/L)	K+ (mg/L)
SD 21	8.09	0.24	1086.84	2.89	26.22	14.52	0.05	17.30	243.20	3378.22	6.97	10.89
SD 22	8.12	0.33	2028.56	4.31	94.01	35.83	0.11	25.29	175.85	3562.11	10.11	23.55
SD 23	7.84	0.18	1225.49	2.88	31.99	23.81	0.08	21.87	339.13	2535.61	6.99	5.47
SD 24	7.93	0.28	1507.39	3.55	42.56	16.92	0.09	33.25	3224.16	4027.46	13.82	10.62
SD 25	7.72	0.22	1526.51	7.08	40.96	16.28	0.11	31.40	772.10	3089.14	6.18	4.69
SD 26	8.10	0.31	2234.27	9.35	83.75	35.83	0.21	43.89	4305.53	4494.04	8.70	5.19
SD 27	7.90	0.20	1640.61	6.39	70.13	23.01	0.08	21.75	94.51	2791.52	4.93	10.59
SD 28	8.10	0.27	1459.19	6.71	35.83	15.80	0.15	32.48	3234.70	3932.96	9.22	4.31
SD 29	8.15	0.27	1040.67	2.72	40.00	12.12	0.03	12.45	275.41	3468.39	5.99	15.92
SD 30	8.16	0.20	325.01	38.47	22.05	2.50	0.02	5.51	3585.54	1977.56	8.78	1.56
SD 31	7.38	0.28	2174.72	6.31	165.64	38.40	0.14	33.67	9537.99	3949.59	6.35	11.51
SD 32	7.95	0.25	870.02	2.44	29.90	9.23	0.04	14.50	469.69	3248.74	8.84	3.78
SD 33	7.94	0.15	1315.15	3.78	75.10	18.21	0.04	13.04	374.14	1668.61	4.24	5.91
SD 34	7.99	0.29	1812.50	3.96	68.04	27.02	0.10	31.92	8065.44	3839.50	13.76	9.40
SD 35	8.10	0.20	1225.01	2.93	31.83	15.96	0.04	14.91	432.34	2784.01	12.37	4.99
SD 36	7.96	0.38	2637.72	2.12	175.26	41.44	0.16	40.08	10256.26	3910.02	10.88	6.76
SD 37	8.16	0.35	2464.83	0.00	140.16	21.73	0.15	37.58	2629.95	3543.39	9.56	12.19
SD 38	8.28	0.29	713.34	0.52	20.93	9.71	0.03	13.66	5735.93	3298.55	13.00	4.10
SD 39	7.99	0.20	346.23	0.38	21.89	6.19	0.02	6.21	1901.01	2377.78	8.94	2.98
SD 40	8.26	0.25	620.48	0.81	23.17	9.55	0.03	10.95	419.71	3264.65	9.77	5.16
SD 41	7.95	0.21	308.25	0.27	19.33	3.94	0.02	5.77	2710.71	2072.00	8.46	1.58
SD R1	8.16	0.20	187.33	3.63	37.44	8.11	0.02	4.40	3438.88	1465.56	6.98	0.73
SD R2	8.11	0.16	208.25	4.28	30.87	5.38	0.02	4.75	3162.91	1350.38	7.08	0.75

Lake	pH	Cond (mS)	TKN (µg/L)	NO3+NO2 (µg/L)	TP (µg/L)	dP (µg/L)	Colour ABS	DOC (mg/L)	SiO2 (µg/L)	Alkalinity (µeq/L)	Na+ (mg/L)	K+ (mg/L)
SD R3	8.13	0.16	250.16	2.56	93.85	3.78	0.02	4.40	3145.01	1341.95	6.68	0.74
SD42	8.13	0.17	608.95	11.10	285.03	2.98	0.02	4.96	3040.61	1591.65	7.69	0.83

Lake	Mg++ (mg/L)	Ca++ (mg/L)	Cl- (mg/L)	NO3- (mg/L)	SO4-- (mg/L)	Chl-a (µg/L)
SD 1	13.00	38.90	6.56	0.00	3.70	0.83
SD 2	11.85	30.68	7.74	2.00	2.78	17.51
SD 3	16.04	35.22	8.65	0.00	3.56	1.33
SD 4	15.75	38.01	6.47	0.00	1.76	1.11
SD 5	15.21	35.62	6.54	0.00	2.64	8.48
SD 6	12.10	39.46	7.25	0.07	2.59	1.00
SD 7	12.04	30.41	7.73	0.00	0.80	4.57
SD 8	16.04	38.03	22.79	0.00	1.87	1.09
SD 9	20.64	43.40	8.83	0.00	3.32	2.83
SD 10	11.04	43.03	7.35	0.00	0.65	0.73
SD 11	9.27	22.56	3.73	0.00	0.15	1.20
SD 12	12.26	31.83	5.33	0.00	1.20	13.55
SD 13	21.67	39.57	3.89	0.00	1.89	1.14
SD 14	17.87	37.01	5.09	0.22	2.53	3.94
SD 15	19.05	43.49	3.41	0.00	0.62	9.51
SD 16	16.17	42.27	2.89	0.00	0.50	2.77
SD 17	16.90	39.16	2.67	0.00	0.85	7.57
SD 18	14.71	39.33	3.84	0.00	0.75	2.81

Lake	Mg++ (mg/L)	Ca++ (mg/L)	Cl- (mg/L)	NO3- (mg/L)	SO4-- (mg/L)	Chl-a (µg/L)
SD 19	17.89	25.85	7.99	0.00	1.31	0.87
SD 20	24.75	26.30	7.77	0.00	1.00	11.10
SD 21	13.59	41.69	4.11	0.00	1.90	1.47
SD 22	15.13	43.15	10.55	0.00	5.44	57.57
SD 23	11.28	30.85	3.28	0.00	1.77	0.64
SD 24	17.09	47.06	8.85	0.00	3.00	11.40
SD 25	14.55	38.36	2.39	0.00	1.30	9.04
SD 26	21.53	61.78	2.32	0.00	4.82	23.49
SD 27	10.88	34.28	2.13	0.00	1.34	27.62
SD 28	18.52	49.65	2.96	0.00	2.43	5.97
SD 29	14.29	45.17	6.35	0.00	5.12	3.20
SD 30	7.15	35.07	8.34	0.03	7.94	1.20
SD 31	14.03	51.30	3.65	0.00	0.54	4.00
SD 32	14.81	40.08	5.76	0.00	2.73	3.21
SD 33	6.62	21.01	2.61	0.00	1.75	10.93
SD 34	24.88	28.00	7.21	0.00	0.12	7.44
SD 35	15.39	25.09	9.03	0.00	0.67	1.43
SD 36	20.15	42.81	6.22	0.00	0.52	30.59
SD 37	20.20	32.61	4.84	0.00	0.71	18.07
SD 38	16.88	55.04	7.39	0.00	2.60	4.82
SD 39	8.84	38.42	9.58	0.00	5.32	1.29
SD 40	12.47	41.22	6.68	0.00	2.61	0.84
SD 41	7.50	33.05	7.99	0.00	5.19	1.48

Lake	Mg++ (mg/L)	Ca++ (mg/L)	Cl- (mg/L)	NO3- (mg/L)	SO4-- (mg/L)	Chl-a (µg/L)
SD R1	5.43	23.69	7.73	0.00	5.76	2.37
SD R2	5.47	23.96	7.67	0.00	5.72	2.84
SD R3	5.28	23.41	7.14	0.00	5.61	2.48
SD42	6.07	27.25	8.38	0.00	6.95	2.74

Table A3 Surface sediment diatoms from a spatial survey of Slave River Delta lakes, September 2002.

Taxon name	SD 1	SD 2	SD 3	SD 4	SD 5	SD 6	SD 7	SD 8	SD 9	SD 10	SD 11	SD 12	SD 13	SD 14
Achnanthes conspicua Mayer	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.14	0.00	1.45	1.15	1.75	0.00	0.25
Achnanthes hungarica (Grunow) Grunow	0.40	0.00	0.00	0.00	0.00	0.00	0.00	1.88	0.00	0.48	0.46	0.87	0.00	6.63
Achnanthes lanceolata var. *frequentissima* Lange-Bertalot	1.20	2.73	1.63	2.43	0.74	0.00	0.45	0.42	0.00	0.97	2.52	16.81	1.18	2.95
Achnanthes lanceolata var. *rostrata* Hustedt	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.77	0.00	0.00	0.00	0.00	0.00	0.00
Achnanthes minutissima Kützing	1.20	5.62	9.09	3.09	0.49	10.13	3.83	17.57	6.09	19.08	19.50	4.80	4.55	12.78
Amphora libyca Ehrenberg	1.80	1.20	0.85	2.21	0.25	1.20	1.58	1.88	2.58	0.24	1.83	0.00	2.53	0.98
Amphora pediculus (Kützing) Grunow	0.00	0.00	2.54	0.00	0.00	1.98	3.15	16.53	0.00	0.00	0.46	0.00	0.34	0.98
Amphora veneta Kützing	0.40	0.24	0.00	0.00	0.00	0.00	0.00	0.00	0.94	0.00	0.00	0.00	0.00	0.00
Caloneis bacillum (Grunow) Cleve	0.60	0.00	1.48	0.66	0.74	0.00	0.00	0.00	0.00	1.21	0.00	0.00	0.34	0.49
Caloneis silicula (Ehrenberg) Cleve	0.00	0.00	1.06	0.22	1.23	0.00	0.00	0.00	0.00	1.21	0.00	0.00	0.00	0.00
Cocconeis placentula small (<15µm)	9.60	6.11	8.25	15.45	0.49	12.56	1.13	2.30	6.09	2.90	0.69	12.88	1.01	3.19
Cocconeis placentula var. *euglypta* Ehrenberg	1.40	0.00	0.00	0.88	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Taxon name	SD 1	SD 2	SD 3	SD 4	SD 5	SD 6	SD 7	SD 8	SD 9	SD 10	SD 11	SD 12	SD 13	SD 14
Cocconeis placentula var. *placentula* Ehrenberg	10.00	2.44	13.53	18.10	3.92	21.37	3.83	3.14	4.68	5.31	3.90	18.56	4.71	25.06
Craticula halophila (Grunow) Cleve	0.60	0.73	0.85	0.22	0.98	0.00	0.00	0.21	2.11	0.24	0.00	0.87	0.51	0.25
Cyclostephanos cf. *tholiformis* Stoermer, Håkansson & Theriot	0.00	0.00	0.00	0.00	0.49	0.00	0.00	0.00	0.00	0.97	0.00	0.00	0.00	0.00
Cyclostephanos PAD sp.2 Hall et al. 2004	9.60	6.85	5.29	2.87	3.68	1.54	1.54	0.00	3.98	0.00	0.00	0.00	0.00	0.00
Cymbella microcephala Grunow	0.00	0.00	2.11	0.44	0.00	3.08	0.90	1.88	0.00	2.90	2.98	0.00	0.00	0.00
Cymbella minuta Hilse	0.00	0.49	0.00	0.00	0.00	0.00	0.00	1.26	0.00	1.21	0.92	0.00	0.00	0.00
Cymbella proxima Reimer	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.97	0.46	0.00	0.34	0.00
Diatoma moniliformis Kützing	0.00	0.73	1.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Diatoma tenuis Agardh	0.60	0.00	0.42	0.00	0.00	0.00	0.00	0.00	0.47	0.00	0.00	0.00	0.00	0.00
Epithemia adnata (Kützing) Brébisson	4.00	0.73	2.54	2.87	0.25	5.51	1.58	1.46	5.85	1.69	0.23	1.31	7.91	5.16
Epithemia turgida (Ehrenberg) Kützing	1.40	0.00	1.90	1.32	0.00	2.42	0.90	2.09	0.00	0.24	0.00	0.00	2.19	0.00
Eunotia bilunaris (Ehrenberg) Mills	0.60	0.00	0.63	0.44	0.49	0.44	0.23	2.09	0.70	1.93	0.46	1.09	0.34	0.00
Eunotia implicata Nörpel, Lange-Bertalot & Alles	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.26	0.00	0.48	0.00	0.00	0.00	0.00
Eunotia incisa W. Smith ex Gregory	0.00	0.00	0.00	0.22	0.49	0.00	0.00	1.26	0.00	0.00	0.69	0.00	0.34	0.00
Fragilaria brevistriata Grunow	0.00	0.00	0.00	0.00	0.00	0.00	0.45	0.00	0.00	0.00	0.46	0.00	0.17	0.00

Taxon name	SD 1	SD 2	SD 3	SD 4	SD 5	SD 6	SD 7	SD 8	SD 9	SD 10	SD 11	SD 12	SD 13	SD 14
Fragilaria capucina var. *gracilis* (Oestrup) Hustedt	0.00	0.00	0.00	1.32	1.47	1.32	0.00	0.21	0.47	0.97	12.16	0.00	0.34	0.00
Fragilaria capucina var. *rumpens* (Kützing) Lange-Bertalot	4.91	0.00	0.00	0.00	1.72	0.00	0.45	0.63	0.47	0.00	0.00	1.24	0.34	0.00
Fragilaria capucina var. *mesolepta* (Rabenhorst) Rabenhorst	5.29	1.96	0.85	3.09	0.98	0.66	0.45	0.00	0.47	0.00	0.00	2.47	1.35	0.00
Fragilaria construens (Ehrenberg) Grunow	0.00	0.00	0.00	0.00	0.00	0.00	0.45	0.84	0.00	0.00	0.00	0.00	2.19	0.00
Fragilaria construens f. *binodis* (Ehrenberg) Grunow	0.00	0.00	0.00	0.00	0.00	0.00	0.45	0.00	0.00	0.00	0.00	0.00	0.34	0.00
Fragilaria construens var. *venter* (Ehrenberg) Grunow	0.00	0.00	0.00	0.00	0.00	0.00	1.80	0.00	0.00	0.48	0.00	0.00	1.68	0.98
Fragilaria famelica (Kützing) Lange-Bertalot	0.00	0.00	0.00	1.77	0.00	1.76	0.00	0.00	0.00	0.48	0.00	0.00	0.00	0.00
Fragilaria pinnata Ehrenberg	0.80	0.00	0.63	0.00	0.00	0.00	45.05	0.42	0.00	0.24	0.00	0.00	12.79	0.00
Fragilaria pinnata var. *intercedens* Ehrenberg	0.00	0.00	0.00	0.00	0.00	0.00	2.48	0.21	0.00	0.00	0.00	0.00	17.00	0.00
Gomphonema acuminatum Ehrenberg	0.00	0.00	1.95	0.22	0.00	1.32	0.00	0.84	0.66	0.00	2.32	0.00	0.95	0.67
Gomphonema angustatum (Kützing) Rabenhorst	0.00	0.00	0.00	0.00	0.00	0.00	0.90	0.00	0.00	0.00	0.00	0.00	0.47	0.67
Gomphonema angustum Agardh	2.20	0.43	4.23	0.88	0.49	1.98	4.95	1.05	3.93	6.81	0.00	0.25	6.87	2.35

Taxon name	SD 1	SD 2	SD 3	SD 4	SD 5	SD 6	SD 7	SD 8	SD 9	SD 10	SD 11	SD 12	SD 13	SD 14
Gomphonema clavatum Ehrenberg	0.00	1.28	1.95	2.43	0.49	2.97	0.90	1.05	1.31	0.72	0.77	2.04	2.84	0.67
Gomphonema gracile Ehrenberg	0.00	0.00	0.00	0.00	0.49	0.00	0.90	1.46	0.66	1.79	1.29	0.00	0.00	0.67
Gomphonema minutum Agardh	2.20	1.71	1.30	0.00	2.94	1.32	0.45	1.05	1.97	0.00	1.55	0.51	0.47	3.69
Gomphonema parvulum (Kützing) Kützing	0.00	0.00	2.28	0.88	0.00	0.00	0.00	1.26	0.00	0.00	0.77	0.25	1.18	0.67
Gomphonema truncatum Ehrenberg	0.00	0.00	0.98	0.00	0.00	1.65	0.00	0.63	2.95	2.51	1.55	0.00	2.37	0.67
Gyrosigma attenuatum (Kützing) Rabenhorst	1.20	0.24	1.48	4.88	15.44	1.44	2.93	0.00	3.75	0.00	0.00	0.00	0.00	0.00
Navicula capitata var. *capitata* Ehrenberg	1.20	2.69	0.42	0.00	3.92	0.00	0.00	0.00	0.94	0.00	0.00	0.00	0.34	0.00
Navicula cryptocephala Kützing	7.20	4.65	0.42	2.65	9.07	2.20	2.03	1.26	6.32	3.38	2.98	1.97	0.84	3.19
Navicula cryptotenella Lange-Bertalot	1.20	9.05	4.02	2.87	3.43	9.03	3.38	3.56	1.64	0.97	1.61	0.66	4.21	1.47
Navicula cuspidata (Kützing) Kützing	0.80	0.24	0.00	0.00	0.98	0.00	0.00	0.00	0.70	0.00	0.00	0.00	0.17	0.25
Navicula laevissima Kützing	0.00	0.00	0.00	0.44	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.87	1.85	0.00
Navicula libonensis Schoeman	3.20	4.40	1.48	1.77	4.41	0.00	1.35	0.84	0.70	1.21	0.00	1.31	0.17	1.47
Navicula menisculus Schumann	0.00	6.60	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.44	0.00	0.00
Navicula minima Grunow	0.00	0.00	0.00	0.00	0.00	0.00	0.00	5.23	0.00	2.90	1.92	4.59	0.00	4.42

Taxon name	SD 1	SD 2	SD 3	SD 4	SD 5	SD 6	SD 7	SD 8	SD 9	SD 10	SD 11	SD 12	SD 13	SD 14
Navicula minuscula var. *muralis* (Grunow in Van Heurck) Lange-Beralot in Lange-Bertalot & Rumrich	0.00	1.22	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.44	0.00	0.00
Navicula oblonga (Kützing) Kützing	0.00	0.00	0.00	0.88	0.74	0.22	0.23	0.00	0.47	3.14	0.23	0.00	1.18	0.00
Navicula pupula Kützing	0.00	3.18	1.27	2.87	8.09	0.66	2.03	2.72	1.17	7.25	6.42	2.40	0.67	5.41
Navicula radiosa Kützing	2.40	0.24	1.48	1.55	0.74	2.64	1.80	2.30	2.11	5.80	1.15	0.44	0.00	0.74
Navicula SD sp.1	0.00	2.93	0.00	0.88	0.00	3.52	0.00	0.00	1.41	0.00	0.00	0.44	0.00	0.00
Navicula seminuloides Hustedt	0.00	0.49	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.09	0.00	0.49
Navicula seminulum Grunow	0.00	0.98	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.93	0.00	0.49
Navicula submuralis Hustedt	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.48	0.00	2.84	0.00	0.98
Navicula subplacentula Hustedt	0.60	0.60	0.63	0.60	0.25	0.60	0.23	0.00	1.17	0.00	0.00	0.00	0.00	0.00
Navicula trivialis Lange-Bertalot	0.80	0.49	0.00	0.88	4.66	0.00	0.68	0.00	1.87	0.00	0.00	1.31	0.34	1.23
Navicula veneta Kützing	0.00	2.69	1.27	0.00	1.47	0.00	0.23	0.00	0.94	0.24	0.46	0.87	0.00	0.00
Neidium ampliatum (Ehrenberg) Krammer	0.00	0.00	0.42	0.00	1.23	0.22	0.90	0.21	0.94	0.00	0.00	0.44	0.00	0.00
Nitzschia acicularis (Kützing) W. Smith	0.00	0.24	0.63	0.00	0.00	0.00	0.00	0.00	0.47	0.00	0.92	0.00	0.00	0.00
Nitzschia amphibia Grunow	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.18	0.00	1.69	2.15	3.49	4.55	1.72
Nitzschia fonticola Grunow	0.00	1.96	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 gracilis Hantzsch	0.20	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 Rabenhorst	0.20	0.24	0.85	1.32	0.98	0.00	0.00	1.05	0.94	1.21	0.00	0.00	0.00	0.49

Taxon name	SD 1	SD 2	SD 3	SD 4	SD 5	SD 6	SD 7	SD 8	SD 9	SD 10	SD 11	SD 12	SD 13	SD 14
Nitzschia palea (Kützing) W. Smith	3.40	6.60	1.06	5.30	3.19	2.86	0.90	1.67	6.09	1.69	3.44	0.87	0.34	0.98
Nitzschia paleacea Grunow	0.40	2.44	1.90	0.00	0.49	0.22	0.00	0.42	2.11	0.72	0.23	1.75	0.34	0.00
Nitzschia perminuta (Grunow) M. Peragallo	0.60	1.71	1.06	0.00	0.00	0.00	0.00	0.00	0.00	0.72	0.00	0.00	0.00	0.00
Nitzschia radicula Hustedt	0.00	3.18	0.00	0.22	0.00	0.44	0.00	0.00	0.00	0.00	0.00	0.44	0.34	0.00
Nitzschia recta Hantzsch	2.00	0.98	0.63	0.66	3.92	0.00	0.45	0.00	2.58	1.21	0.92	0.00	0.00	0.00
Nitzschia sigmoidia (Ehrenberg) W. Smith	0.00	0.24	1.48	0.00	1.96	0.00	0.23	0.00	0.47	0.48	0.69	0.00	0.17	0.00
Pinnularia interrupta W. Smith	0.40	0.00	0.00	0.00	0.00	1.32	0.68	0.21	0.00	0.00	0.00	0.00	0.00	0.00
Pinnularia microstauron (Ehrenberg) Cleve	0.00	0.49	0.00	0.00	0.00	0.00	0.00	1.05	0.00	1.45	1.38	0.22	0.34	0.00
Rhopalodia gibba (Ehrenberg) O. Müller	1.40	0.73	2.33	1.10	0.00	1.76	3.15	0.42	5.85	2.17	0.00	0.22	2.02	0.00
Stauroneis anceps Ehrenberg	2.40	0.98	0.00	1.32	4.90	0.22	0.23	0.21	1.64	0.72	13.07	0.00	0.17	0.00
Stauroneis phoenicenteron (Nitzsch) Ehrenberg	1.00	0.00	0.00	0.00	2.21	0.00	0.00	0.00	0.47	0.48	0.46	0.00	0.34	0.00
Stauroneis SD sp.1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.69	0.00	2.18	0.00	0.00
Stephanodiscus minutulus (Kützing) Cleve & Möller	0.00	1.22	2.96	0.88	1.23	0.22	0.00	0.00	4.68	0.72	0.00	0.00	0.34	2.70
Stephanodiscus parvus Stoermer & Håkansson	1.60	0.24	0.42	0.00	0.98	0.22	0.00	0.00	0.70	0.00	0.00	0.00	0.00	0.25
Surirella angusta Kützing	0.40	0.00	0.42	0.66	0.00	0.00	0.00	0.00	0.00	0.48	0.00	0.00	0.00	0.00

Taxon name	SD 1	SD 2	SD 3	SD 4	SD 5	SD 6	SD 7	SD 8	SD 9	SD 10	SD 11	SD 12	SD 13	SD 14
Surirella minuta Brebissonii ex Kützing	1.20	0.00	0.00	0.22	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Synedra ulna var. *acus* Ehrenberg	0.40	0.00	0.00	0.00	0.98	0.44	0.23	0.00	0.00	0.00	0.69	0.22	0.00	0.00
Tabellaria flocculosa (Roth) Kützing	0.00	0.00	1.48	0.66	0.00	0.00	0.00	0.00	0.23	0.24	0.69	0.00	0.00	0.00

Taxon name	SD 15	SD 16	SD 17	SD 18	SD 19	SD 20	SD 21	SD 22	SD 23	SD 24	SD 25	SD 26	SD 27	SD 28
Achnanthes conspicua Mayer	0.00	0.00	0.00	0.00	1.14	0.00	0.00	0.23	0.43	0.36	0.00	1.10	0.44	0.00
Achnanthes hungarica (Grunow) Grunow	0.63	0.54	1.22	1.46	1.14	1.01	1.09	3.67	0.86	0.00	0.24	1.47	2.21	0.00
Achnanthes lanceolata var. *frequentissima* Lange-Bertalot	2.54	4.12	4.01	3.88	3.86	2.02	1.31	1.38	11.23	4.68	0.73	8.29	11.48	0.47
Achnanthes lanceolata var. *rostrata* Hustedt	1.38	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.36	0.00	0.00	0.88	0.00
Achnanthes minutissima Kützing	7.19	11.11	1.22	8.25	10.23	2.42	38.34	8.03	9.94	4.86	27.43	11.60	8.17	1.89
Amphora libyca Ehrenberg	2.96	2.69	0.17	1.46	1.59	0.00	0.00	0.69	0.86	1.62	0.00	2.21	0.44	0.24
Amphora pediculus (Kützing) Grunow	0.21	5.20	7.85	1.46	1.36	0.00	1.09	0.46	0.00	0.36	0.97	0.37	0.00	0.00
Amphora veneta Kützing	1.06	0.00	0.35	0.00	2.27	1.21	0.44	0.46	0.00	0.00	0.00	0.37	0.00	0.00
Caloneis bacillum (Grunow) Cleve	0.00	0.00	0.00	0.49	0.00	0.00	0.00	0.46	0.00	0.54	0.00	0.00	0.00	0.00
Caloneis silicula (Ehrenberg) Cleve	0.00	0.00	1.05	0.49	0.00	0.00	0.00	0.00	0.00	0.36	0.00	0.00	0.00	0.00

Taxon name	SD 15	SD 16	SD 17	SD 18	SD 19	SD 20	SD 21	SD 22	SD 23	SD 24	SD 25	SD 26	SD 27	SD 28
Cocconeis placentula small (<15µm)	5.07	6.27	4.54	4.61	8.18	26.81	4.36	11.24	7.99	2.16	8.01	8.84	11.70	7.57
Cocconeis placentula var. *euglypta* Ehrenberg	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 var. *placentula* Ehrenberg	14.16	18.28	15.01	15.53	7.73	14.31	6.54	31.88	12.74	2.70	13.83	14.36	22.08	5.91
Craticula halophila (Grunow) Cleve	0.85	0.00	0.17	0.24	0.91	0.81	0.44	0.23	0.65	0.00	0.24	0.00	0.44	0.00
Cyclostephanos cf. *tholiformis* Stoermer, Håkansson & Theriot	0.00	0.00	0.87	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	10.17
Cyclostephanos PAD sp.2 Hall et al. 2004	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 microcephala Grunow	0.42	1.43	1.22	0.24	0.91	0.00	2.40	0.00	0.00	0.00	0.24	0.55	0.00	0.00
Cymbella minuta Hilse	0.21	0.36	1.22	0.24	0.00	0.00	0.44	0.00	0.00	0.00	0.49	0.00	0.66	0.00
Cymbella proxima Reimer	0.00	0.18	0.17	0.00	0.00	0.00	0.00	0.23	0.00	0.00	0.24	0.37	0.00	0.00
Diatoma moniliformis Kützing	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
Diatoma tenuis Agardh	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	1.42
Epithemia adnata (Kützing) Brébisson	2.54	1.43	2.79	0.24	8.86	2.62	1.31	5.96	0.22	1.80	2.67	2.58	0.66	0.00
Epithemia turgida (Ehrenberg) Kützing	0.42	0.18	0.35	1.21	0.68	0.00	0.00	1.15	0.65	0.54	0.00	0.37	0.00	0.00
Eunotia bilunaris (Ehrenberg) Mills	0.48	0.08	2.09	1.94	0.00	0.00	0.00	0.46	0.65	0.36	0.00	0.37	0.00	0.71

Taxon name	SD 15	SD 16	SD 17	SD 18	SD 19	SD 20	SD 21	SD 22	SD 23	SD 24	SD 25	SD 26	SD 27	SD 28
Eunotia implicata Nörpel, Lange-Bertalot & Alles	0.00	0.54	0.52	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.44	0.00
Eunotia incisa W. Smith ex Gregory	0.00	0.36	1.22	0.97	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Fragilaria brevistriata Grunow	0.21	0.00	0.00	0.00	0.00	0.40	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.95
Fragilaria capucina var. *gracilis* (Oestrup) Hustedt	0.00	0.72	1.22	1.46	0.00	1.13	0.40	0.46	0.52	2.16	1.46	0.18	0.00	4.82
Fragilaria capucina var. *rumpens* (Kützing) Lange-Bertalot	0.00	0.00	0.00	0.73	0.00	2.26	0.40	0.46	1.04	0.48	1.70	0.00	0.00	0.00
Fragilaria capucina var. *mesolepta* (Rabenhorst) Rabenhorst	1.06	0.00	1.05	0.00	2.05	2.26	4.86	4.13	11.40	3.12	2.91	3.13	1.32	11.25
Fragilaria construens (Ehrenberg) Grunow	0.00	0.00	0.35	0.00	0.00	0.00	0.00	0.00	0.43	0.00	0.00	0.00	0.00	0.24
Fragilaria construens f. *binodis* (Ehrenberg) Grunow	0.00	0.36	1.22	0.00	0.00	0.00	0.00	0.00	0.00	1.62	0.00	0.00	0.00	0.00
Fragilaria construens var. *venter* (Ehrenberg) Grunow	0.21	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.22	0.36	0.00	0.18	0.00	0.00
Fragilaria famelica (Kützing) Lange-Bertalot	0.00	0.00	0.00	0.00	0.00	0.40	0.00	0.00	6.26	0.00	0.00	0.00	0.44	0.24
Fragilaria pinnata Ehrenberg	0.21	1.08	2.97	0.00	0.00	0.00	0.00	0.00	0.43	35.61	0.73	0.37	0.00	0.24
Fragilaria pinnata var. *intercedens* Ehrenberg	0.21	0.00	2.79	0.00	0.00	0.00	0.00	0.00	0.00	18.53	1.70	0.00	0.00	0.24

Taxon name	SD 15	SD 16	SD 17	SD 18	SD 19	SD 20	SD 21	SD 22	SD 23	SD 24	SD 25	SD 26	SD 27	SD 28
Gomphonema acuminatum Ehrenberg	0.00	1.02	1.99	0.00	0.00	0.00	0.32	0.25	0.00	0.51	0.82	0.49	0.52	0.00
Gomphonema angustatum (Kützing) Rabenhorst	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 angustum Agardh	3.09	2.04	3.48	0.00	1.50	1.91	0.64	2.02	0.00	2.81	5.34	1.95	0.52	4.73
Gomphonema clavatum Ehrenberg	3.86	2.30	2.49	2.74	1.50	2.23	1.27	1.01	0.22	0.51	2.46	2.68	1.55	1.89
Gomphonema gracile Ehrenberg	0.00	0.51	2.49	4.38	0.00	1.27	0.64	0.25	0.43	0.00	0.00	0.00	0.52	0.00
Gomphonema minutum Agardh	3.09	1.02	3.73	5.20	2.40	5.09	3.82	1.01	1.51	0.51	0.00	0.49	1.55	1.89
Gomphonema parvulum (Kützing) Kützing	0.00	0.51	0.50	0.55	0.00	0.00	0.32	0.25	0.86	0.51	1.23	0.00	1.03	0.00
Gomphonema truncatum Ehrenberg	1.16	1.02	0.50	0.00	2.10	1.59	1.27	0.25	0.86	0.00	0.82	1.95	0.52	0.00
Gyrosigma attenuatum (Kützing) Rabenhorst	0.00	1.27	0.00	0.00	0.00	0.00	0.22	0.00	0.00	0.00	0.00	0.00	0.00	0.47
Navicula capitata var. *capitata* Ehrenberg	2.54	3.58	0.00	0.00	1.59	0.00	0.00	0.00	0.00	0.72	0.00	0.74	0.00	0.00
Navicula cryptocephala Kützing	4.44	2.33	1.05	4.13	4.09	3.02	3.27	2.06	1.51	0.36	1.21	0.00	0.88	4.26
Navicula cryptotenella Lange-Bertalot	2.54	1.43	2.62	1.94	2.95	1.41	2.18	2.75	0.86	1.08	2.91	2.58	0.22	2.60
Navicula cuspidata (Kützing) Kützing	0.42	0.36	0.17	0.24	0.45	0.40	0.00	0.00	0.00	0.18	0.24	0.00	0.00	0.00
Navicula laevissima Kützing	0.42	0.18	0.00	0.97	0.00	1.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Taxon name	SD 15	SD 16	SD 17	SD 18	SD 19	SD 20	SD 21	SD 22	SD 23	SD 24	SD 25	SD 26	SD 27	SD 28
Navicula libonensis Schoeman	0.42	1.08	0.00	0.00	7.73	0.60	1.31	1.61	0.00	0.36	0.00	0.55	0.22	1.42
Navicula menisculus Schumann	0.42	0.00	0.00	0.00	0.00	0.00	0.22	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Navicula minima Grunow	2.42	2.36	0.00	1.70	10.45	6.05	3.49	9.86	6.91	2.34	1.94	11.60	17.88	0.00
Navicula minuscula var. *muralis* (Grunow in Van Heurck) Lange-Beralot in Lange-Bertalot & Rumrich	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	0.47
Navicula oblonga (Kützing) Kützing	0.21	0.00	0.00	1.94	0.00	0.40	0.00	0.00	0.00	0.18	0.00	0.00	0.66	0.00
Navicula pupula Kützing	6.34	4.30	1.05	3.40	4.55	1.21	2.18	2.06	4.54	1.08	3.40	4.24	3.53	0.00
Navicula radiosa Kützing	2.75	3.76	3.66	7.28	0.00	0.40	0.65	0.00	0.43	0.90	3.64	0.37	0.88	1.65
Navicula SD sp.1	2.11	0.36	0.00	0.00	0.00	0.00	0.22	0.00	0.00	0.00	0.00	0.00	0.00	8.51
Navicula seminuloides Hustedt	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 seminulum Grunow	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 submuralis Hustedt	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.44	0.00
Navicula subplacentula Hustedt	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 trivialis Lange-Bertalot	2.11	0.18	0.00	1.94	0.45	0.00	0.65	0.00	3.89	0.00	0.24	0.92	0.88	0.95
Navicula veneta Kützing	0.42	0.00	0.17	0.49	2.73	0.00	0.00	0.00	0.43	0.36	0.00	0.74	0.00	0.00
Neidium ampliatum (Ehrenberg) Krammer	0.21	0.72	0.17	0.24	0.45	0.81	0.44	0.69	0.00	0.36	0.24	0.74	0.44	0.00
Nitzschia acicularis (Kützing) W. Smith	0.00	0.00	0.00	0.00	0.00	0.00	0.44	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Nitzschia amphibia Grunow	1.84	1.79	2.27	1.70	1.14	3.02	0.65	0.46	2.81	0.90	1.94	4.97	1.32	0.95

Taxon name	SD 15	SD 16	SD 17	SD 18	SD 19	SD 20	SD 21	SD 22	SD 23	SD 24	SD 25	SD 26	SD 27	SD 28
Nitzschia fonticola Grunow	0.42	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 gracilis Hantzsch	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 Rabenhorst	1.06	0.00	0.52	0.97	0.45	0.00	1.09	0.46	0.00	0.00	0.49	0.74	0.00	0.47
Nitzschia palea (Kützing) W. Smith	2.96	1.08	2.09	6.55	1.59	3.63	5.45	0.69	5.62	1.26	3.88	2.21	1.99	4.49
Nitzschia paleacea Grunow	0.63	0.00	0.35	0.73	0.00	0.81	0.44	0.00	0.86	0.00	0.49	0.37	0.00	1.42
Nitzschia perminuta (Grunow) M. Peragallo	0.00	0.00	0.00	0.00	0.68	0.40	0.65	0.00	0.00	0.00	0.73	0.00	0.00	0.47
Nitzschia radicula Hustedt	0.42	0.00	0.52	0.49	0.91	0.40	2.18	0.23	0.43	0.36	0.97	0.00	0.44	0.95
Nitzschia recta Hantzsch	1.90	1.79	0.70	1.46	0.00	0.40	0.00	0.00	0.00	0.00	0.97	0.37	0.00	2.13
Nitzschia sigmoidia (Ehrenberg) W. Smith	0.00	0.54	0.17	0.97	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.37	0.00	0.00
Pinnularia interrupta W. Smith	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.49	0.55	0.00	0.00
Pinnularia microstauron (Ehrenberg) Cleve	0.42	0.36	0.35	0.97	0.00	0.00	0.44	0.00	0.43	0.00	0.00	0.55	0.44	0.00
Rhopalodia gibba (Ehrenberg) O. Müller	0.00	0.00	0.52	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.49	1.47	0.00	0.24
Stauroneis anceps Ehrenberg	1.90	1.25	0.87	0.73	0.00	0.00	0.00	0.00	0.22	0.00	0.24	0.00	0.44	1.18
Stauroneis phoenicenteron (Nitzsch) Ehrenberg	0.00	0.18	0.17	0.73	0.45	0.00	0.00	0.00	0.43	0.00	0.00	0.00	0.22	0.00
Stauroneis SD sp.1	0.85	0.90	0.00	0.00	0.00	0.00	0.00	0.00	0.22	0.00	0.00	0.00	0.00	0.00
Stephanodiscus minutulus (Kützing) Cleve & Möller	0.00	0.00	0.35	0.00	0.00	0.00	0.00	0.69	0.00	0.00	0.00	0.37	0.00	2.60

Taxon name	SD 15	SD 16	SD 17	SD 18	SD 19	SD 20	SD 21	SD 22	SD 23	SD 24	SD 25	SD 26	SD 27	SD 28
Stephanodiscus parvus Stoermer & Håkansson	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.18	0.00	0.47
Surirella angusta Kützing	0.42	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.47
Surirella minuta Brebissonii ex Kützing	0.21	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
Synedra ulna var. *acus* Ehrenberg	0.00	0.18	1.40	1.21	0.00	0.20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.42
Tabellaria flocculosa (Roth) Kützing	0.00	0.00	0.35	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.89

Taxon name	SD 29	SD 30	SD 31	SD 32	SD 33	SD 34	SD 35	SD 36	SD 37	SD 38	SD 39	SD 40	SD 41
Achnanthes conspicua Mayer	0.48	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.91
Achnanthes hungarica (Grunow) Grunow	0.00	0.00	0.00	0.00	0.00	0.69	0.00	0.00	0.00	0.24	0.00	0.00	0.23
Achnanthes lanceolata var. *frequentissima* Lange-Bertalot	5.26	8.00	13.40	0.00	3.20	0.69	3.39	4.24	1.87	3.65	0.59	11.52	5.69
Achnanthes lanceolata var. *rostrata* Hustedt	0.00	0.00	0.00	0.00	0.00	0.00	1.38	0.00	3.98	0.00	0.00	0.00	0.00
Achnanthes minutissima Kützing	6.94	33.00	1.60	5.78	5.95	0.46	4.54	2.42	0.00	23.84	19.84	15.20	9.34
Amphora libyca Ehrenberg	1.67	0.00	0.00	1.45	4.81	1.15	1.38	0.81	0.94	2.43	1.96	1.23	0.46
Amphora pediculus (Kützing) Grunow	0.00	3.00	0.00	0.48	0.00	0.00	0.99	0.00	0.00	0.00	0.00	0.00	0.00
Amphora veneta Kützing	0.48	0.00	0.00	0.00	0.00	1.61	0.00	0.00	0.00	0.24	0.39	0.00	0.00
Caloneis bacillum (Grunow) Cleve	0.00	0.00	0.40	0.00	0.46	0.00	0.00	0.00	0.00	0.49	0.00	0.00	0.00

Taxon name	SD 29	SD 30	SD 31	SD 32	SD 33	SD 34	SD 35	SD 36	SD 37	SD 38	SD 39	SD 40	SD 41
Caloneis silicula (Ehrenberg) Cleve	0.48	0.00	0.00	0.24	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cocconeis placentula small (<15µm)	10.29	0.00	0.00	1.69	9.15	31.03	7.10	5.25	12.88	9.00	2.95	5.64	2.51
Cocconeis placentula var. *euglypta* Ehrenberg	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.39	0.49	0.46
Cocconeis placentula var. *placentula* Ehrenberg	6.46	2.00	0.00	3.61	10.07	24.83	14.00	10.71	12.41	10.46	7.86	4.41	4.10
Craticula halophila (Grunow) Cleve	0.96	2.00	5.00	3.13	1.14	0.00	0.99	3.23	0.47	0.00	0.00	0.00	0.00
Cyclostephanos cf. *tholiformis* Stoermer, Håkansson & Theriot	0.00	2.00	0.00	2.00	0.00	0.00	0.00	0.00	0.00	0.00	4.72	0.00	1.14
Cyclostephanos PAD sp.2 Hall et al. 2004	0.00	0.00	0.00	6.75	0.00	0.00	0.00	0.00	0.00	2.92	0.00	3.43	0.00
Cymbella microcephala Grunow	0.00	3.00	0.40	1.93	1.60	0.00	0.00	0.40	0.00	1.70	0.00	0.74	0.00
Cymbella minuta Hilse	0.00	0.00	0.00	0.00	0.00	0.00	0.39	0.00	0.47	0.00	0.79	0.00	0.68
Cymbella proxima Reimer	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.40	0.00	0.00	0.00	0.00	0.00
Diatoma moniliformis Kützing	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
Diatoma tenuis Agardh	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
Epithemia adnata (Kützing) Brébisson	4.78	0.00	0.00	0.24	1.14	0.23	2.17	2.22	2.34	1.22	1.38	2.94	1.14
Epithemia turgida (Ehrenberg) Kützing	0.00	0.00	0.00	0.00	0.00	0.00	0.79	0.40	0.00	0.73	0.79	0.74	1.37

Taxon name	SD 29	SD 30	SD 31	SD 32	SD 33	SD 34	SD 35	SD 36	SD 37	SD 38	SD 39	SD 40	SD 41
Eunotia bilunaris (Ehrenberg) Mills	0.00	0.00	1.00	0.00	0.00	0.46	0.00	2.02	0.23	0.49	1.57	0.25	1.59
Eunotia implicata Nörpel, Lange-Bertalot & Alles	0.00	0.00	0.00	0.00	0.46	0.46	0.00	0.00	0.47	0.00	0.39	0.00	0.00
Eunotia incisa W. Smith ex Gregory	0.00	0.00	1.20	0.00	0.23	0.23	0.00	1.82	0.00	0.00	0.39	0.00	0.46
Fragilaria brevistriata Grunow	0.00	0.00	0.00	0.00	0.00	2.30	0.00	0.00	0.47	0.00	0.00	0.00	0.00
Fragilaria capucina var. *gracilis* (Oestrup) Hustedt	0.24	0.00	2.40	0.74	1.37	0.23	0.94	1.62	1.64	1.67	1.38	0.00	1.90
Fragilaria capucina var. *rumpens* (Kützing) Lange-Bertalot	0.24	0.00	0.00	0.74	0.00	0.00	2.20	0.61	3.04	0.33	1.38	0.00	1.90
Fragilaria capucina var. *mesolepta* (Rabenhorst) Rabenhorst	0.96	7.00	0.00	3.34	2.97	0.23	11.65	1.41	2.58	6.02	2.75	2.45	7.59
Fragilaria construens (Ehrenberg) Grunow	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
Fragilaria construens f. *binodis* (Ehrenberg) Grunow	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
Fragilaria construens var. *venter* (Ehrenberg) Grunow	0.00	4.00	0.00	0.00	0.00	0.46	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Fragilaria famelica (Kützing) Lange-Bertalot	0.00	0.00	0.00	0.00	1.37	0.00	0.59	2.42	0.94	0.00	0.00	0.00	0.00
Fragilaria pinnata Ehrenberg	0.00	0.00	1.00	1.93	0.00	5.29	0.00	0.40	0.94	0.00	0.79	0.00	0.46

Taxon name	SD 29	SD 30	SD 31	SD 32	SD 33	SD 34	SD 35	SD 36	SD 37	SD 38	SD 39	SD 40	SD 41
Fragilaria pinnata var. *intercedens* Ehrenberg	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.39	0.00	0.00
Gomphonema acuminatum Ehrenberg	0.00	0.00	1.80	0.47	1.06	0.57	1.62	1.11	0.70	3.14	1.83	0.94	0.30
Gomphonema angustatum (Kützing) Rabenhorst	0.00	0.00	0.00	0.00	0.00	1.14	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Gomphonema angustum Agardh	0.00	2.00	0.00	3.75	0.00	0.57	2.60	1.78	0.00	2.69	5.50	3.12	1.18
Gomphonema clavatum Ehrenberg	1.20	0.00	1.80	0.94	1.86	1.99	2.27	5.10	0.94	0.90	4.58	0.62	0.00
Gomphonema gracile Ehrenberg	0.00	0.00	0.00	0.00	1.06	0.00	0.00	0.89	1.17	0.90	0.00	0.00	0.00
Gomphonema minutum Agardh	0.00	0.00	1.20	1.41	2.12	4.54	0.00	4.22	0.00	0.90	3.06	1.25	0.59
Gomphonema parvulum (Kützing) Kützing	0.00	0.00	0.00	0.47	0.53	0.00	0.65	0.44	0.23	0.00	1.22	0.94	0.89
Gomphonema truncatum Ehrenberg	0.48	0.00	0.00	1.88	0.00	0.85	2.92	0.00	0.00	0.00	0.31	0.00	0.00
Gyrosigma attenuatum (Kützing) Rabenhorst	0.24	0.00	0.00	4.58	0.00	0.00	0.00	0.00	0.00	1.22	0.59	2.98	2.98
Navicula capitata var. *capitata* Ehrenberg	0.48	0.00	0.00	0.00	1.60	0.00	0.00	0.00	0.00	0.49	0.20	0.49	0.00
Navicula cryptocephala Kützing	9.81	3.00	1.80	9.88	5.72	0.92	4.14	0.40	6.09	2.43	2.55	1.72	1.14
Navicula cryptotenella Lange-Bertalot	1.67	6.00	0.00	2.41	0.23	1.15	4.34	2.22	1.64	1.95	0.39	1.72	0.91

Taxon name	SD 29	SD 30	SD 31	SD 32	SD 33	SD 34	SD 35	SD 36	SD 37	SD 38	SD 39	SD 40	SD 41
Navicula cuspidata (Kützing) Kützing	0.72	1.00	0.20	1.45	0.46	0.00	1.18	0.40	0.00	0.00	0.20	0.00	0.00
Navicula laevissima Kützing	0.48	0.00	0.00	0.00	0.92	0.92	0.00	0.61	0.00	0.00	0.00	0.00	0.00
Navicula libonensis Schoeman	0.00	0.00	0.00	1.93	1.14	0.00	1.18	0.00	0.00	0.00	0.39	1.47	0.46
Navicula menisculus Schumann	0.48	0.00	0.00	0.48	0.00	0.00	0.39	0.20	0.00	0.00	0.00	0.00	0.00
Navicula minima Grunow	5.98	0.00	56.00	0.00	9.38	4.14	10.20	11.72	11.48	0.00	0.00	0.00	0.00
Navicula minuscula var. *muralis* (Grunow in Van Heurck) Lange-Beralot in Lange-Bertalot & Rumrich	0.00	0.00	0.00	0.00	0.46	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Navicula oblonga (Kützing) Kützing	0.00	0.00	0.00	0.24	0.00	0.00	0.20	0.00	0.00	0.73	0.00	0.25	2.51
Navicula pupula Kützing	5.50	5.00	0.40	4.10	11.90	0.92	4.34	6.26	3.98	2.68	1.18	1.96	2.28
Navicula radiosa Kützing	0.48	0.00	0.40	1.20	1.37	0.23	6.51	0.61	0.23	0.73	1.77	1.72	1.59
Navicula SD sp.1	2.15	0.00	0.00	0.00	0.00	0.00	0.20	0.00	0.00	3.41	0.00	0.74	0.00
Navicula seminuloides Hustedt	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 seminulum Grunow	0.48	0.00	0.40	0.00	0.46	0.00	0.00	0.00	0.94	0.00	0.00	0.00	1.37
Navicula submuralis Hustedt	1.44	0.00	0.00	0.00	0.00	0.00	0.39	0.00	0.00	0.00	0.00	0.00	1.82
Navicula subplacentula Hustedt	0.00	3.00	0.00	2.41	0.00	0.00	0.00	0.00	0.00	1.46	0.20	0.20	0.20
Navicula trivialis Lange-Bertalot	0.72	0.00	0.00	3.86	1.83	0.00	0.39	0.00	0.00	0.00	0.98	0.00	0.00
Navicula veneta Kützing	0.00	0.00	0.00	1.93	0.69	0.00	0.39	0.00	1.41	0.97	0.79	0.00	0.00
Neidium ampliatum (Ehrenberg) Krammer	0.48	0.00	0.00	0.48	0.00	0.69	0.00	0.00	0.23	0.00	0.00	0.00	0.00

Taxon name	SD 29	SD 30	SD 31	SD 32	SD 33	SD 34	SD 35	SD 36	SD 37	SD 38	SD 39	SD 40	SD 41
Nitzschia acicularis (Kützing) W. Smith	0.24	0.00	0.00	1.20	0.00	0.00	0.20	2.22	2.34	0.00	2.95	1.23	1.14
Nitzschia amphibia Grunow	2.87	0.00	2.40	0.00	2.29	1.84	1.84	2.22	6.32	1.22	0.00	0.00	0.00
Nitzschia fonticola Grunow	0.48	0.00	0.00	0.00	0.00	0.00	0.39	0.00	0.00	0.00	0.39	0.49	0.00
Nitzschia gracilis Hantzsch	0.24	0.00	0.00	0.48	0.00	0.00	0.00	0.00	0.00	0.49	0.00	0.49	1.37
Nitzschia liebetruthii Rabenhorst	0.72	0.00	0.20	0.96	0.23	0.00	0.79	0.81	1.41	0.00	0.79	0.00	0.46
Nitzschia palea (Kützing) W. Smith	14.59	8.00	3.40	6.99	5.49	0.23	4.93	2.42	4.92	0.73	3.93	5.64	9.11
Nitzschia paleacea Grunow	0.96	0.00	0.00	0.96	0.46	0.00	1.78	0.61	0.70	0.49	1.38	0.98	2.96
Nitzschia perminuta (Grunow) M. Peragallo	0.72	2.00	0.00	0.72	0.00	0.00	0.39	0.00	0.70	0.49	3.14	0.00	0.68
Nitzschia radicula Hustedt	0.48	0.00	0.00	0.48	0.92	0.46	1.18	0.40	0.47	0.24	0.20	0.98	2.73
Nitzschia recta Hantzsch	1.67	1.00	0.00	1.93	0.46	0.00	0.99	0.40	0.00	0.73	1.57	1.96	1.14
Nitzschia sigmoidia (Ehrenberg) W. Smith	0.48	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.24	0.00	0.00	0.46
Pinnularia interrupta W. Smith	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 microstauron (Ehrenberg) Cleve	0.72	0.00	0.60	1.45	0.00	0.00	0.79	1.62	0.00	0.00	0.00	0.00	0.00
Rhopalodia gibba (Ehrenberg) O. Müller	0.00	0.00	0.00	4.10	0.00	0.00	0.99	0.81	0.00	0.73	0.39	3.19	2.96
Stauroneis anceps Ehrenberg	0.72	0.00	2.00	1.69	0.00	0.23	1.97	0.40	1.17	0.24	0.00	1.72	0.68

Taxon name	SD 29	SD 30	SD 31	SD 32	SD 33	SD 34	SD 35	SD 36	SD 37	SD 38	SD 39	SD 40	SD 41
Stauroneis phoenicenteron (Nitzsch) Ehrenberg	0.00	0.00	0.40	0.48	0.23	0.00	0.00	0.00	0.23	0.00	0.20	0.25	0.46
Stauroneis SD sp.1	0.48	0.00	0.00	0.00	0.00	0.46	0.39	0.00	0.00	0.00	0.39	0.00	0.00
Stephanodiscus minutulus (Kützing) Cleve & Möller	0.00	1.00	0.00	0.48	0.46	1.84	0.20	4.24	0.00	1.70	1.18	0.00	0.23
Stephanodiscus parvus Stoermer & Håkansson	0.00	1.00	0.00	0.24	0.00	0.00	0.00	1.41	0.00	0.00	0.59	0.00	0.00
Surirella angusta Kützing	0.00	2.00	0.00	0.00	0.00	0.00	0.39	0.00	0.00	0.00	0.00	0.00	0.00
Surirella minuta Brebissonii ex Kützing	0.24	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.23
Synedra ulna var. *acus* Ehrenberg	0.24	0.00	0.00	0.00	0.00	0.92	0.00	0.00	0.23	0.00	1.18	0.00	0.46
Tabellaria flocculosa (Roth) Kützing	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.47	0.00	0.00	0.00	0.00

Appendix B

Slave River Delta seasonal, inter-annual and paleolimnological study lakes

The following appendix provides photographs of the study lakes (SD2, SD15, SD20, SD28, SD29, SD33 and SD39) and diatom percent abundance data from Chapters 3, 4 and 5.

Figure B1 Photo of lake SD2 in July 2004.

Figure B2 Photo of lake SD15 in July 2004.

Figure B3 Photo of lake SD20 in July 2004.

Figure B4 Photo of lake SD28 in September 2004.

Figure B5 Photo of lake SD29 in July 2004.

Figure B6 Photo of lake SD33 in July 2004.

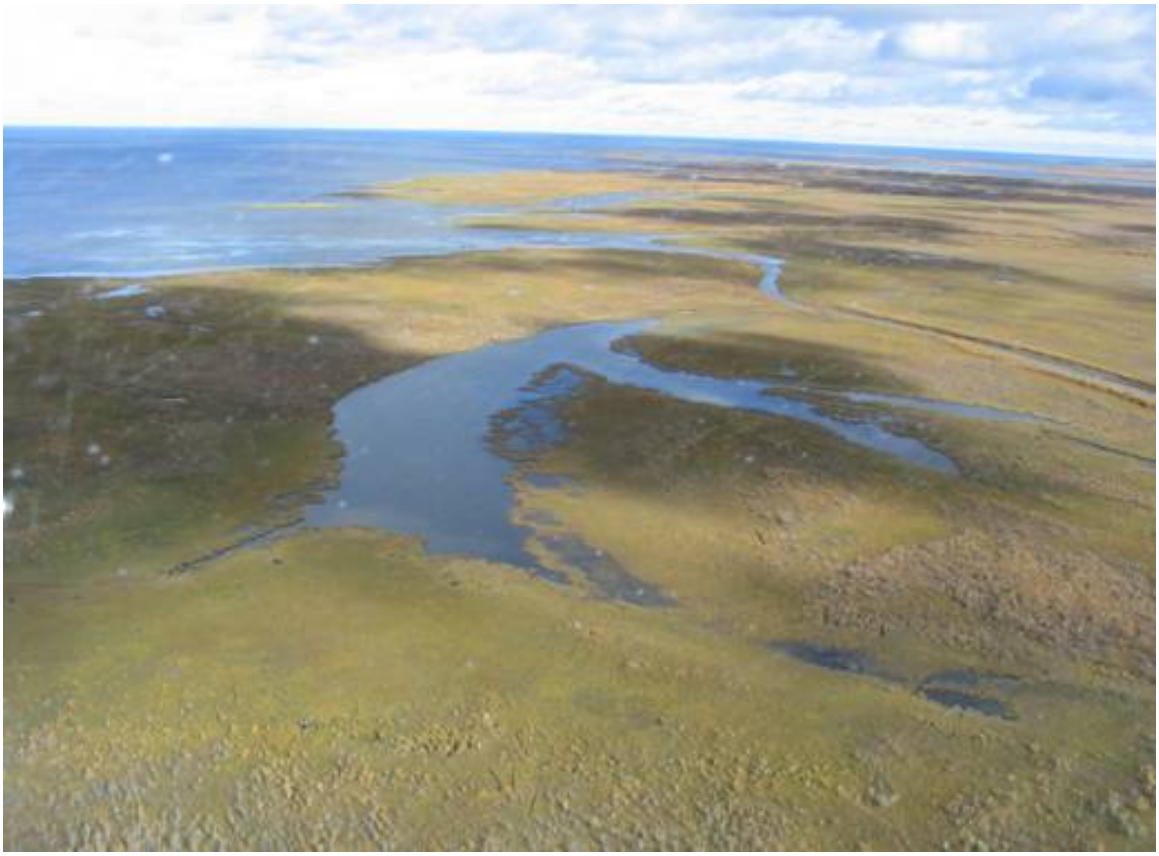

Figure B7 Photo of lake SD39 in September 2003.

Table B1 Diatom percent abundance data from Chapter 3 (Phytoplankton samples).

Diatom Taxon	Rivers May 2003	Rivers July 2003	Rivers August 2003	SD39 May 2003	SD28 May 2003	SD2 May 2003
ACHN conspicua	0.33	0.00	0.00	0.00	0.00	0.00
ACHN lanceolata var. frequentissima	0.67	0.75	0.74	1.33	1.67	0.95
ACHN lanceolata var. rostrata	0.00	1.25	0.00	0.00	0.00	0.00
ACHN minutissima	3.33	3.00	1.49	2.67	3.33	2.38
AMPH pediculus	0.67	1.25	0.50	0.00	0.00	0.00
ASTE formosa	1.33	5.00	3.47	1.67	0.67	1.43
AULA alpigena	2.33	3.25	12.16	0.67	1.33	0.95
AULA crenulata	0.00	1.50	0.00	0.00	0.00	0.00
AULA distans	2.67	4.00	3.23	0.00	0.67	0.48
AULA granulata	0.33	0.75	0.00	0.00	0.00	0.00
AULA subarctica	0.00	0.00	0.00	0.00	0.00	0.00
CALO bacillum	0.33	0.00	0.00	0.00	0.67	1.43
CYCL meneghiniana	0.00	1.50	5.71	0.33	0.00	0.00
CYCL michiganiana	0.33	0.25	0.00	0.33	0.00	0.00
CYCL pseudostelligera	0.67	0.50	4.47	0.33	0.33	0.48
CYCL stelligera	0.00	0.00	0.50	0.33	0.00	0.00
CYCO PAD sp. 1	2.00	2.75	4.47	0.33	2.00	1.43
CYCO PAD sp. 2	4.33	2.25	5.46	1.00	4.33	0.95
CYCO cf. Tholiformis	12.33	10.00	21.84	5.00	9.67	4.29

Diatom Taxon	Rivers May 2003	Rivers July 2003	Rivers August 2003	SD39 May 2003	SD28 May 2003	SD2 May 2003
CYMB microcephala	0.67	0.25	0.00	0.00	0.00	0.00
CYMB silesiaca	2.67	2.25	0.25	0.00	0.00	0.95
DIPL elliptica	0.33	0.50	0.25	0.00	0.00	0.00
DIAT tenuis	1.00	3.25	0.00	1.00	0.00	0.48
DIAT moniliformis	3.67	4.75	3.23	0.00	0.67	1.43
EUNO bilunaris	0.00	0.00	0.00	0.33	0.67	0.48
FRAG brevistriata	0.33	0.00	0.00	0.00	0.00	0.00
FRAG capucina var. capucina	0.67	0.75	0.00	0.67	0.00	0.00
FRAG capucina var. gracilis	0.00	0.00	0.00	6.00	1.00	2.86
FRAG capucina var. mesolepta	0.33	0.00	0.25	1.67	0.00	0.95
FRAG capucina var. perminuta	0.00	0.00	0.00	0.67	0.00	0.00
FRAG capucina var. rumpens	0.33	0.00	0.99	0.00	0.00	0.00
FRAG capucina var. vaucheriae	1.67	1.75	0.25	0.33	0.00	1.90
FRAG construens var. venter	0.00	0.50	0.25	0.00	0.00	0.00
FRAG nanana	0.33	0.00	1.49	3.33	0.67	1.43
FRAG pinnata	0.00	0.75	0.50	0.00	0.00	0.00
FRAG pinnata var. intercedens	0.67	2.00	0.00	0.00	0.00	0.00
FRAG tenera	1.67	1.00	0.99	10.00	2.00	8.57
GYRO attenuatum	0.00	0.25	0.00	0.33	1.33	2.38
GOMP acuminatum	0.00	0.00	0.00	0.33	0.00	0.00
GOMP clavatum	0.00	0.00	0.00	0.00	0.67	0.95
GOMP olivaceum	3.67	3.25	0.00	0.00	0.67	0.00

Diatom Taxon	Rivers May 2003	Rivers July 2003	Rivers August 2003	SD39 May 2003	SD28 May 2003	SD2 May 2003
GOMP parvulum	0.00	0.00	0.74	0.67	0.67	0.95
HANT amphioxys	0.33	0.25	0.00	0.00	0.00	0.00
MERI circulare	0.00	0.00	0.00	0.00	0.00	0.00
NAVI capitata var. capitata	0.00	0.25	0.00	0.00	0.67	1.90
NAVI capitata var. hungarica	0.67	1.00	0.25	0.00	0.00	0.00
NAVI cryptocephala	1.00	2.50	0.00	0.67	2.00	0.95
NAVI cryptotenella	2.00	2.75	0.50	2.00	2.00	0.95
NAVI libonensis	0.33	1.00	0.00	5.00	3.67	0.95
NAVI pupula	1.00	0.00	0.00	0.00	0.67	2.86
NAVI radiosa	0.00	0.00	0.00	0.33	1.00	2.86
NAVI subplacentula	1.00	0.25	0.00	0.00	1.33	1.43
NAVI trivialis	0.33	0.00	0.00	2.67	0.00	2.38
NITZ acicularis	0.00	0.75	1.24	1.00	1.33	1.43
NITZ amphibia	0.00	0.00	0.00	1.33	0.00	0.00
NITZ dissipata	1.67	1.00	1.24	2.33	0.00	3.33
NITZ fonticola	0.00	0.25	0.00	0.67	0.00	1.43
NITZ graciliformis	0.00	0.75	0.00	0.67	0.00	0.00
NITZ laccum	0.33	0.50	1.74	0.00	0.00	0.00
NITZ liebetruthii	0.00	0.25	0.25	1.67	1.33	0.48
NITZ linearis	0.67	1.50	0.74	1.67	1.33	2.38
NITZ palea	1.67	1.25	2.48	14.00	3.67	6.67
NITZ paleacea	0.00	0.00	0.25	1.00	0.33	0.95

Diatom Taxon	Rivers May 2003	Rivers July 2003	Rivers August 2003	SD39 May 2003	SD28 May 2003	SD2 May 2003
NITZ perminuta	0.00	0.25	0.25	1.67	2.00	2.38
NITZ radicula	0.00	0.00	0.00	4.00	0.67	3.81
NITZ recta	0.67	0.25	0.25	0.00	1.67	0.95
NITZ sigmoidea	0.00	0.00	0.00	0.00	0.67	0.00
NITZ subacicularis	0.00	0.00	0.00	0.67	0.67	1.90
NITZ sublinearis	0.00	0.00	1.49	2.00	0.33	2.38
NITZ tryblionella	0.00	0.00	0.00	0.00	0.00	0.00
RHOI abbreviata	0.33	0.50	0.00	0.67	0.67	0.00
STAU anceps	0.33	0.00	0.00	0.33	1.00	0.48
STEP hantzschii	24.67	8.75	4.71	7.67	29.33	11.90
STEP minutulus	0.00	0.00	0.00	0.00	0.00	0.00
STEP niagarae	0.00	2.00	0.99	0.33	0.33	0.48
STEP parvus	3.00	0.25	0.00	1.00	1.00	0.48
SURI angusta	0.33	0.00	0.00	0.00	0.33	0.00
SYNE ulna var. acus	1.33	1.50	0.25	2.33	1.33	0.48
TABE flocculosa	0.33	0.50	0.25	0.00	0.33	0.00

Diatom Taxon	Rivers May 2004	Rivers July 2004	Rivers September 2004	SD28 May 2004	SD39 May 2004
ACHN conspicua	0.14	0.00	0.00	0.00	0.00
ACHN lanceolata var. frequentissima	0.48	0.36	0.00	0.67	0.00
ACHN lanceolata var. rostrata	0.00	0.18	0.65	0.00	0.00
ACHN minutissima	2.15	3.28	10.65	2.67	1.75

Diatom Taxon	Rivers May 2004	Rivers July 2004	Rivers September 2004	SD28 May 2004	SD39 May 2004
AMPH pediculus	0.00	0.36	0.00	0.00	0.00
ASTE formosa	0.64	0.55	0.65	0.67	0.00
AULA alpigena	0.00	2.00	1.29	0.00	0.00
AULA crenulata	0.00	0.55	0.00	0.00	0.00
AULA distans	0.00	0.00	0.00	0.00	0.00
AULA granulata	0.00	1.46	0.00	0.00	0.00
AULA subarctica	4.05	0.55	0.00	1.33	0.70
CALO bacillum	0.00	0.00	0.00	0.00	0.00
CYCL meneghiniana	0.71	1.82	1.61	0.00	0.00
CYCL michiganiana	0.00	0.00	0.32	0.00	0.00
CYCL pseudostelligera	0.17	0.91	1.61	0.67	0.00
CYCL stelligera	0.48	0.36	0.97	0.33	0.00
CYCO PAD sp. 1	1.33	7.65	3.87	1.33	0.70
CYCO PAD sp. 2	0.17	9.11	8.71	0.67	0.70
CYCO cf. Tholiformis	1.00	15.12	15.48	2.00	0.70
CYMB microcephala	0.00	0.00	0.00	0.00	0.00
CYMB silesiaca	0.00	0.00	0.65	0.00	0.00
DIPL elliptica	0.31	0.18	0.00	0.00	0.00
DIAT tenuis	1.70	1.64	2.58	1.33	1.75
DIAT moniliformis	1.90	2.91	8.71	3.33	3.86
EUNO bilunaris	0.00	0.00	0.00	0.33	0.70
FRAG brevistriata	0.00	0.36	0.65	0.00	0.00

Diatom Taxon	Rivers May 2004	Rivers July 2004	Rivers September 2004	SD28 May 2004	SD39 May 2004
FRAG capucina var. capucina	0.14	0.00	0.00	0.00	0.00
FRAG capucina var. gracilis	0.31	0.73	0.00	0.67	0.70
FRAG capucina var. mesolepta	0.00	0.00	0.00	0.00	0.00
FRAG capucina var. perminuta	0.00	0.00	0.00	0.00	0.00
FRAG capucina var. rumpens	0.48	0.00	0.65	0.67	0.70
FRAG capucina var. vaucheriae	0.17	0.00	0.00	0.00	0.00
FRAG construens var. venter	0.67	0.00	0.00	0.67	0.00
FRAG nanana	1.33	0.36	0.65	1.33	0.00
FRAG pinnata	0.00	0.73	0.00	0.00	0.00
FRAG pinnata var. intercedens	0.00	0.36	0.00	0.00	0.00
FRAG tenera	1.40	1.09	0.65	1.67	0.70
GYRO attenuatum	0.00	0.00	0.00	0.00	0.00
GOMP acuminatum	0.00	0.00	0.65	0.00	0.00
GOMP clavatum	0.00	0.18	0.65	0.00	1.40
GOMP olivaceum	0.00	0.00	0.00	0.00	0.00
GOMP parvulum	0.17	0.91	1.94	1.33	0.00
HANT amphioxys	0.00	0.00	0.00	0.00	0.00
MERI circulare	0.81	0.00	0.00	0.67	0.00
NAVI capitata var. capitata	0.00	0.00	0.00	0.00	0.00
NAVI capitata var. hungarica	0.00	0.00	0.00	0.00	0.00
NAVI cryptocephala	0.80	0.73	2.90	1.33	1.40
NAVI cryptotenella	0.64	0.00	0.00	0.67	0.00

Diatom Taxon	Rivers May 2004	Rivers July 2004	Rivers September 2004	SD28 May 2004	SD39 May 2004
NAVI libonensis	0.31	0.00	0.65	0.00	0.70
NAVI pupula	0.14	0.00	0.65	0.67	1.40
NAVI radiosa	0.00	0.55	0.00	0.67	0.70
NAVI subplacentula	0.00	0.00	0.00	0.00	0.00
NAVI trivialis	0.00	0.36	0.00	0.00	0.00
NITZ acicularis	1.27	4.37	2.90	1.33	0.00
NITZ amphibia	0.17	0.00	0.00	0.00	1.75
NITZ dissipata	0.21	0.18	1.94	0.67	1.40
NITZ fonticola	0.00	0.36	0.00	0.00	0.00
NITZ graciliformis	0.00	0.36	0.00	0.00	0.00
NITZ laccum	0.31	0.00	0.00	0.67	0.00
NITZ liebetruthii	0.73	0.73	0.00	1.33	0.70
NITZ linearis	0.38	2.19	1.29	1.33	1.40
NITZ palea	1.10	2.19	2.26	0.67	0.70
NITZ paleacea	0.00	0.73	0.00	0.00	0.00
NITZ perminuta	0.00	0.00	0.97	0.00	0.70
NITZ radicula	0.00	0.73	0.00	0.00	0.00
NITZ recta	0.87	1.28	1.29	0.67	0.00
NITZ sigmoidea	0.00	0.00	0.65	0.00	0.00
NITZ subacicularis	0.17	0.73	0.32	0.67	0.00
NITZ sublinearis	0.00	0.00	0.00	0.00	0.00
NITZ tryblionella	0.00	0.36	0.32	0.00	0.00

Diatom Taxon	Rivers May 2004	Rivers July 2004	Rivers September 2004	SD28 May 2004	SD39 May 2004
RHOI abbreviata	0.54	0.00	0.00	0.00	0.00
STAU anceps	0.00	0.00	0.00	0.00	0.00
STEP hantzschii	43.19	11.84	6.13	43.33	46.67
STEP minutulus	4.81	4.55	2.58	5.00	4.56
STEP niagarae	0.39	0.00	0.00	0.67	0.00
STEP parvus	20.30	7.83	5.16	13.00	20.00
SURI angusta	0.00	0.00	0.00	0.00	0.00
SYNE ulna var. acus	1.04	0.55	2.58	1.67	0.00
TABE flocculosa	0.00	1.46	0.00	0.00	0.00

Diatom Taxon	Rivers May 2005	Rivers July 2005	Rivers September 2005	SD33 May 2005	SD2 May 2005	SD28 May 2005	SD29 May 2005	SD39 May 2005
ACHN conspicua	0.29	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ACHN lanceolata var. frequentissima	0.68	0.32	0.00	0.00	0.00	0.00	0.00	0.00
ACHN lanceolata var. rostrata	0.14	0.32	0.62	0.00	0.00	0.00	0.00	0.00
ACHN minutissima	5.17	5.06	0.92	1.75	5.00	3.24	0.62	1.85
AMPH pediculus	0.58	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ASTE formosa	1.77	1.90	8.00	0.00	0.00	0.00	0.92	0.92
AULA alpigena	0.00	3.16	1.23	0.00	0.00	0.00	0.00	0.00
AULA crenulata	0.14	2.53	0.62	0.00	0.00	0.81	0.00	0.00
AULA distans	0.00	1.27	0.00	0.00	0.00	0.00	0.00	0.00
AULA granulata	0.00	0.63	0.62	0.00	0.00	0.00	0.00	0.00
AULA subarctica	0.79	1.90	0.62	0.00	1.33	0.00	0.00	0.00

Diatom Taxon	Rivers May 2005	Rivers July 2005	Rivers September 2005	SD33 May 2005	SD2 May 2005	SD28 May 2005	SD29 May 2005	SD39 May 2005
CALO bacillum	0.00	0.63	0.00	0.00	0.00	0.00	0.00	1.23
CYCL meneghiniana	0.00	2.53	0.92	0.00	0.00	0.00	0.00	0.00
CYCL michiganiana	0.00	0.32	0.31	0.00	0.00	0.00	0.00	0.00
CYCL pseudostelligera	0.59	0.00	2.46	0.00	0.00	0.00	0.31	0.62
CYCL stelligera	0.18	0.00	1.85	0.00	0.67	0.00	0.00	0.00
CYCO PAD sp. 1	1.17	5.38	5.23	0.00	2.33	2.83	1.54	0.62
CYCO PAD sp. 2	0.00	8.23	9.23	0.00	0.67	0.81	0.31	0.00
CYCO cf. Tholiformis	0.96	10.13	24.31	0.00	2.33	2.83	1.85	0.00
CYMB microcephala	1.00	1.27	0.62	0.00	0.00	0.00	0.00	0.00
CYMB silesiaca	0.90	0.00	0.62	0.00	0.00	0.40	0.00	0.00
DIPL elliptica	0.37	0.00	0.00	0.00	0.00	0.00	0.00	0.62
DIAT tenuis	1.62	1.58	1.85	0.00	1.33	2.02	0.00	1.54
DIAT moniliformis	3.58	4.11	3.69	0.00	1.33	0.00	0.00	0.00
EUNO bilunaris	0.31	0.00	0.00	0.00	1.33	0.00	0.00	0.00
FRAG brevistriata	0.00	1.58	0.00	0.00	0.00	0.00	0.00	0.00
FRAG capucina var. capucina	0.14	0.00	0.00	0.00	0.00	0.00	0.00	0.00
FRAG capucina var. gracilis	0.55	0.00	0.00	0.00	0.00	0.00	0.00	1.23
FRAG capucina var. mesolepta	0.00	2.53	0.00	0.00	0.00	0.00	0.00	0.00
FRAG capucina var. perminuta	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
FRAG capucina var. rumpens	0.76	0.00	0.62	0.50	1.33	0.00	0.00	2.15
FRAG capucina var. vaucheriae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
FRAG construens var. venter	1.49	0.00	0.00	0.00	1.33	0.00	0.00	0.00

Diatom Taxon	Rivers May 2005	Rivers July 2005	Rivers September 2005	SD33 May 2005	SD2 May 2005	SD28 May 2005	SD29 May 2005	SD39 May 2005
FRAG nanana	0.67	0.00	3.08	0.00	0.00	0.00	0.00	1.54
FRAG pinnata	0.70	0.95	0.00	0.00	0.00	0.00	0.00	0.00
FRAG pinnata var. intercedens	0.14	0.00	0.00	0.00	0.00	0.00	0.00	0.00
FRAG tenera	1.36	0.63	3.69	0.00	0.33	0.40	0.62	1.54
GYRO attenuatum	0.07	0.63	0.31	0.00	0.00	0.00	0.00	0.00
GOMP acuminatum	0.28	1.27	0.31	0.00	0.00	0.81	0.00	0.00
GOMP clavatum	0.20	0.00	0.00	0.50	0.00	0.00	0.00	0.00
GOMP olivaceum	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
GOMP parvulum	0.81	0.00	1.85	0.00	0.67	0.81	0.00	0.62
HANT amphioxys	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MERI circulare	0.70	0.00	0.00	0.00	0.00	0.00	0.00	0.00
NAVI capitata var. capitata	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
NAVI capitata var. hungarica	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
NAVI cryptocephala	1.84	0.00	0.62	0.25	0.00	0.00	0.00	0.00
NAVI cryptotenella	0.62	0.00	0.00	0.00	0.00	0.00	0.00	0.00
NAVI libonensis	0.14	0.00	0.00	0.00	0.00	0.00	0.00	0.31
NAVI pupula	0.36	0.00	0.00	0.00	0.00	0.00	0.00	0.00
NAVI radiosa	0.31	0.00	0.00	0.00	0.00	0.00	0.00	0.00
NAVI subplacentula	0.31	0.00	0.00	0.00	0.00	0.00	0.00	0.00
NAVI trivialis	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
NITZ acicularis	1.13	3.48	5.23	91.75	1.33	0.00	4.31	1.85
NITZ amphibia	0.00	0.32	0.00	0.25	0.00	0.00	0.00	0.00

Diatom Taxon	Rivers May 2005	Rivers July 2005	Rivers September 2005	SD33 May 2005	SD2 May 2005	SD28 May 2005	SD29 May 2005	SD39 May 2005
NITZ dissipata	0.55	0.00	0.00	0.50	1.33	0.40	0.00	0.00
NITZ fonticola	0.14	0.63	0.00	0.50	0.33	0.00	0.00	0.00
NITZ graciliformis	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
NITZ laccum	0.45	0.00	0.00	0.00	0.00	0.00	0.00	0.62
NITZ liebetruthii	0.85	1.27	0.00	0.50	1.33	0.00	0.00	1.54
NITZ linearis	0.56	0.00	0.62	0.50	4.00	0.00	0.00	0.00
NITZ palea	2.18	1.58	0.00	0.00	0.00	0.81	3.38	2.15
NITZ paleacea	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
NITZ perminuta	0.25	0.00	0.00	0.00	0.00	0.00	0.62	0.00
NITZ radicula	0.76	0.63	0.00	0.00	0.67	0.00	0.00	0.62
NITZ recta	0.64	0.00	0.31	0.00	0.33	0.40	0.00	0.00
NITZ sigmoidea	0.45	0.00	0.00	0.00	0.00	0.00	0.00	0.00
NITZ subacicularis	0.73	1.58	2.15	0.00	0.00	0.00	0.00	0.00
NITZ sublinearis	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
NITZ tryblionella	0.25	0.95	0.00	0.00	0.00	0.00	0.00	0.00
RHOI abbreviata	0.00	0.00	0.31	0.00	0.00	0.00	0.00	0.00
STAU anceps	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
STEP hantzschii	32.08	10.76	6.46	0.00	39.33	53.04	50.15	48.92
STEP minutulus	3.35	4.11	3.38	0.00	4.67	4.86	4.92	5.54
STEP niagarae	0.61	0.63	0.00	0.00	0.00	0.00	0.00	0.00
STEP parvus	18.27	6.96	5.54	0.00	23.33	24.29	27.38	21.54
SURI angusta	0.00	0.32	0.00	1.25	0.67	0.00	2.15	0.00

Diatom Taxon	Rivers May 2005	Rivers July 2005	Rivers September 2005	SD33 May 2005	SD2 May 2005	SD28 May 2005	SD29 May 2005	SD39 May 2005
SYNE ulna var. acus	0.64	2.22	0.62	0.00	0.00	0.81	0.00	1.85
TABE flocculosa	0.77	0.63	0.62	0.00	0.00	0.00	0.00	0.00

Table B2 Diatom percent abundance data from Chapter 4 (Epiphytic diatom communities).

Diatom Taxon	SD28 2004								
	M. exalbescens			P. friesii			Equisetum sp.		
	Basin 1	Basin 2	Basin 3	Basin 1	Basin 2	Basin 3	Basin 1	Basin 2	Basin 3
ACHNhungarica	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
ACHNlanceolata var. frequentissima	0.4832	0.5020	0.1062	0.1613	0.2478	0.0559	0.0000	0.0000	0.7071
ACHNminutissima	13.9693	19.0883	5.1787	7.1407	14.1748	1.4993	16.1914	31.7801	22.4420
AMPHlibyca	0.0000	0.0000	0.0000	0.0000	0.0000	0.2127	0.1777	0.0553	0.0000
CALObacillum	0.3602	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Cplaeug	0.4761	0.2959	0.4522	0.3602	0.3210	0.1666	0.3514	0.1174	0.2195
Cplalin	0.2321	0.5442	1.0370	0.2939	0.5321	0.2213	0.1188	0.0000	0.1066
Cplapla	4.8965	11.4688	18.0265	17.3911	18.6492	5.7267	2.3753	2.4771	3.1387
CRAThalophila	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.1208	0.0000	0.0000
CYCOPAD sp. 2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
CYMBmicrocephala	6.1973	1.9404	0.3587	7.8564	3.7455	0.0000	3.4011	2.0187	0.0000
CYMBproxima	0.2463	0.2905	0.4482	0.1188	0.2087	0.0000	0.1214	0.1104	0.0000
EPITadnata	2.6539	9.5632	9.5783	10.9173	11.6554	11.6457	4.3247	1.3673	7.7923
EPITturgida	0.7221	3.7323	2.4021	1.9890	4.5069	2.1148	0.7801	0.4485	2.2340
EUNObilunaris	0.1802	0.1244	0.1116	0.1188	0.0590	4.1843	0.3462	0.2826	1.9090
EUNOminor	0.0000	0.0000	0.1144	0.0000	0.0000	0.1482	0.0000	0.0000	0.0000
Fcapcap	0.0000	0.8213	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Fcapgra	0.1244	0.0622	0.1145	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Fcapmes	1.0949	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Fcaprum	0.1142	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Diatom Taxon	SD28 2004								
	M. exalbescens			P. friesii			Equisetum sp.		
	Basin 1	Basin 2	Basin 3	Basin 1	Basin 2	Basin 3	Basin 1	Basin 2	Basin 3
Fcapvau	0.1217	0.9581	0.4104	0.0000	0.0590	0.0000	0.0000	0.0000	0.0000
FRAGnanana	0.0000	0.4792	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
FRAGtenera	0.2475	1.3528	0.1688	0.1813	0.6389	0.2802	0.1208	0.3938	0.1182
GYROattenuatum	0.4234	0.0000	0.0000	0.0538	0.0000	0.0559	0.2939	0.0551	0.1182
GOMPacuminatum	0.4821	2.0641	3.9143	1.6331	0.7161	4.2374	2.1483	2.0498	3.8460
Gangsttm	0.0000	0.0622	0.9214	0.1182	0.1131	1.6187	0.1214	0.6765	3.2563
Gangstum	1.9187	7.4310	1.1434	10.3666	13.1211	13.8545	5.0214	26.3215	12.9941
GOMPclavatum	0.9583	4.3711	6.5896	1.4286	2.3970	9.5799	2.1289	2.1014	4.7416
GOMPgracile	1.0541	1.2072	6.6678	2.4625	2.9188	11.5640	2.4742	2.5318	8.7746
GOMPminutum	2.4075	2.0191	2.3005	0.9316	1.3686	2.7212	1.0708	0.5802	0.8882
GOMPparvulum	6.1243	5.6531	24.1072	6.1666	7.8102	17.4850	11.7121	5.8019	12.5019
GOMPpseudotenellum	1.8498	1.2968	1.8902	1.1589	1.2475	4.1797	1.0603	4.7267	2.6404
GOMPsubtile	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
GOMPtruncatum	0.6050	2.3210	1.9389	0.2905	0.4636	1.6798	0.0000	0.0000	0.7039
Ncrypcep	4.4564	1.5097	1.1234	1.5250	0.8054	0.5689	3.9539	1.6016	2.7244
Ncrypten	1.6980	1.2163	0.2178	1.0884	0.7735	0.2191	2.3760	0.9261	1.4895
NAVIlibonensis	0.5328	0.0000	0.0000	0.3496	0.0549	0.0000	0.3514	0.0000	0.0591
NAVminima	0.1142	0.0000	0.0000	0.0000	0.0000	0.0000	0.1149	0.0000	0.0473
NAVminuscula	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
NAVmenisculus	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
NAVIpupula	0.2433	0.0000	0.0000	0.0000	0.0000	0.0559	0.1149	0.0000	0.1777
NAVIradiosa	2.7751	0.5182	0.3978	1.0423	0.7329	0.4889	5.5448	1.7547	1.3584

Diatom Taxon	SD28 2004								
	M. exalbescens			P. friesii			Equisetum sp.		
	Basin 1	Basin 2	Basin 3	Basin 1	Basin 2	Basin 3	Basin 1	Basin 2	Basin 3
NAVItrivialis	0.7745	0.1040	0.0531	0.1129	0.0000	0.1119	0.4199	0.0000	0.0591
NAVIseminulum	0.0000	0.0000	0.0000	0.0000	0.0478	0.0000	0.1208	0.0000	0.0000
NEIDampliatum	0.1217	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
NITZacicularis	0.6117	0.0605	0.1229	0.0000	0.0000	0.0000	0.1149	0.1690	0.0000
NITZamphibia	0.3590	0.1617	0.0000	0.2151	0.0000	0.0000	0.1214	0.0000	0.1776
NITZfonticola	0.6685	0.2280	0.0000	0.1738	0.0478	0.0000	0.8152	0.0000	0.0000
NITZhungarica	0.0571	0.0000	0.0000	0.0000	0.0000	0.0000	0.0607	0.0587	0.0000
NITZliebetruthii	5.9099	2.8370	0.9726	0.8366	0.8221	0.6411	4.7034	0.3489	0.2314
NITZlinearis	1.4433	0.7552	0.5737	0.2926	0.3282	0.6329	0.9339	0.2245	0.3467
Npalea	7.8862	2.6380	3.1177	0.6227	1.0317	0.4889	2.5959	0.2283	0.7426
Npaleaca	1.7594	0.4677	0.3991	0.1797	0.0478	0.0461	0.4670	0.0588	0.3785
NITZperminuta	0.7809	0.2137	0.2261	0.0610	0.1505	0.0000	0.1757	0.2283	0.0000
NITZradicula	2.0048	0.7070	0.4675	0.5384	0.2111	0.1384	0.7758	0.2275	0.0000
NITZrecta	1.6735	0.1645	0.0000	0.2870	0.0478	0.0000	1.1910	0.1141	0.0000
NITZsigmoidea	0.6014	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
NITZsublinearis	0.6089	0.1821	0.1116	0.0594	0.0566	0.0000	0.1202	0.0000	0.1182
RHOIabbreviata	0.4341	0.1040	0.0000	0.0000	0.0000	0.2289	0.2365	0.2275	0.2129
RHOPgibba	14.9448	8.5746	3.3792	20.8860	9.2182	2.3204	18.8663	9.1454	2.3501
STAUphoenicenteron	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
STEPminutulus	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
SURIangusta	0.1142	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
SYNEulna var. acus	0.1193	0.8139	0.3461	0.1185	0.3266	0.0000	0.1809	0.4490	0.1629

Diatom Taxon	SD29 2004								
	C. demersum			P. friesii			Floating Algae		
	Basin 1	Basin 2	Basin 3	Basin 1	Basin 2	Basin 3	Basin 1	Basin 2	Basin 3
ACHNhungarica	0.0000	0.1222	0.0000	0.7689	0.0598	0.0000	0.5368	0.0000	0.1086
ACHNlanceolata var. frequentissima	0.1623	0.8558	2.1244	1.3261	0.1590	0.3683	1.0516	0.1064	0.7039
ACHNminutissima	5.4618	3.7616	2.3580	4.5878	3.4306	4.0946	17.3326	8.2771	20.0768
AMPHlibyca	0.0540	0.0581	0.0622	0.2315	0.0000	0.0514	0.0000	0.0548	0.3112
CALObacillum	0.0000	0.0000	0.0000	0.1225	0.0000	0.0000	0.0870	0.0548	0.0984
Cplaeug	0.5704	1.3520	1.3528	0.9716	0.4308	1.3438	0.0435	0.1080	0.2825
Cplalin	0.2270	0.3470	0.5734	0.1224	0.2074	0.7365	0.0000	0.0000	0.0000
Cplapla	37.2342	45.8895	28.7856	13.2788	54.5050	19.3918	1.5398	1.7492	4.2372
CRAThalophila	0.0000	0.0000	0.0000	0.0000	0.0000	0.0514	0.0000	0.1542	0.0000
CYCOPAD sp. 2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
CYMBmicrocephala	0.0000	0.0000	0.0000	0.1931	0.0000	0.0000	0.0000	0.0000	0.0000
CYMBproxima	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
EPITadnata	13.4801	12.1269	3.1088	21.6271	15.7223	6.4156	27.1377	25.5823	9.8249
EPITturgida	3.6078	5.8126	1.2012	4.8662	4.6029	1.7475	9.1227	20.8984	3.1758
EUNObilunaris	0.0000	0.0000	0.0000	0.1575	0.0541	0.0000	0.0000	0.0000	0.0000
EUNOminor	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Fcapcap	0.0000	0.2445	0.0000	0.5114	0.0000	0.0000	0.0000	0.1010	0.0000
Fcapgra	0.0000	0.0000	0.0000	0.0965	0.0000	0.0000	0.0000	0.0000	0.0000
Fcapmes	27.6176	16.9521	4.0409	11.8986	7.4038	3.8775	8.4232	27.7315	14.2233
Fcaprum	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Fcapvau	0.0000	0.0000	0.0000	0.4023	0.0000	0.0000	0.0000	0.0000	0.0000
FRAGnanana	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Diatom Taxon	SD29 2004								
	C. demersum			P. friesii			Floating Algae		
	Basin 1	Basin 2	Basin 3	Basin 1	Basin 2	Basin 3	Basin 1	Basin 2	Basin 3
FRAGtenera	0.0000	0.0000	0.0000	0.3766	0.0541	0.0000	0.2547	0.0000	0.0492
GYROattenuatum	0.0000	0.0000	0.0000	0.0611	0.0000	0.0000	0.0000	0.0000	0.0000
GOMPacuminatum	0.7891	1.2443	1.4202	1.2586	1.7031	2.3938	0.2938	1.1649	1.5550
Gangsttm	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Gangstum	0.0000	0.0000	0.0000	0.1220	0.0000	0.0000	0.0000	0.0000	0.0000
GOMPclavatum	2.6471	3.5519	6.7654	0.6461	3.3178	8.7465	1.2605	2.9440	9.5563
GOMPgracile	0.0000	0.0611	0.0569	0.4633	0.0000	0.1053	0.3325	0.0000	0.0000
GOMPminutum	0.1168	0.0000	0.0000	0.0000	0.0000	0.5997	0.0000	0.0000	0.1188
GOMPparvulum	0.3544	0.2167	0.6678	0.8654	0.3270	1.1909	0.8745	0.1558	0.7941
GOMPpseudotenellum	0.0000	0.0000	0.0000	0.1225	0.0000	0.0000	0.0000	0.0000	0.0000
GOMPsubtile	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
GOMPtruncatum	1.2857	1.9057	1.8023	1.1089	1.7755	2.1121	0.4116	2.2345	0.9207
Ncrypcep	0.0584	0.0000	0.0000	0.0610	0.0000	0.0000	0.0000	0.0532	0.0000
Ncrypten	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.2277	0.0000	0.0000
NAVIlibonensis	0.0541	0.1744	0.1190	0.1220	0.1082	0.2191	0.0000	0.0000	0.0984
NAVminima	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
NAVminuscula	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
NAVmenisculus	0.1664	0.0000	0.1191	0.0000	0.0000	0.1121	0.0870	0.0000	0.0000
NAVIpupula	0.0000	0.1082	0.1761	0.2061	0.0000	0.0000	0.2069	0.0532	0.0000
NAVIradiosa	0.1623	0.0000	0.0000	0.5822	0.0000	0.0000	0.0000	0.0000	0.0000
NAVItrivialis	0.0000	0.0000	0.0000	0.1225	0.1139	0.0514	0.0000	0.0000	0.0000
NAVIseminulum	0.0000	0.0000	0.0000	0.1578	0.0496	0.0000	0.0000	0.1010	0.2701

Diatom Taxon	SD29 2004								
	C. demersum			P. friesii			Floating Algae		
	Basin 1	Basin 2	Basin 3	Basin 1	Basin 2	Basin 3	Basin 1	Basin 2	Basin 3
NEIDampliatum	0.0584	0.0611	0.0000	0.1705	0.0000	0.0000	0.0000	0.0548	0.0000
NITZacicularis	0.0000	0.0000	0.0000	0.0613	0.0000	0.0000	0.0000	0.0000	0.0000
NITZamphibia	1.2115	1.8872	2.1451	2.3262	1.3451	1.9401	5.4914	3.2601	11.0127
NITZfonticola	0.0000	0.0541	0.1190	0.9753	0.2215	0.0000	0.2700	0.2128	0.4297
NITZhungarica	0.0000	0.2247	0.0622	0.0000	0.5602	0.0577	0.0553	0.3145	0.0000
NITZliebetruthii	1.2798	0.4510	2.6061	6.4970	0.1196	1.8493	8.7001	0.0000	2.5294
NITZlinearis	0.6846	0.2385	0.1244	1.1331	0.0598	0.5408	0.5400	0.1599	0.6452
Npalea	0.5658	1.0797	37.2175	12.4725	2.1282	39.2700	8.5106	1.2273	16.9327
Npaleaca	0.0604	0.0541	0.8906	1.4576	0.1121	0.4837	0.4781	0.0532	0.3829
NITZperminuta	0.2336	0.0000	0.0000	0.5598	0.0000	0.4345	0.0000	0.0000	0.0492
NITZradicula	0.4514	0.2780	1.9772	3.0191	0.0000	1.1596	3.1142	0.2141	1.1789
NITZrecta	0.0000	0.0541	0.0620	0.2799	0.0000	0.1606	0.0435	0.0000	0.0000
NITZsigmoidea	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
NITZsublinearis	0.0000	0.0000	0.0000	0.1222	0.0000	0.1155	0.0000	0.0000	0.0000
RHOIabbreviata	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	1.9039	0.3589	0.0000
RHOPgibba	1.2426	0.5544	0.0620	2.7048	1.2602	0.1647	1.3307	2.3565	0.2149
STAUphoenicenteron	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
STEPminutulus	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
SURIangusta	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
SYNEulna var. acus	0.0000	0.0611	0.0000	0.1223	0.0541	0.1053	0.0000	0.1040	0.0000

Diatom Taxon	SD28 2005								
	M. exalbescens			P. friesii			Equisetum sp.		
	Basin 1	Basin 2	Basin 3	Basin 1	Basin 2	Basin 3	Basin 1	Basin 2	Basin 3
ACHNhungarica	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
ACHNlanceolata var. frequentissima	0.5852	0.5995	0.0594	0.4856	0.0557	0.1753	0.0000	0.0000	0.0000
ACHNminutissima	26.8995	37.5721	12.4210	12.6497	24.3190	10.0571	22.2458	11.6549	15.7054
AMPHlibyca	0.0000	0.0024	0.0012	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
CALObacillum	0.3122	0.1199	0.0000	0.0000	0.5679	0.2695	0.0000	0.0000	0.0000
Cplaeug	0.1042	0.0000	0.0000	0.2586	0.3410	0.9181	0.0000	0.0000	0.0000
Cplalin	0.0000	0.0006	0.0006	0.0005	0.0006	0.0023	0.0000	0.0000	0.0000
Cplapla	1.8506	3.1949	10.7710	4.5652	6.0815	11.5159	2.1640	2.4823	6.5482
CRAThalophila	0.0005	0.0000	0.0000	0.0005	0.0000	0.0000	0.0012	0.0000	0.0000
CYCOPAD sp. 2	0.0000	0.0012	0.0000	0.0026	0.0012	0.0000	0.0026	0.0000	0.0000
CYMBmicrocephala	4.4132	1.6211	0.0000	3.0067	4.3821	0.2037	1.9905	0.5217	0.4879
CYMBproxima	0.4767	0.4782	1.2686	0.3949	0.0000	0.1623	1.0091	0.2593	2.1521
EPITadnata	2.0951	4.1612	6.1779	2.6844	5.0139	8.8626	3.8174	4.9013	14.0946
EPITturgida	0.3726	0.9686	4.9646	0.4147	1.3976	2.8199	0.0000	3.7827	6.1040
EUNObilunaris	0.0521	0.2447	1.7832	1.8900	1.0591	1.3181	0.1313	0.0000	0.4215
EUNOminor	0.1752	0.3079	0.0000	0.1080	0.9047	0.0000	0.0000	0.0000	0.0000
Fcapcap	0.1042	0.0000	0.0000	1.7131	0.0529	0.1960	0.0000	0.0000	0.0000
Fcapgra	0.0000	0.0000	0.0000	0.6634	0.4588	0.0973	0.0000	0.6508	0.5433
Fcapmes	7.1144	0.3079	0.1229	13.0206	0.4798	0.0000	0.4631	0.0000	0.0000
Fcaprum	1.0801	1.6856	1.3291	3.0180	2.5912	1.0842	0.3661	0.0000	0.5591
Fcapvau	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
FRAGnanana	0.3622	0.6600	0.6283	0.4440	0.6187	0.4211	0.0000	0.6564	0.4879

Diatom Taxon	SD28 2005								
	M. exalbescens			P. friesii			Equisetum sp.		
	Basin 1	Basin 2	Basin 3	Basin 1	Basin 2	Basin 3	Basin 1	Basin 2	Basin 3
FRAGtenera	1.5409	1.5010	2.3420	1.9144	3.1034	0.7278	0.6225	0.9641	1.4131
GYROattenuatum	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
GOMPacuminatum	2.0983	4.0286	6.5729	3.1757	3.4024	5.2941	1.8177	3.0834	3.2381
Gangsttm	0.0000	0.0000	0.0014	0.0044	0.0000	0.0008	0.0031	0.0007	0.0021
Gangstum	2.4714	7.9230	4.9279	8.6125	5.4231	9.1381	26.8517	17.6431	5.6399
GOMPclavatum	1.1017	2.5944	2.5324	0.8559	1.6207	3.2795	3.6324	5.1452	3.1305
GOMPgracile	0.1062	1.0229	3.4911	4.4325	0.8526	5.8237	1.6316	2.3212	1.9187
GOMPminutum	1.2846	0.8389	1.4340	1.0701	1.5036	1.5410	0.6431	0.7810	0.8608
GOMPparvulum	9.3455	7.9847	15.9212	13.9691	13.6345	13.6505	10.2219	11.5398	4.3881
GOMPpseudotenellum	4.6948	2.1089	2.6131	1.5432	0.3228	1.0540	1.4767	1.9781	1.1071
GOMPsubtile	0.0000	0.0000	0.0000	0.0000	0.0000	0.5157	2.5434	0.8507	0.9057
GOMPtruncatum	0.2083	0.7223	2.4428	0.4209	0.3777	0.2271	0.4220	0.3200	0.2738
Ncrypcep	1.2455	0.1232	0.2375	0.1235	0.5338	0.7239	0.1179	0.2623	0.4325
Ncrypten	2.0057	0.1790	0.9052	0.8979	0.9817	0.3905	3.0171	3.8955	0.7063
NAVIlibonensis	0.4270	0.0600	0.0000	0.3240	0.2304	0.1830	0.0000	0.0000	0.2217
NAVminima	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
NAVminuscula	0.0000	0.0000	0.0000	0.4282	0.1681	0.4609	0.0000	0.1268	0.3807
NAVmenisculus	0.0000	0.0000	0.0000	0.0000	0.0011	0.0000	0.0000	0.0032	0.0000
NAVIpupula	0.0000	0.0000	0.0000	0.0011	0.0006	0.0010	0.0000	0.0000	0.0000
NAVIradiosa	0.5757	0.2988	0.5014	0.3226	0.1681	0.6578	2.2530	2.0553	1.7321
NAVItrivialis	0.0012	0.0000	0.0000	0.0000	0.0000	0.0010	0.0018	0.0000	0.0000
NAVIseminulum	0.0010	0.0000	0.0000	0.0000	0.0000	0.0000	0.0012	0.0000	0.0000

Diatom Taxon	SD28 2005								
	M. exalbescens			P. friesii			Equisetum sp.		
	Basin 1	Basin 2	Basin 3	Basin 1	Basin 2	Basin 3	Basin 1	Basin 2	Basin 3
NEIDampliatum	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
NITZacicularis	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
NITZamphibia	0.4206	0.0000	0.0000	0.6579	0.2360	0.0973	0.0000	0.2582	0.0000
NITZfonticola	0.5418	0.0000	0.0000	0.2771	0.0553	0.0000	0.0000	0.0000	0.0000
NITZhungarica	0.6792	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0694	0.0000
NITZliebetruthii	3.2905	1.6220	0.9172	2.3769	2.7764	2.1283	0.3836	1.9354	0.2152
NITZlinearis	0.8220	0.0601	0.0000	0.0000	0.3883	0.3009	0.0000	0.0000	1.0813
Npalea	3.3786	2.8865	1.3159	3.1469	3.3807	2.6017	0.0000	0.5968	0.8013
Npaleaca	0.6373	0.5398	0.1843	0.4856	0.0553	0.0812	0.1313	0.0000	0.0000
NITZperminuta	0.3098	0.3012	0.0000	0.4320	0.3386	0.2366	0.0000	0.0000	0.0000
NITZradicula	0.3228	1.4435	1.2312	0.4387	0.4443	0.1505	0.4220	1.5246	0.3123
NITZrecta	0.5257	0.0000	0.0685	0.0617	0.2716	0.1727	0.1313	0.0000	0.1112
NITZsigmoidea	0.0005	0.0000	0.0000	0.0016	0.0012	0.0020	0.0000	0.0000	0.0006
NITZsublinearis	0.0043	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
RHOIabbreviata	0.6476	0.7190	0.1188	0.0512	0.4524	0.3055	0.0000	0.2582	0.0000
RHOPgibba	9.5607	7.0273	9.3042	5.3068	6.3692	7.5474	8.2375	15.8482	20.4607
STAUphoenicenteron	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
STEPminutulus	0.5586	0.0000	0.0000	0.0000	0.0529	0.0000	0.0000	0.0000	0.0000
SURIangusta	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
SYNEulna var. acus	3.3006	2.6402	1.9250	1.5198	1.8560	2.5500	1.5137	1.8021	3.1364

Diatom Taxon	SD29 2005								
	C. demersum			P. friesii			Floating Algae		
	Basin 1	Basin 2	Basin 3	Basin 1	Basin 2	Basin 3	Basin 1	Basin 2	Basin 3
ACHNhungarica	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.1606
ACHNlanceolata var. frequentissima	0.7066	10.8426	2.9709	0.3829	0.2243	0.1576	0.2304	0.0489	0.5483
ACHNminutissima	0.7241	12.8441	9.1525	1.8038	2.3395	1.1131	0.9185	0.6368	1.6687
AMPHlibyca	0.2458	1.6212	0.0000	0.0000	0.3332	0.0000	0.2348	0.0000	0.0000
CALObacillum	0.0000	0.0000	0.0000	0.0000	0.1106	0.0000	0.0000	0.0000	0.0000
Cplaeug	0.7887	1.6748	1.0462	0.1750	0.5553	0.3391	0.0000	0.0000	0.0000
Cplalin	1.2625	1.5659	1.1086	0.4313	1.3036	0.1744	0.0000	0.0000	0.1000
Cplapla	10.1109	9.7062	12.4825	5.2149	42.1208	12.8530	0.0000	1.0156	0.2241
CRAThalophila	0.1250	0.5943	0.4648	0.0000	0.1659	0.0000	0.0000	0.0000	0.0000
CYCOPAD sp. 2	0.0000	0.3552	0.0000	0.0000	0.0553	0.0000	0.0000	0.0000	0.0000
CYMBmicrocephala	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
CYMBproxima	0.0000	0.0585	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
EPITadnata	2.6484	2.1958	0.3591	1.6943	2.9621	7.2303	0.3500	0.1149	0.0000
EPITturgida	0.1075	0.3014	0.1134	0.2069	0.1634	2.9589	0.1152	0.0000	0.0000
EUNObilunaris	13.5701	13.1463	14.0095	15.8212	5.4615	18.7314	0.6324	0.0000	0.4553
EUNOminor	0.0000	0.0000	0.0000	0.3376	0.0000	0.1790	0.0000	0.0000	0.0000
Fcapcap	2.3746	0.7774	2.8422	1.4621	0.9773	0.3488	1.5593	0.9516	0.8965
Fcapgra	0.3851	0.0000	0.0000	0.6565	0.3195	0.0000	7.2492	7.2964	1.0898
Fcapmes	0.1250	0.1171	0.0000	0.0000	0.0000	0.0000	0.2312	0.2128	0.3412
Fcaprum	0.5519	0.3592	1.3045	0.4098	1.1345	0.4634	6.6824	1.3699	2.5933
Fcapvau	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.7949	0.4399	0.2168
FRAGnanana	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.6872	1.1047	0.0000

Diatom Taxon	SD29 2005								
	C. demersum			P. friesii			Floating Algae		
	Basin 1	Basin 2	Basin 3	Basin 1	Basin 2	Basin 3	Basin 1	Basin 2	Basin 3
FRAGtenera	0.0000	0.0000	0.3591	0.0547	2.0986	0.5100	57.4053	60.8503	9.2754
GYROattenuatum	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
GOMPacuminatum	5.2153	1.7081	1.8203	2.4033	3.0857	2.4997	4.1414	1.5474	1.3448
Gangsttm	0.2283	0.0000	0.0000	0.0579	0.0000	0.0000	0.0000	0.0000	0.0000
Gangstum	2.6606	0.1220	0.8251	0.8279	0.3101	0.4395	0.0000	0.0000	0.0000
GOMPclavatum	3.5009	1.6998	1.7405	4.2940	2.0146	3.0824	0.9248	0.0000	1.1209
GOMPgracile	30.2709	3.0345	2.1807	53.1028	14.5046	23.2933	0.5748	0.6430	1.3448
GOMPminutum	0.5000	0.1171	0.5669	0.2132	0.2119	0.4634	0.0000	0.0000	0.0000
GOMPparvulum	7.3551	2.2391	6.3998	4.2531	5.0195	11.9459	1.9043	3.5525	3.2919
GOMPpseudotenellum	0.1208	0.0000	0.0000	0.1157	0.0000	0.0000	0.0000	0.0000	0.0000
GOMPsubtile	0.1812	0.0000	0.1134	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
GOMPtruncatum	0.2415	0.0000	0.0000	0.2328	0.2796	1.0938	0.1096	0.0000	0.4483
Ncrypcep	0.3401	0.7784	0.1802	0.0975	0.6597	0.1636	0.0000	0.0000	0.2000
Ncrypten	0.0000	0.3640	1.2397	0.1949	0.3379	0.0000	0.1160	0.0000	0.4483
NAVIlibonensis	0.1075	2.7101	0.4713	0.0000	0.5561	0.0000	0.0000	0.0978	0.4483
NAVminima	0.0000	1.6289	0.9127	0.0000	0.1113	0.0000	0.0000	0.0000	0.0000
NAVminuscula	0.0000	3.7236	2.5763	0.0000	0.5531	0.0000	0.1152	0.0000	0.8797
NAVmenisculus	0.0000	0.6533	0.0567	0.0000	0.3825	0.3918	0.0000	0.0000	0.0000
NAVIpupula	0.8186	2.4022	0.4648	0.0000	0.4425	0.7953	0.0000	0.0000	0.0000
NAVIradiosa	0.0538	0.2997	0.0000	0.4927	0.3753	0.4538	0.5151	0.0000	0.0000
NAVItrivialis	0.0000	0.0000	0.0000	0.0000	0.1106	0.0000	0.0000	0.0000	0.0000
NAVIseminulum	0.9084	1.4248	0.7527	0.0487	0.0000	0.0000	0.0576	0.0000	0.0000

Diatom Taxon	SD29 2005								
	C. demersum			P. friesii			Floating Algae		
	Basin 1	Basin 2	Basin 3	Basin 1	Basin 2	Basin 3	Basin 1	Basin 2	Basin 3
NEIDampliatum	0.1613	0.8292	0.2980	0.0000	0.4301	0.0000	0.0000	0.0000	0.0000
NITZacicularis	0.0000	1.0729	0.7628	0.0000	0.0568	0.0000	0.0000	0.0000	0.3168
NITZamphibia	0.2413	3.9567	2.8767	0.5898	0.4438	0.3415	0.9073	0.0000	1.5605
NITZfonticola	0.2283	0.0000	0.9385	0.3812	0.2226	0.0000	0.0000	0.0000	0.3239
NITZhungarica	0.0000	0.7774	0.0000	0.0000	0.0000	0.1193	0.0000	0.0000	0.0000
NITZliebetruthii	2.6566	0.6010	1.7644	0.4944	0.7356	0.9075	0.4541	0.4399	0.9084
NITZlinearis	0.3687	0.6596	0.7182	0.0000	0.2119	0.0000	0.0000	0.4691	1.5588
Npalea	6.4232	6.3824	20.4183	1.4517	4.0036	6.5175	9.1360	10.8534	61.1143
Npaleaca	0.4849	0.3029	1.2542	0.2647	0.7071	0.6128	1.4768	2.3281	4.4556
NITZperminuta	0.4783	0.0000	0.3056	0.0487	0.1136	0.3345	0.0000	0.0978	0.4483
NITZradicula	0.6854	0.2370	1.2490	0.4983	0.5451	0.1050	0.3456	0.1516	0.6624
NITZrecta	0.3665	0.4145	0.0567	0.0487	0.0553	0.3415	0.0000	0.0000	0.1244
NITZsigmoidea	0.1250	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
NITZsublinearis	0.0538	0.0000	0.2469	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
RHOIabbreviata	0.0000	0.3620	0.1757	0.1171	0.0000	0.0000	0.0000	0.0000	0.0000
RHOPgibba	0.0000	0.6738	0.0000	0.6823	0.4366	0.0000	0.0000	0.2299	0.0000
STAUphoenicenteron	0.9073	0.8380	0.1846	0.0975	0.4314	0.3380	0.0000	0.0000	0.2790
STEPminutulus	0.1163	0.8944	1.1231	0.1645	0.7236	0.0000	0.0000	0.0000	0.0000
SURIangusta	0.1163	0.6027	0.0000	0.0000	0.1106	0.0000	0.0000	0.0000	0.0000
SYNEulna var. acus	0.0000	0.0000	0.0000	0.0000	0.4237	0.0000	1.4460	4.6928	0.6726

Table B3 Diatom percent abundance data from Chapter 5 (Lakes SD2, SD28 and SD20).

Diatom Taxon (SD2)	2004.0	2003.7	2002.9	2002.2	1999.7	1997.6	1995.5	1993.8	1991.9	1990.0	1988.0	1986.9
ACHNconspicua	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
ACHNhungarica	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
ACHNlanceolata var. frequentissima	14.214	6.912	5.693	5.366	1.460	2.558	1.333	1.603	2.000	4.241	2.326	8.333
ACHNlanceolata var. rostrata	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.670	0.000	0.000
ACHNminutissima	23.192	10.829	6.436	7.073	6.569	6.512	5.667	2.885	7.000	11.607	5.316	7.000
AMPHlibyca	1.746	7.373	5.446	2.439	4.866	3.023	3.000	3.526	3.333	4.018	2.658	7.667
AMPHpediculus	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.333	0.000	0.000	0.000
AMPHveneta	0.000	0.000	0.495	0.488	0.487	0.233	0.000	0.321	0.000	0.000	0.000	0.000
CALObacillum	0.499	0.461	0.495	0.000	0.487	0.233	0.667	1.282	0.000	0.893	0.997	0.667
CALOsilicula	0.000	0.691	0.000	0.000	0.000	0.233	0.000	0.000	0.333	0.000	0.000	2.000
COCCplacentula small (<15um)	0.249	1.843	2.475	2.927	1.703	0.465	0.000	0.000	0.000	0.000	1.329	0.000
COCCplacentula var. euglypta	0.748	1.613	1.980	1.951	2.190	0.698	1.333	0.000	2.000	1.786	1.993	4.000
COCCplacentula var. placentula	4.489	3.456	7.426	10.976	11.922	9.070	8.333	8.654	7.000	5.357	9.302	15.667
CRAThalophila	0.000	0.000	0.000	0.000	0.243	0.000	0.667	0.000	0.333	0.223	0.000	0.000
CYCOcf. Tholiformis	0.499	0.461	0.248	1.220	0.487	0.465	0.000	0.000	0.333	0.670	0.000	0.333
CYCOPAD sp. 2	0.000	0.000	0.000	1.463	0.973	0.233	1.333	0.000	0.333	0.670	0.664	0.000
CYMBmicrocephala	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.664	0.667
CYMBminuta	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
CYMBproxima	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.223	0.000	0.000
DIATmoniliformis	0.000	0.000	0.000	0.000	0.243	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Diatom Taxon (SD2)	2004.0	2003.7	2002.9	2002.2	1999.7	1997.6	1995.5	1993.8	1991.9	1990.0	1988.0	1986.9
DIATtenuis	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
EPITadnata	4.489	3.687	3.713	2.683	3.650	3.256	5.000	0.321	2.000	4.464	10.963	6.667
EPITturgida	0.000	0.230	0.743	1.463	0.730	1.163	3.667	0.962	1.000	2.232	4.651	2.000
EUNObilunaris	0.000	0.000	0.000	0.244	0.000	0.465	0.000	0.000	0.667	0.000	0.000	0.000
EUNOimplicata	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
EUNOincisa	0.000	0.000	0.000	0.000	0.000	0.233	0.000	0.000	0.000	0.000	0.332	0.000
FRAGbrevistriata	0.000	0.000	0.000	0.000	0.000	0.465	0.000	0.000	0.000	0.000	0.000	0.000
FRAGcapucina var. gracilis	0.499	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
FRAGcapucina var. rumpens	0.000	0.000	0.000	0.000	0.973	0.465	0.000	0.000	0.000	0.000	0.000	0.000
FRAGcapucina var.mesolepta	0.000	0.000	0.000	0.976	0.000	0.930	7.000	3.205	2.667	0.446	0.000	0.000
FRAGconstruens	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.333	0.446	1.661	0.000
FRAGconstruens f. binodis	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
FRAGconstruens var. venter	0.000	0.000	0.000	0.976	0.000	0.000	0.000	0.641	3.667	3.125	0.664	0.000
FRAGfamelica	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
FRAGpinnata	0.499	1.152	0.000	0.244	0.000	0.000	0.667	0.000	2.000	0.670	0.664	0.000
FRAGpinnata var. intercedens	0.000	0.230	0.000	0.488	0.000	0.000	0.000	0.321	0.000	1.339	0.664	1.000
GOMPacuminatum	0.249	0.000	0.000	0.000	0.973	0.233	3.333	1.282	2.000	0.893	0.997	0.000
GOMPangustatum	0.499	0.000	0.000	0.000	0.730	0.465	0.000	0.000	1.000	0.000	0.000	0.667
GOMPangustum	0.000	0.691	0.000	0.244	0.730	0.465	1.000	0.000	0.000	0.000	0.000	1.333
GOMPclavatum	0.748	1.382	0.000	0.732	0.973	0.698	1.667	1.282	0.333	0.000	0.000	0.000
GOMPgracile	0.000	1.152	0.000	0.000	0.487	0.233	0.667	0.641	0.333	0.446	0.000	0.000
GOMPparvulum	5.486	1.382	0.743	1.707	3.406	2.791	2.000	2.244	1.667	0.446	0.664	1.333
GOMPtruncatum	0.000	0.461	0.000	0.000	0.000	0.000	0.333	3.526	1.333	0.000	0.664	0.333
GOMP minutum	0.000	0.000	0.990	0.000	0.000	0.000	0.667	0.641	0.667	0.446	1.993	0.333

Diatom Taxon (SD2)	2004.0	2003.7	2002.9	2002.2	1999.7	1997.6	1995.5	1993.8	1991.9	1990.0	1988.0	1986.9
GYRO attenuatum	0.249	2.995	1.238	1.220	0.487	1.163	1.667	0.962	1.000	0.223	0.664	1.000
NAVIcapitata var. capitata	2.244	1.613	1.980	2.439	2.920	0.233	1.000	0.962	0.333	0.893	0.664	0.000
NAVIcryptocephala	2.244	1.382	3.465	2.439	2.676	2.791	3.667	2.244	3.000	3.348	4.983	2.333
NAVIcryptotenella	0.249	1.152	2.228	0.976	1.460	2.093	0.667	2.244	2.333	3.571	2.658	1.667
NAVIcuspidata	0.000	0.000	0.743	0.244	0.487	0.233	0.667	0.321	1.000	0.223	0.000	0.000
NAVIlaevissima	0.000	0.000	0.000	0.000	0.000	0.000	0.667	0.000	0.000	0.000	0.000	0.000
NAVIlibonensis	7.481	15.207	15.099	14.146	13.869	12.326	11.333	15.064	15.000	13.170	9.302	7.667
NAVImenisculus	0.249	0.230	0.495	0.000	0.487	0.000	1.333	0.641	0.667	0.000	0.664	0.000
NAVIminima	0.000	0.000	0.000	0.000	0.243	0.000	0.000	0.000	0.000	0.670	1.329	0.000
NAVIminuscula var. muralis	2.993	0.922	1.733	0.488	0.000	1.163	0.000	1.923	0.333	1.116	1.329	0.000
NAVIoblonga	0.000	0.000	0.000	0.488	0.243	0.465	0.333	0.000	0.000	0.223	0.000	0.000
NAVIpupula	4.738	3.226	5.693	4.878	3.650	7.442	2.333	4.167	5.333	5.357	2.658	9.667
NAVIradiosa	1.496	3.917	3.218	3.415	2.676	7.442	8.667	8.013	6.667	4.911	2.990	1.000
NAVISD sp. 1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
NAVIseminuloides	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
NAVIseminulum	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
NAVIsubmuralis	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
NAVIsubplacentula	0.499	0.691	0.248	0.000	0.973	0.930	0.333	1.923	0.667	0.446	0.000	0.000
NAVItrivialis	0.000	0.230	0.000	0.732	0.730	0.930	1.000	1.282	1.333	0.000	0.332	0.333
NAVIveneta	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.667	0.000	0.332	0.000
NEIDampliatum	0.249	0.461	0.495	0.976	0.000	0.465	0.333	0.641	0.333	0.223	0.000	0.000
NITZacicularis	0.000	0.000	0.000	0.000	0.000	1.163	0.000	0.000	0.000	0.000	0.000	0.000
NITZamphibia	5.736	1.613	1.733	0.244	0.973	0.000	1.333	3.205	2.333	2.679	3.987	3.000
NITZfonticola	0.000	0.000	0.000	0.488	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Diatom Taxon (SD2)	2004.0	2003.7	2002.9	2002.2	1999.7	1997.6	1995.5	1993.8	1991.9	1990.0	1988.0	1986.9
NITZgracilis	0.249	0.000	0.000	0.000	0.243	0.000	0.667	0.000	0.000	0.000	0.997	0.333
NITZliebetruthii	1.247	0.922	0.248	0.976	0.973	0.233	0.667	1.603	0.000	0.446	0.997	1.000
NITZpalea	0.748	0.000	0.000	0.976	0.487	0.000	1.333	0.000	0.000	0.000	0.000	0.000
NITZpaleacea	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
NITZperminuta	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
NITZradicula	0.000	0.000	0.000	0.000	0.730	0.233	0.000	0.000	0.000	0.000	0.000	0.000
NITZrecta	0.000	0.230	0.743	0.488	0.973	0.465	0.667	0.641	1.000	0.893	0.000	0.000
NITZsigmoidea	0.249	0.922	0.495	0.976	0.487	0.930	0.667	0.962	1.000	0.446	0.664	0.000
PINNinterrupta	0.000	0.000	0.000	0.000	0.487	0.465	0.000	0.000	0.000	0.000	0.000	0.000
PINNmicrostauron	0.000	1.843	0.990	1.707	1.946	1.395	0.667	1.603	1.000	0.893	0.332	0.667
RHOPgibba	2.494	2.074	1.980	1.707	1.460	2.326	2.333	4.487	2.667	1.786	0.332	1.333
STAUanceps	0.249	4.147	3.713	2.439	1.946	3.953	0.333	0.962	1.667	2.455	1.661	2.000
STAUphoenicenteron	1.247	1.152	0.743	0.488	0.243	0.930	0.333	0.321	0.000	0.670	0.332	0.000
STAUsp. 1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
STEPminutulus	0.000	0.000	0.495	0.976	0.487	0.000	0.000	0.000	0.000	0.000	0.000	0.000
STEPparvus	0.000	0.461	1.238	0.488	0.730	0.233	0.667	1.603	1.000	0.000	0.000	0.000
SURIangusta	0.748	0.000	0.000	0.000	0.243	0.000	0.000	0.321	0.000	0.000	0.000	0.000
SURIminuta	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
SYNEulna var. acus	0.249	0.691	0.495	0.244	0.243	0.233	0.000	0.000	0.000	0.446	1.661	0.333
TABEflocculosa	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.333	0.000	0.332	0.333
Diatom Taxon (SD2)	**1986.0**	**1984.7**	**1983.1**	**1981.3**	**1979.4**	**1977.8**	**1975.4**	**1973.3**	**1971.1**	**1968.8**	**1966.7**	**1965.4**
ACHNconspicua	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
ACHNhungarica	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Diatom Taxon (SD2)	1986.0	1984.7	1983.1	1981.3	1979.4	1977.8	1975.4	1973.3	1971.1	1968.8	1966.7	1965.4
ACHNlanceolata var. frequentissima	2.849	1.231	1.639	0.500	0.000	0.000	1.176	1.778	1.714	0.000	0.763	0.885
ACHNlanceolata var. rostrata	0.000	0.000	0.000	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.763	0.000
ACHNminutissima	7.692	13.846	8.197	8.500	0.604	4.934	4.706	1.333	6.857	3.365	2.672	7.965
AMPHlibyca	4.843	3.077	3.934	2.500	6.042	2.303	6.275	5.333	6.286	2.404	3.435	3.982
AMPHpediculus	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
AMPHveneta	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.778	0.000	0.000	0.000	0.885
CALObacillum	1.140	0.615	1.639	0.000	0.000	0.000	0.000	2.222	1.143	0.962	0.000	0.885
CALOsilicula	0.285	0.000	0.000	0.500	0.000	0.000	0.392	0.000	0.000	0.000	0.000	0.000
COCCplacentula small (<15um)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
COCCplacentula var. euglypta	0.570	1.538	3.279	2.000	0.604	1.645	1.961	1.778	2.286	0.962	0.763	3.540
COCCplacentula var. placentula	12.251	11.077	14.426	12.500	12.085	9.868	18.039	23.556	6.857	10.577	16.031	24.336
CRAThalophila	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
CYCOcf. Tholiformis	0.570	0.000	0.328	0.000	0.000	0.329	1.961	0.889	0.000	0.000	0.000	0.442
CYCOPAD sp. 2	0.000	0.923	0.000	0.000	0.000	0.000	1.961	0.000	0.000	0.000	0.382	0.000
CYMBmicrocephala	0.000	0.923	0.656	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.442
CYMBminuta	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
CYMBproxima	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
DIATmoniliformis	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
DIATtenuis	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
EPITadnata	4.843	4.923	6.885	3.000	0.604	1.974	3.529	4.444	15.429	12.019	17.557	2.655
EPITturgida	1.709	3.077	3.279	2.500	0.906	1.974	1.961	3.556	2.857	7.212	3.817	2.212
EUNObilunaris	1.140	0.000	0.328	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.763	0.000
EUNOimplicata	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
EUNOincisa	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Diatom Taxon (SD2)	1986.0	1984.7	1983.1	1981.3	1979.4	1977.8	1975.4	1973.3	1971.1	1968.8	1966.7	1965.4
FRAGbrevistriata	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
FRAGcapucina var. gracilis	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.885
FRAGcapucina var. rumpens	0.000	0.000	0.000	0.000	3.021	5.263	1.961	6.222	0.000	0.000	0.000	0.000
FRAGcapucina var.mesolepta	0.570	0.923	0.656	0.000	0.906	7.237	1.961	1.333	1.143	0.000	0.763	0.000
FRAGconstruens	0.000	0.000	0.000	2.000	0.000	0.000	0.000	0.000	0.000	0.962	2.672	1.770
FRAGconstruens f. binodis	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
FRAGconstruens var. venter	0.000	0.000	0.000	3.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
FRAGfamelica	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
FRAGpinnata	0.570	0.000	0.656	0.000	1.208	0.000	0.000	3.556	6.286	2.885	2.290	1.770
FRAGpinnata var. intercedens	0.000	0.000	0.000	3.500	0.000	2.632	0.784	0.000	0.571	0.000	0.000	0.442
GOMPacuminatum	1.709	0.000	0.000	1.000	1.813	1.974	0.000	0.444	0.000	0.000	0.000	0.885
GOMPangustatum	0.000	0.000	0.000	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.382	0.442
GOMPangustum	3.704	3.385	5.574	5.000	2.115	1.316	0.784	0.000	1.143	1.923	0.000	0.000
GOMPclavatum	1.140	1.231	0.000	2.000	3.323	2.303	0.392	0.444	0.571	0.000	0.000	2.212
GOMPgracile	0.000	3.385	1.967	0.500	1.813	0.000	0.000	0.000	0.000	0.000	0.000	0.885
GOMPparvulum	2.564	4.000	2.295	2.000	3.323	0.987	0.392	0.000	4.000	1.923	1.527	6.195
GOMPtruncatum	0.000	1.231	0.656	0.500	1.208	0.000	0.392	0.444	0.000	0.000	0.000	0.000
GOMP minutum	3.419	4.308	1.311	1.000	1.813	0.000	0.000	0.000	1.143	0.962	1.527	0.000
GYRO attenuatum	1.425	1.538	1.311	3.000	1.511	0.658	0.392	0.889	1.714	2.404	2.290	0.442
NAVIcapitata var. capitata	1.140	0.000	0.328	0.000	0.000	0.000	0.392	0.000	0.000	0.000	0.000	0.885
NAVIcryptocephala	3.134	0.000	0.328	2.000	0.906	1.645	0.784	1.333	1.143	1.442	1.145	0.885
NAVIcryptotenella	1.425	0.923	1.967	2.000	1.208	0.329	0.000	0.889	0.571	0.000	0.763	2.212
NAVIcuspidata	0.570	0.000	0.328	0.000	0.302	0.658	0.000	0.444	0.571	1.923	0.763	0.442
NAVIlaevissima	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Diatom Taxon (SD2)	1986.0	1984.7	1983.1	1981.3	1979.4	1977.8	1975.4	1973.3	1971.1	1968.8	1966.7	1965.4
NAVIlibonensis	9.687	4.923	6.557	9.500	25.378	25.658	23.922	17.778	16.000	19.712	8.015	2.655
NAVImenisculus	0.000	0.923	0.656	0.000	0.604	0.000	0.000	0.444	0.571	0.000	0.000	0.000
NAVIminima	0.000	0.615	0.656	1.000	0.000	0.000	0.000	0.000	1.143	0.000	0.000	0.000
NAVIminuscula var. muralis	0.000	0.923	0.000	0.000	0.302	0.329	3.137	0.889	0.000	0.000	0.000	0.000
NAVIoblonga	0.285	0.000	0.328	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
NAVIpupula	6.553	2.769	3.607	5.500	3.625	2.632	1.176	4.000	2.286	5.769	1.908	1.770
NAVIradiosa	1.425	3.077	2.623	2.000	1.511	0.329	0.392	0.889	1.714	2.404	3.817	4.867
NAVISD sp. 1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
NAVIseminuloides	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
NAVIseminulum	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
NAVIsubmuralis	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
NAVIsubplacentula	0.000	0.000	0.000	0.000	0.000	0.329	0.000	0.889	0.000	0.000	0.000	0.000
NAVItrivialis	0.000	0.308	0.000	0.000	1.511	0.329	0.000	0.000	0.000	3.365	0.763	0.885
NAVIveneta	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
NEIDampliatum	1.425	0.923	0.000	0.500	0.906	0.329	1.176	0.444	0.000	0.962	0.763	0.000
NITZacicularis	0.570	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
NITZamphibia	3.134	2.462	1.967	5.500	3.021	0.658	3.922	0.889	0.571	0.481	1.908	0.885
NITZfonticola	0.000	0.615	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
NITZgracilis	0.000	0.000	0.000	0.000	0.604	0.000	0.000	0.000	0.000	0.000	0.000	0.000
NITZliebetruthii	0.285	0.000	0.000	1.500	3.625	1.974	0.000	1.333	0.000	0.000	1.145	0.885
NITZpalea	0.000	0.615	1.311	0.000	0.000	1.316	1.569	0.000	0.000	0.000	0.763	0.000
NITZpaleacea	0.000	0.000	0.000	0.000	1.208	0.000	0.000	0.000	0.000	0.000	0.000	0.000
NITZperminuta	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
NITZradicula	0.000	0.000	0.000	0.000	0.000	0.658	0.000	0.000	0.000	0.000	0.000	0.885

Diatom Taxon (SD2)	1986.0	1984.7	1983.1	1981.3	1979.4	1977.8	1975.4	1973.3	1971.1	1968.8	1966.7	1965.4
NITZrecta	0.570	0.308	0.328	0.500	1.813	0.987	0.392	0.889	0.000	0.481	0.000	0.000
NITZsigmoidea	0.285	0.308	0.328	0.500	2.115	0.658	0.392	0.444	0.571	1.923	0.000	0.000
PINNinterrupta	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
PINNmicrostauron	0.000	0.308	0.984	0.500	0.604	1.645	1.176	0.000	3.429	0.962	0.382	0.000
RHOPgibba	2.564	5.846	3.279	1.000	0.302	1.645	0.784	1.778	3.429	2.885	6.870	3.982
STAUanceps	1.140	3.385	0.984	1.000	0.604	1.645	0.784	1.333	1.714	0.962	0.763	0.000
STAUphoenicenteron	0.285	0.308	0.000	0.500	0.604	0.329	0.392	0.000	0.571	0.000	0.000	0.000
STAUsp. 1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
STEPminutulus	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
STEPparvus	0.000	0.308	0.000	0.000	0.000	0.000	0.392	0.444	0.000	0.481	0.763	0.000
SURIangusta	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.442
SURIminuta	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.481	0.000	0.000
SYNEulna var. acus	0.285	0.308	0.328	0.500	0.000	0.329	0.392	0.000	0.571	0.000	0.000	0.000
TABEflocculosa	0.000	0.000	0.000	0.000	0.302	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Diatom Taxon (SD2)	1963.1	1961.8	1959.5	1952.2	1950.4	1947.3	1944.7	1943.7	1941.6	1939.4	1937.3	1935.0
ACHNconspicua	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.633	0.000	0.000	0.667	0.000
ACHNhungarica	0.000	0.000	2.956	3.059	3.196	1.481	2.258	1.582	0.000	0.000	0.667	0.000
ACHNlanceolata var. frequentissima	3.416	1.875	12.315	10.353	11.416	5.185	5.484	5.063	5.960	1.333	2.667	5.785
ACHNlanceolata var. rostrata	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
ACHNminutissima	6.211	13.750	17.488	28.706	12.557	5.926	6.129	6.329	8.609	5.333	5.333	5.785
AMPHlibyca	2.484	1.563	5.419	4.000	5.936	10.864	10.000	10.759	11.921	11.333	4.667	4.132
AMPHpediculus	0.000	0.625	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.333	0.000	0.000
AMPHveneta	0.000	0.000	0.000	0.235	0.000	0.741	0.323	0.949	0.000	0.667	0.667	0.000

Diatom Taxon (SD2)	1963.1	1961.8	1959.5	1952.2	1950.4	1947.3	1944.7	1943.7	1941.6	1939.4	1937.3	1935.0
CALObacillum	0.621	0.000	0.000	0.000	0.457	0.000	0.000	0.633	0.000	0.000	0.000	0.000
CALOsilicula	0.000	0.000	1.232	0.000	0.457	0.000	0.323	0.000	0.000	0.000	0.000	0.826
COCCplacentula small (<15um)	0.000	0.625	0.000	0.000	0.228	0.494	0.000	0.949	1.325	0.000	0.000	0.000
COCCplacentula var. euglypta	0.311	1.250	0.985	0.000	1.826	1.235	0.323	0.000	0.662	0.667	0.667	0.000
COCCplacentula var. placentula	8.385	9.375	11.823	5.412	11.872	9.136	6.452	8.861	7.947	7.333	5.333	3.306
CRAThalophila	0.000	0.000	0.000	0.000	0.228	0.000	0.000	0.000	0.000	0.000	0.000	0.000
CYCOcf. Tholiformis	0.000	0.000	0.000	0.000	0.000	0.247	0.000	0.000	0.000	0.000	0.000	0.000
CYCOPAD sp. 2	0.621	0.625	0.000	0.000	0.000	0.247	0.645	0.633	0.000	0.000	0.000	0.000
CYMBmicrocephala	0.000	1.563	0.000	0.000	0.000	0.000	0.323	0.949	0.000	0.667	0.000	0.000
CYMBminuta	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
CYMBproxima	0.000	0.000	0.000	0.235	0.000	0.000	0.000	0.000	0.000	0.667	0.000	0.000
DIATmoniliformis	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
DIATtenuis	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
EPITadnata	2.484	0.625	5.665	3.529	5.936	2.716	4.839	3.481	5.298	4.667	3.333	0.000
EPITturgida	5.280	0.313	1.724	1.882	2.511	3.457	3.226	2.215	1.987	1.333	2.667	0.000
EUNObilunaris	0.000	0.313	0.246	0.706	0.457	0.247	0.000	0.000	0.000	0.000	0.000	0.000
EUNOimplicata	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
EUNOincisa	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
FRAGbrevistriata	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
FRAGcapucina var. gracilis	0.000	1.875	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
FRAGcapucina var. rumpens	0.932	0.000	0.493	0.000	0.913	0.000	0.000	0.949	0.000	0.000	0.000	0.826
FRAGcapucina var.mesolepta	0.932	3.438	0.739	0.000	0.000	0.000	0.000	2.532	0.000	0.000	0.000	0.000

Diatom Taxon (SD2)	1963.1	1961.8	1959.5	1952.2	1950.4	1947.3	1944.7	1943.7	1941.6	1939.4	1937.3	1935.0
FRAGconstruens	0.000	0.000	3.695	4.000	1.826	0.988	3.548	4.114	5.960	5.333	5.333	0.000
FRAGconstruens f. binodis	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
FRAGconstruens var. venter	0.000	0.000	0.000	2.588	0.913	0.000	1.290	0.000	0.000	4.000	0.000	0.000
FRAGfamelica	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
FRAGpinnata	0.621	3.438	1.970	0.000	0.228	0.494	0.000	0.633	0.662	2.000	6.000	8.264
FRAGpinnata var. intercedens	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	2.667	0.667	9.917
GOMPacuminatum	0.000	0.625	0.246	0.000	0.000	0.000	0.645	0.000	0.000	0.000	0.000	0.000
GOMPangustatum	0.000	0.000	0.246	0.235	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
GOMPangustum	0.000	0.313	0.246	0.000	0.228	0.000	0.000	0.000	0.000	0.000	0.000	0.000
GOMPclavatum	0.311	0.313	1.970	0.000	2.055	0.988	0.968	0.633	0.000	0.000	0.000	0.000
GOMPgracile	0.621	0.000	0.493	0.941	0.000	0.494	0.323	0.633	1.325	0.000	0.000	0.000
GOMPparvulum	2.795	2.500	0.000	1.176	0.685	2.222	0.968	0.949	0.662	1.333	1.333	1.653
GOMPtruncatum	0.932	0.313	0.739	0.941	0.685	1.728	0.645	0.949	0.000	0.000	0.000	0.000
GOMP minutum	0.000	0.625	0.493	0.471	0.913	0.000	0.000	0.000	0.000	0.000	0.000	0.000
GYRO attenuatum	1.242	0.313	0.000	0.000	0.000	0.494	0.000	0.316	0.662	0.667	0.000	0.826
NAVIcapitata var. capitata	0.000	0.000	0.000	0.471	0.457	0.247	0.000	0.633	0.000	3.333	0.667	1.653
NAVIcryptocephala	8.075	7.500	0.493	1.647	2.283	4.198	4.194	4.114	2.649	1.333	2.000	4.959
NAVIcryptotenella	3.106	3.750	1.478	0.941	0.457	3.704	1.935	3.165	0.662	0.000	3.333	4.959
NAVIcuspidata	0.621	0.000	0.000	0.000	0.228	0.494	0.968	0.000	0.000	0.000	0.000	0.826
NAVIlaevissima	0.000	0.625	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
NAVIlibonensis	9.006	6.250	4.187	1.176	6.164	18.765	16.452	13.291	17.219	22.000	16.667	12.397
NAVImenisculus	0.000	0.000	0.000	0.000	0.000	0.741	0.000	0.000	0.000	0.000	0.667	0.000

Diatom Taxon (SD2)	1963.1	1961.8	1959.5	1952.2	1950.4	1947.3	1944.7	1943.7	1941.6	1939.4	1937.3	1935.0
NAVIminima	0.621	2.500	2.217	1.412	1.826	0.494	1.935	0.633	1.325	0.000	0.000	0.000
NAVIminuscula var. muralis	0.000	0.625	1.232	0.941	1.598	0.000	0.000	0.000	0.662	0.000	0.667	0.000
NAVIoblonga	0.000	0.000	0.000	0.000	0.228	0.000	0.000	0.000	0.000	0.000	0.000	0.000
NAVIpupula	3.106	2.813	3.941	4.235	2.968	4.444	5.161	3.165	1.325	4.667	2.667	3.306
NAVIradiosa	6.522	9.375	1.232	2.824	0.457	1.481	0.968	0.633	0.662	1.333	1.333	0.000
NAVISD sp. 1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
NAVIseminuloides	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
NAVIseminulum	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
NAVIsubmuralis	0.000	0.000	0.000	0.000	0.685	0.000	0.000	0.000	0.000	0.000	0.000	0.000
NAVIsubplacentula	0.621	0.000	0.000	0.000	0.000	0.494	0.323	0.000	1.987	0.000	3.333	2.479
NAVItrivialis	2.484	1.250	0.246	0.471	0.457	0.000	0.000	0.000	0.000	0.000	0.667	0.000
NAVIveneta	0.000	0.313	0.000	0.000	0.000	0.494	0.000	0.000	0.662	0.000	0.000	0.826
NEIDampliatum	0.000	0.000	0.000	0.235	0.228	0.000	0.323	0.316	0.000	1.333	0.000	0.000
NITZacicularis	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
NITZamphibia	3.106	2.813	4.187	7.529	5.479	4.938	4.839	5.696	3.311	0.667	6.667	6.612
NITZfonticola	0.000	0.313	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
NITZgracilis	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
NITZliebetruthii	0.621	0.625	0.493	0.471	0.000	0.741	1.613	0.633	2.649	0.667	2.667	1.653
NITZpalea	0.000	0.313	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.826
NITZpaleacea	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
NITZperminuta	0.000	0.000	0.000	0.000	0.000	0.000	0.645	0.000	0.000	0.000	1.333	0.826
NITZradicula	0.000	0.313	0.000	0.471	0.457	0.000	0.323	0.000	0.000	0.000	0.000	0.000

Diatom Taxon (SD2)	1963.1	1961.8	1959.5	1952.2	1950.4	1947.3	1944.7	1943.7	1941.6	1939.4	1937.3	1935.0
NITZrecta	0.621	0.313	0.000	0.000	0.000	0.000	0.000	0.316	0.000	0.000	0.000	0.000
NITZsigmoidea	1.553	0.313	0.493	0.000	0.000	0.000	0.323	0.000	0.000	0.667	0.667	0.000
PINNinterrupta	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
PINNmicrostauron	0.311	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
RHOPgibba	6.522	0.313	0.739	0.471	0.228	0.247	0.000	3.165	1.987	2.000	1.333	0.000
STAUanceps	1.242	3.750	0.493	0.471	1.142	0.494	0.645	0.633	1.325	0.000	0.000	0.826
STAUphoenicenteron	0.621	0.938	0.246	0.000	0.685	0.988	0.968	0.316	0.000	0.000	0.667	0.000
STAUsp. 1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
STEPminutulus	0.621	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
STEPparvus	1.553	0.313	0.739	0.000	0.000	0.741	0.968	0.000	0.000	0.000	2.000	0.826
SURIangusta	0.000	0.000	0.000	0.235	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
SURIminuta	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
SYNEulna var. acus	0.000	0.313	0.493	0.471	0.457	0.000	0.323	0.316	0.000	0.000	0.667	0.000
TABEflocculosa	1.242	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Diatom Taxon (SD2)	1932.8	1930.5	1928.0	1926.0	1924.6	1922.7	1920.4	1918.4	1915.9	1915.2	1914.2
ACHNconspicua	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
ACHNhungarica	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
ACHNlanceolata var. frequentissima	2.727	1.194	2.000	9.302	15.459	11.013	15.714	18.750	19.143	14.667	4.500
ACHNlanceolata var. rostrata	0.909	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
ACHNminutissima	4.545	5.970	6.800	8.605	1.449	5.727	6.857	5.500	5.714	11.667	4.500
AMPHlibyca	1.818	4.478	3.200	5.814	5.314	5.286	2.857	3.000	4.571	8.333	8.500
AMPHpediculus	0.000	0.000	0.000	0.465	0.000	0.000	0.000	0.000	0.000	0.000	0.000
AMPHveneta	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.286	0.000	0.000

Diatom Taxon (SD2)	1932.8	1930.5	1928.0	1926.0	1924.6	1922.7	1920.4	1918.4	1915.9	1915.2	1914.2
CALObacillum	0.000	0.597	0.800	0.233	0.000	0.881	0.000	0.000	0.571	0.667	1.000
CALOsilicula	0.000	0.299	1.200	0.000	0.966	0.000	0.000	0.500	0.571	0.000	1.000
COCCplacentula small (<15um)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
COCCplacentula var. euglypta	0.000	0.299	0.800	0.930	0.483	0.000	0.857	1.000	0.000	1.667	1.500
COCCplacentula var. placentula	7.273	3.582	2.000	5.814	2.899	4.405	1.429	2.250	4.286	10.000	5.500
CRAThalophila	0.000	0.000	0.000	0.000	0.000	0.441	0.000	0.000	0.000	0.000	0.000
CYCOcf. Tholiformis	0.000	0.000	0.000	0.000	0.000	0.441	0.000	0.000	0.000	0.333	0.000
CYCOPAD sp. 2	0.909	0.597	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.333	0.000
CYMBmicrocephala	0.000	3.284	2.400	0.930	0.000	0.441	0.000	0.000	0.000	0.000	1.000
CYMBminuta	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
CYMBproxima	0.000	0.000	0.000	0.000	0.000	0.441	0.000	0.500	0.000	0.333	0.000
DIATmoniliformis	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
DIATtenuis	0.909	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
EPITadnata	6.364	0.896	1.200	3.023	2.899	4.846	4.000	1.750	4.000	2.333	6.000
EPITturgida	1.818	0.299	0.000	1.628	3.382	3.084	1.429	3.500	2.857	1.667	5.000
EUNObilunaris	0.000	0.597	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
EUNOimplicata	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
EUNOincisa	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
FRAGbrevistriata	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
FRAGcapucina var. gracilis	0.000	0.000	1.600	3.721	0.000	5.286	0.000	0.000	0.000	0.000	0.000
FRAGcapucina var. rumpens	0.000	0.000	3.200	0.000	0.000	5.286	0.000	0.000	0.000	0.000	0.000
FRAGcapucina var.mesolepta	0.000	0.896	0.800	3.256	2.899	4.405	2.286	1.250	0.857	1.333	3.500
FRAGconstruens	6.364	0.896	3.200	0.930	1.932	0.441	1.429	3.000	2.857	0.000	0.000
FRAGconstruens f. binodis	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Diatom Taxon (SD2)	1932.8	1930.5	1928.0	1926.0	1924.6	1922.7	1920.4	1918.4	1915.9	1915.2	1914.2
FRAGconstruens var. venter	1.818	0.000	0.000	1.860	3.865	0.000	1.143	0.500	0.000	0.000	0.500
FRAGfamelica	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
FRAGpinnata	6.364	4.776	2.800	7.442	3.865	3.965	6.286	5.000	0.000	0.667	1.000
FRAGpinnata var. intercedens	3.636	0.597	0.000	0.000	0.000	3.524	0.000	0.000	0.000	0.000	0.000
GOMPacuminatum	0.000	0.597	0.000	0.930	0.000	0.000	0.000	0.000	0.286	0.000	0.000
GOMPangustatum	0.000	0.000	0.000	0.000	0.000	0.000	0.571	0.000	0.286	0.000	1.500
GOMPangustum	0.000	0.000	0.000	5.349	0.000	0.000	0.000	0.000	0.857	1.333	0.000
GOMPclavatum	0.000	0.000	0.400	1.860	0.000	0.881	0.000	0.000	0.286	0.000	0.000
GOMPgracile	0.909	0.000	0.800	0.000	0.966	0.000	0.000	0.000	0.000	0.000	0.000
GOMPparvulum	2.727	0.299	0.800	3.721	0.000	0.000	2.000	0.500	2.286	1.333	7.000
GOMPtruncatum	0.000	0.000	0.000	0.000	0.966	0.000	0.000	0.000	0.000	1.333	0.000
GOMP minutum	0.000	0.000	0.400	0.465	0.000	0.000	0.000	0.750	0.000	0.667	0.000
GYRO attenuatum	0.000	0.896	0.400	0.698	1.449	1.762	0.000	0.250	0.571	0.000	1.500
NAVIcapitata var. capitata	0.000	1.194	0.000	0.000	0.966	0.000	1.143	0.000	0.000	0.000	0.000
NAVIcryptocephala	2.727	4.478	7.200	1.860	0.483	3.524	1.429	1.250	2.571	0.667	1.000
NAVIcryptotenella	1.818	4.478	5.600	1.163	1.932	1.322	1.429	1.000	1.714	0.000	1.500
NAVIcuspidata	0.000	0.000	0.000	0.465	1.449	0.881	0.000	0.000	0.000	1.000	0.000
NAVIlaevissima	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
NAVIlibonensis	15.455	22.687	20.400	6.977	14.976	6.167	10.000	13.500	8.857	11.667	18.000
NAVImenisculus	0.909	0.000	0.000	0.233	0.000	0.000	0.000	0.000	0.000	0.000	0.000
NAVIminima	0.000	0.597	0.800	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
NAVIminuscula var. muralis	0.909	1.194	0.000	0.465	0.000	0.000	0.000	0.000	1.143	0.000	1.000
NAVIoblonga	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
NAVIpupula	1.818	3.881	4.000	2.791	1.932	2.203	14.000	12.500	8.571	8.333	7.500

Diatom Taxon (SD2)	1932.8	1930.5	1928.0	1926.0	1924.6	1922.7	1920.4	1918.4	1915.9	1915.2	1914.2
NAVIradiosa	0.000	1.791	0.800	5.116	2.415	2.643	0.857	0.500	0.857	0.333	0.000
NAVISD sp. 1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
NAVIseminuloides	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
NAVIseminulum	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
NAVIsubmuralis	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
NAVIsubplacentula	1.818	3.582	2.800	0.233	0.966	1.762	0.000	0.000	0.000	0.000	0.000
NAVItrivialis	1.818	1.194	0.800	0.233	0.000	0.000	0.571	0.000	0.286	0.000	0.500
NAVIveneta	0.000	2.388	0.400	0.465	0.000	1.322	0.571	0.750	0.857	0.000	1.000
NEIDampliatum	0.000	0.299	0.400	0.000	0.483	0.000	0.000	0.000	0.000	0.000	0.000
NITZacicularis	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
NITZamphibia	1.818	3.881	4.000	6.279	10.628	8.370	12.000	14.250	13.429	5.000	2.500
NITZfonticola	0.000	0.000	1.600	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
NITZgracilis	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
NITZliebetruthii	1.818	1.194	0.000	1.163	0.000	0.000	1.429	0.000	0.571	0.000	0.000
NITZpalea	0.000	0.000	1.600	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
NITZpaleacea	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
NITZperminuta	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
NITZradicula	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
NITZrecta	0.909	1.791	0.800	0.233	0.000	0.881	0.571	0.000	0.571	0.667	0.000
NITZsigmoidea	0.000	0.597	0.800	0.233	0.000	0.000	0.571	0.250	0.000	0.667	0.000
PINNinterrupta	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
PINNmicrostauron	0.000	0.000	0.000	0.000	0.966	1.762	0.000	0.000	1.143	0.000	0.000
RHOPgibba	4.545	1.194	1.600	0.000	1.449	0.441	0.000	1.250	0.857	2.000	3.000
STAUanceps	0.909	0.000	1.200	0.000	0.483	1.322	3.143	1.000	2.857	0.667	3.500

Diatom Taxon (SD2)	1932.8	1930.5	1928.0	1926.0	1924.6	1922.7	1920.4	1918.4	1915.9	1915.2	1914.2
STAUphoenicenteron	0.909	0.000	0.000	0.233	0.483	0.441	0.286	0.000	0.571	0.333	1.000
STAUsp. 1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
STEPminutulus	0.000	0.299	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
STEPparvus	0.000	0.299	0.000	0.000	0.000	0.441	0.000	0.750	0.000	0.333	0.000
SURIangusta	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
SURIminuta	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
SYNEulna var. acus	0.000	0.000	0.000	0.233	0.000	0.000	0.000	0.000	0.000	0.000	0.500
TABEflocculosa	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Diatom Taxon (SD28)	2002	2001.8	2001.2	2001	2000.7	2000.3	1999.9	1999.6	1999.1	1998.2	1997	1996.3
ACHNconspicua	0.000	0.000	0.000	0.244	0.488	0.244	0.000	0.000	0.000	0.000	0.000	0.000
ACHNhungarica	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
ACHNlanceolata var. frequentissima	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
ACHNlanceolata var. rostrata	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
ACHNminutissima	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
AMPHlibyca	0.236	0.980	1.724	2.204	2.683	3.162	3.641	2.620	1.600	2.061	2.521	1.914
AMPHpediculus	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.400	0.800	0.400	0.000	0.327
AMPHveneta	17.925	17.952	17.980	17.039	16.098	13.146	10.194	9.897	9.600	7.741	5.882	6.699
CALObacillum	0.000	0.000	0.000	0.000	0.000	0.485	0.971	0.485	0.000	0.000	0.000	0.327
CALOsilicula	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
COCCplacentula small (<15um)	0.236	0.980	1.724	0.862	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
COCCplacentula var. euglypta	1.887	2.544	3.202	2.089	0.976	1.459	1.942	1.571	1.200	1.720	2.241	1.611
COCCplacentula var. placentula	8.255	8.561	8.867	9.190	9.512	10.096	10.680	9.540	8.400	7.421	6.443	7.796
CRAThalophila	0.000	0.000	0.000	0.244	0.488	0.244	0.000	0.000	0.000	0.000	0.000	0.000

Diatom Taxon (SD28)	2002	2001.8	2001.2	2001	2000.7	2000.3	1999.9	1999.6	1999.1	1998.2	1997	1996.3
CYCOcf. Tholiformis	2.594	1.667	0.739	1.467	2.195	0.826	0.456	1.128	0.800	1.661	2.521	2.914
CYCOPAD sp. 2	0.708	0.970	1.232	0.860	0.488	0.093	1.099	0.850	1.000	0.140	2.280	1.140
CYMBmicrocephala	3.302	1.897	0.493	0.856	1.220	1.459	1.699	1.650	1.600	0.800	0.000	0.000
CYMBminuta	0.472	0.236	0.000	0.122	0.244	0.122	0.000	0.000	0.000	0.280	0.560	0.280
CYMBproxima	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.163
DIATmoniliformis	1.179	0.713	0.246	0.489	0.732	0.366	0.000	0.000	0.000	1.600	0.000	0.000
DIATtenuis	0.000	0.246	0.493	0.734	0.976	1.915	0.854	0.027	3.200	0.300	2.401	2.334
EPITadnata	3.302	3.745	4.187	3.923	3.659	2.436	1.214	2.807	4.400	3.461	2.521	3.221
EPITturgida	2.594	2.898	3.202	2.333	1.463	1.339	1.214	1.807	2.400	2.601	2.801	2.708
EUNObilunaris	0.943	0.472	0.000	0.000	0.000	0.121	0.243	1.321	2.400	1.200	0.000	0.327
EUNOimplicata	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
EUNOincisa	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
FRAGbrevistriata	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
FRAGcapucina var. gracilis	0.000	1.847	3.695	3.920	4.146	3.287	2.427	1.214	0.000	1.261	2.521	1.261
FRAGcapucina var. rumpens	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
FRAGcapucina var.mesolepta	6.132	5.406	4.680	3.559	2.439	3.768	5.097	4.349	3.600	4.181	4.762	5.486
FRAGconstruens	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
FRAGconstruens f. binodis	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
FRAGconstruens var. venter	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.307
FRAGfamelica	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
FRAGpinnata	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.200	0.400	0.620	0.840	0.910
FRAGpinnata var. intercedens	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
GOMPacuminatum	0.472	1.344	2.217	1.352	0.488	0.487	0.485	0.643	0.800	1.520	2.241	2.754
GOMPangustatum	0.000	0.246	0.493	0.246	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Diatom Taxon (SD28)	2002	2001.8	2001.2	2001	2000.7	2000.3	1999.9	1999.6	1999.1	1998.2	1997	1996.3
GOMPangustum	3.774	4.966	6.158	4.054	1.951	3.160	4.369	3.384	2.400	2.741	3.081	2.684
GOMPclavatum	0.943	0.718	0.493	0.490	0.488	0.729	0.971	0.685	0.400	0.200	0.000	1.144
GOMPgracile	0.236	1.103	1.970	1.351	0.732	0.609	0.485	0.243	0.000	1.541	3.081	2.194
GOMPparvulum	4.245	5.325	6.404	6.251	6.098	4.384	2.670	2.535	2.400	1.760	1.120	2.031
GOMPtruncatum	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.280	0.560	0.280
GOMP minutum	0.943	0.595	0.246	1.221	2.195	1.340	0.485	0.643	0.800	0.400	0.000	0.000
GYRO attenuatum	0.472	0.852	1.232	2.689	4.146	3.651	3.155	7.378	11.600	8.041	4.482	5.672
NAVIcapitata var. capitata	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.280	0.560	0.280
NAVIcryptocephala	4.481	3.595	2.709	2.452	2.195	2.311	2.427	3.414	4.400	2.480	0.560	2.568
NAVIcryptotenella	0.472	0.482	0.493	0.368	0.244	0.486	0.728	1.964	3.200	2.160	1.120	1.214
NAVIcuspidata	0.000	0.000	0.000	0.366	0.732	0.487	0.243	0.121	0.000	0.420	0.840	0.584
NAVIlaevissima	0.000	0.000	0.000	0.000	0.000	0.243	0.485	0.243	0.000	0.000	0.000	0.000
NAVIlibonensis	1.651	1.688	1.724	2.447	3.171	3.770	4.369	3.984	3.600	3.481	3.361	3.641
NAVImenisculus	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.280	0.560	0.280
NAVIminima	0.000	0.246	0.493	0.246	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
NAVIminuscula var. muralis	0.000	0.000	0.000	0.000	0.000	0.364	0.728	0.364	0.000	0.280	0.560	0.280
NAVIoblonga	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.400	0.800	0.400	0.000	0.000
NAVIpupula	0.000	0.246	0.493	0.856	1.220	1.459	1.699	2.050	2.400	2.040	1.681	1.167
NAVIradiosa	0.708	0.600	0.493	1.100	1.707	1.703	1.699	0.850	0.000	1.120	2.241	1.447
NAVISD sp. 1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
NAVIseminuloides	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
NAVIseminulum	1.179	0.590	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
NAVIsubmuralis	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
NAVIsubplacentula	0.000	0.000	0.000	0.000	0.000	0.243	0.485	0.443	0.400	0.480	0.560	0.280

Diatom Taxon (SD28)	2002	2001.8	2001.2	2001	2000.7	2000.3	1999.9	1999.6	1999.1	1998.2	1997	1996.3
NAVItrivialis	0.472	0.482	0.493	0.246	0.000	0.364	0.728	0.564	0.400	0.200	0.000	0.654
NAVIveneta	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.280	0.560	0.280
NEIDampliatum	0.000	0.246	0.493	0.246	0.000	0.364	0.728	0.364	0.000	0.000	0.000	0.000
NITZacicularis	0.943	0.472	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
NITZamphibia	0.472	0.236	0.000	0.000	0.000	0.485	0.971	0.485	0.000	0.700	1.401	0.864
NITZfonticola	0.000	0.246	0.493	0.246	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.327
NITZgracilis	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
NITZliebetruthii	2.123	1.061	0.000	0.244	0.488	0.487	0.485	1.043	1.600	1.220	0.840	1.074
NITZpalea	2.358	1.918	1.478	1.227	0.976	0.488	0.000	1.400	2.800	1.960	1.120	0.887
NITZpaleacea	0.236	0.118	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
NITZperminuta	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
NITZradicula	0.000	0.246	0.493	0.246	0.000	0.243	0.485	0.443	0.400	0.480	0.560	0.280
NITZrecta	0.943	0.841	0.739	0.369	0.000	0.607	1.214	2.007	2.800	1.960	1.120	1.377
NITZsigmoidea	0.472	0.605	0.739	0.491	0.244	0.971	1.699	1.250	0.800	0.820	0.840	0.584
PINNinterrupta	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
PINNmicrostauron	0.000	0.000	0.000	0.000	0.000	0.485	0.971	1.085	1.200	0.600	0.000	0.163
RHOPgibba	2.358	2.288	2.217	2.816	3.415	2.557	1.699	2.650	3.600	4.461	5.322	6.256
STAUanceps	0.000	0.000	0.000	0.244	0.488	0.244	0.000	0.400	0.800	0.960	1.120	0.724
STAUphoenicenteron	0.000	0.000	0.000	0.122	0.244	0.365	0.485	0.243	0.000	0.560	1.120	0.560
STAUsp. 1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.280	0.560	0.444
STEPminutulus	0.708	0.354	0.000	1.341	2.283	1.070	1.056	1.528	1.600	1.341	3.081	2.194
STEPparvus	2.472	0.852	1.685	0.713	2.051	1.433	1.670	1.335	1.600	1.620	4.241	3.937
SURIangusta	0.472	0.236	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.163
SURIminuta	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Diatom Taxon (SD28)	2002	2001.8	2001.2	2001	2000.7	2000.3	1999.9	1999.6	1999.1	1998.2	1997	1996.3
SYNEulna var. acus	0.708	0.270	1.232	0.060	0.488	0.851	0.214	1.207	1.200	0.740	2.280	0.467
TABEflocculosa	0.410	0.431	0.493	0.246	0.000	0.000	0.000	0.000	0.800	0.140	0.280	0.303

Diatom Taxon (SD28)	1995.9	1995.1	1994.4	1993.8	1993.3	1992.9	1992.6	1992.1	1991.6	1991.1	1990.6	1990.1
ACHNconspicua	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.286	0.571	0.520
ACHNhungarica	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
ACHNlanceolata var. frequentissima	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
ACHNlanceolata var. rostrata	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
ACHNminutissima	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
AMPHlibyca	1.307	1.370	1.434	1.183	0.932	1.866	2.800	1.839	0.877	0.724	0.571	0.286
AMPHpediculus	0.654	0.327	0.000	0.000	0.000	0.400	0.800	0.400	0.000	0.000	0.000	0.000
AMPHveneta	7.516	8.059	8.602	6.320	4.037	4.819	5.600	6.418	7.237	6.904	6.571	8.098
CALObacillum	0.654	0.327	0.000	0.000	0.000	0.000	0.000	0.219	0.439	0.648	0.857	0.429
CALOsilicula	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.286	0.571	0.520
COCCplacentula small (<15um)	0.000	1.254	2.509	1.410	0.311	0.355	0.400	0.419	0.439	0.505	0.571	0.286
COCCplacentula var. euglypta	0.980	2.282	3.584	2.103	0.621	2.711	4.800	3.168	1.535	2.768	4.000	2.704
COCCplacentula var. placentula	9.150	7.622	6.093	7.550	9.006	9.303	9.600	10.831	12.061	11.031	10.000	9.695
CRAThalophila	0.000	0.179	0.358	0.179	0.000	0.000	0.000	0.110	0.219	0.253	0.286	1.434
CYCOcf. Tholiformis	1.307	1.729	2.151	1.075	0.000	0.000	0.000	1.439	2.877	1.867	0.857	0.663
CYCOPAD sp. 2	2.400	0.358	0.717	0.358	0.000	1.000	2.000	1.000	2.000	1.714	1.429	1.301
CYMBmicrocephala	0.000	0.179	0.358	0.490	0.621	0.711	0.800	0.619	0.439	0.934	1.429	1.771
CYMBminuta	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.286	0.571	0.286
CYMBproxima	0.327	0.522	0.717	0.514	0.311	0.155	0.000	0.110	0.219	0.253	0.286	0.143
DIATmoniliformis	0.000	0.179	0.358	0.179	0.000	0.000	0.000	0.000	0.000	0.800	0.000	0.117

Diatom Taxon (SD28)	1995.9	1995.1	1994.4	1993.8	1993.3	1992.9	1992.6	1992.1	1991.6	1991.1	1990.6	1990.1
DIATtenuis	3.268	0.172	1.075	1.780	2.484	2.842	3.200	2.258	1.316	0.944	0.571	1.107
EPITadnata	3.922	2.319	0.717	1.445	2.174	3.087	4.000	2.548	1.096	1.834	2.571	3.046
EPITturgida	2.614	1.486	0.358	2.664	4.969	2.684	0.400	0.748	1.096	2.263	3.429	1.714
EUNObilunaris	0.654	0.327	0.000	0.311	0.621	0.711	0.800	1.168	1.535	1.196	0.857	0.781
EUNOimplicata	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
EUNOincisa	0.000	0.000	0.000	0.000	0.000	0.800	1.600	1.239	0.877	0.439	0.000	0.000
FRAGbrevistriata	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
FRAGcapucina var. gracilis	0.000	0.717	1.434	0.717	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.117
FRAGcapucina var. rumpens	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
FRAGcapucina var.mesolepta	6.209	3.105	0.000	0.932	1.863	0.932	0.000	0.439	0.877	0.439	0.000	0.000
FRAGconstruens	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
FRAGconstruens f. binodis	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
FRAGconstruens var. venter	2.614	1.307	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
FRAGfamelica	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
FRAGpinnata	0.980	1.207	1.434	2.735	4.037	2.019	0.000	0.000	0.000	0.000	0.000	0.469
FRAGpinnata var. intercedens	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
GOMPacuminatum	3.268	1.992	0.717	0.669	0.621	0.511	0.400	1.296	2.193	1.382	0.571	0.638
GOMPangustatum	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
GOMPangustum	2.288	3.474	4.659	4.038	3.416	3.708	4.000	2.987	1.974	2.130	2.286	3.138
GOMPclavatum	2.288	1.144	0.000	0.155	0.311	0.155	0.000	0.439	0.877	0.581	0.286	0.143
GOMPgracile	1.307	1.012	0.717	0.824	0.932	0.466	0.000	1.206	2.412	2.778	3.143	2.158
GOMPparvulum	2.941	4.338	5.735	3.954	2.174	1.487	0.800	1.387	1.974	4.701	7.429	6.531
GOMPtruncatum	0.000	0.000	0.000	0.000	0.000	0.400	0.800	0.400	0.000	0.857	1.714	0.857
GOMP minutum	0.000	0.717	1.434	1.027	0.621	0.711	0.800	0.619	0.439	0.219	0.000	0.235

Diatom Taxon (SD28)	1995.9	1995.1	1994.4	1993.8	1993.3	1992.9	1992.6	1992.1	1991.6	1991.1	1990.6	1990.1
GYRO attenuatum	6.863	5.403	3.943	7.872	11.801	9.701	7.600	8.405	9.211	6.462	3.714	4.322
NAVIcapitata var. capitata	0.000	0.179	0.358	0.645	0.932	0.666	0.400	0.529	0.658	0.615	0.571	0.520
NAVIcryptocephala	4.575	4.259	3.943	4.301	4.658	4.729	4.800	4.374	3.947	3.259	2.571	3.985
NAVIcryptotenella	1.307	1.908	2.509	2.031	1.553	3.576	5.600	4.225	2.851	2.711	2.571	3.281
NAVIcuspidata	0.327	0.522	0.717	0.514	0.311	0.355	0.400	0.200	0.000	0.286	0.571	0.403
NAVIlaevissima	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.286	0.571	0.286
NAVIlibonensis	3.922	6.441	8.961	6.033	3.106	2.353	1.600	3.432	5.263	4.774	4.286	3.082
NAVImenisculus	0.000	0.717	1.434	0.717	0.000	1.200	2.400	1.529	0.658	0.758	0.857	0.429
NAVIminima	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.235
NAVIminuscula var. muralis	0.000	0.000	0.000	0.155	0.311	0.155	0.000	0.000	0.000	0.000	0.000	0.000
NAVIoblonga	0.000	0.358	0.717	0.358	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
NAVIpupula	0.654	0.685	0.717	0.358	0.000	0.400	0.800	0.948	1.096	1.691	2.286	2.434
NAVIradiosa	0.654	0.506	0.358	0.800	1.242	1.821	2.400	1.200	0.000	0.286	0.571	0.520
NAVISD sp. 1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
NAVIseminuloides	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
NAVIseminulum	0.000	0.000	0.000	0.466	0.932	0.466	0.000	0.000	0.000	0.000	0.000	0.000
NAVIsubmuralis	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
NAVIsubplacentula	0.000	0.358	0.717	0.358	0.000	0.000	0.000	0.000	0.000	0.143	0.286	0.143
NAVItrivialis	1.307	1.908	2.509	1.565	0.621	0.311	0.000	0.987	1.974	1.130	0.286	0.260
NAVIveneta	0.000	0.179	0.358	0.179	0.000	0.000	0.000	0.219	0.439	0.505	0.571	0.520
NEIDampliatum	0.000	0.179	0.358	0.490	0.621	0.711	0.800	0.948	1.096	0.691	0.286	0.143
NITZacicularis	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.219	0.439	0.219	0.000	0.000
NITZamphibia	0.327	0.522	0.717	0.358	0.000	0.000	0.000	0.110	0.219	0.110	0.000	0.469
NITZfonticola	0.654	0.685	0.717	0.358	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Diatom Taxon (SD28)	1995.9	1995.1	1994.4	1993.8	1993.3	1992.9	1992.6	1992.1	1991.6	1991.1	1990.6	1990.1
NITZgracilis	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
NITZliebetruthii	1.307	0.654	0.000	0.932	1.863	0.932	0.000	0.219	0.439	0.791	1.143	1.041
NITZpalea	0.654	0.506	0.358	0.645	0.932	0.466	0.000	0.219	0.439	0.219	0.000	0.352
NITZpaleacea	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
NITZperminuta	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
NITZradicula	0.000	0.358	0.717	0.358	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
NITZrecta	1.634	1.534	1.434	1.493	1.553	1.776	2.000	1.768	1.535	1.482	1.429	1.419
NITZsigmoidea	0.327	0.880	1.434	1.338	1.242	0.621	0.000	0.219	0.439	0.505	0.571	0.638
PINNinterrupta	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
PINNmicrostauron	0.327	0.343	0.358	0.334	0.311	0.955	1.600	1.239	0.877	0.439	0.000	0.822
RHOPgibba	7.190	5.745	4.301	3.703	3.106	3.553	4.000	3.096	2.193	2.668	3.143	2.393
STAUanceps	0.327	0.163	0.000	0.466	0.932	0.466	0.000	0.110	0.219	0.110	0.000	0.117
STAUphoenicenteron	0.000	0.000	0.000	0.155	0.311	0.355	0.400	0.310	0.219	0.110	0.000	0.469
STAUsp. 1	0.327	0.163	0.000	0.000	0.000	0.000	0.000	0.219	0.439	0.362	0.286	0.143
STEPminutulus	2.307	1.012	0.717	1.601	2.484	1.442	0.400	1.529	3.658	0.472	1.386	0.143
STEPparvus	2.634	1.355	1.075	2.848	0.621	0.511	0.400	1.968	2.535	0.910	0.286	1.434
SURIangusta	0.327	0.343	0.358	0.179	0.000	0.200	0.400	0.419	0.439	0.505	0.571	0.403
SURIminuta	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
SYNEulna var. acus	0.654	0.506	0.358	0.956	1.553	2.076	0.200	1.039	0.877	0.867	0.857	0.898
TABEflocculosa	0.327	0.163	0.000	0.000	0.000	0.000	0.000	0.219	0.439	0.362	0.286	0.143

Diatom Taxon (SD28)	1989.6	1989.1	1988.7	1988.3	1987.6	1986.7	1985.4	1984.1	1982.6	1980.5	1978.5	1976.3
ACHNconspicua	0.469	0.235	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
ACHNhungarica	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Diatom Taxon (SD28)	1989.6	1989.1	1988.7	1988.3	1987.6	1986.7	1985.4	1984.1	1982.6	1980.5	1978.5	1976.3
ACHNlanceolata var. frequentissima	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
ACHNlanceolata var. rostrata	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
ACHNminutissima	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
AMPHlibyca	0.000	0.488	0.976	1.259	1.542	1.593	1.645	1.407	1.170	0.585	0.000	0.962
AMPHpediculus	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.120
AMPHveneta	9.624	7.617	5.610	5.778	5.947	6.099	6.250	4.148	2.047	4.249	6.452	6.231
CALObacillum	0.000	0.000	0.000	0.441	0.881	0.441	0.000	0.292	0.585	0.561	0.538	0.509
CALOsilicula	0.469	0.479	0.488	0.464	0.441	0.220	0.000	0.439	0.877	0.439	0.000	0.000
COCCplacentula small (<15um)	0.000	0.366	0.732	0.806	0.881	0.441	0.000	0.000	0.000	0.269	0.538	0.389
COCCplacentula var. euglypta	1.408	1.924	2.439	1.440	0.441	0.878	1.316	1.243	1.170	1.526	1.882	1.422
COCCplacentula var. placentula	9.390	7.744	6.098	7.564	9.031	8.298	7.566	8.754	9.942	7.121	4.301	7.439
CRAThalophila	2.582	1.535	0.488	0.464	0.441	0.714	0.987	0.493	0.000	0.134	0.269	0.976
CYCOcf. Tholiformis	0.469	3.088	2.707	1.955	2.203	2.088	1.974	1.279	1.585	1.099	2.613	1.287
CYCOPAD sp. 2	1.174	2.953	1.732	0.586	0.441	0.878	2.316	1.681	2.047	1.427	2.806	1.694
CYMBmicrocephala	2.113	1.056	0.000	0.441	0.881	0.605	0.329	0.749	1.170	1.122	1.075	0.658
CYMBminuta	0.000	0.000	0.000	0.551	1.101	0.880	0.658	0.475	0.292	0.146	0.000	0.000
CYMBproxima	0.000	0.244	0.488	0.244	0.000	0.000	0.000	0.146	0.292	0.281	0.269	0.134
DIATmoniliformis	0.235	0.361	1.488	0.244	0.000	0.000	1.950	0.000	0.000	0.134	0.269	0.134
DIATtenuis	1.643	1.187	0.732	1.247	1.762	1.868	1.974	1.864	1.754	2.162	4.570	3.246
EPITadnata	3.521	2.370	1.220	3.363	5.507	3.905	2.303	2.029	1.754	0.877	0.000	0.841
EPITturgida	0.000	1.098	2.195	1.648	1.101	1.044	0.987	0.786	0.585	0.964	1.344	1.513
EUNObilunaris	0.704	1.572	2.439	2.101	1.762	0.881	0.000	0.292	0.585	0.292	0.000	0.481

Diatom Taxon (SD28)	1989.6	1989.1	1988.7	1988.3	1987.6	1986.7	1985.4	1984.1	1982.6	1980.5	1978.5	1976.3
EUNOimplicata	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
EUNOincisa	0.000	0.000	0.000	0.220	0.441	0.220	0.000	0.000	0.000	0.000	0.000	0.000
FRAGbrevistriata	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
FRAGcapucina var. gracilis	0.235	0.117	0.000	0.441	0.881	0.769	0.658	0.621	0.585	0.292	0.000	0.361
FRAGcapucina var. rumpens	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
FRAGcapucina var.mesolepta	0.000	0.122	0.244	0.122	0.000	0.329	0.658	0.475	0.292	0.146	0.000	0.841
FRAGconstruens	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
FRAGconstruens f. binodis	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
FRAGconstruens var. venter	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.877	1.754	0.877	0.000	0.000
FRAGfamelica	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
FRAGpinnata	0.939	1.201	1.463	2.163	2.863	1.432	0.000	0.877	1.754	2.087	2.419	2.772
FRAGpinnata var. intercedens	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
GOMPacuminatum	0.704	1.084	1.463	0.952	0.441	0.220	0.000	0.000	0.000	0.000	0.000	0.120
GOMPangustatum	0.000	0.000	0.000	0.000	0.000	0.329	0.658	0.475	0.292	0.684	1.075	0.538
GOMPangustum	3.991	4.800	5.610	3.356	1.101	2.689	4.276	3.893	3.509	3.233	2.957	1.959
GOMPclavatum	0.000	1.220	2.439	1.880	1.322	1.483	1.645	1.115	0.585	0.292	0.000	0.481
GOMPgracile	1.174	2.050	2.927	1.684	0.441	0.549	0.658	1.206	1.754	1.684	1.613	1.167
GOMPparvulum	5.634	3.914	2.195	3.300	4.405	3.189	1.974	2.741	3.509	2.292	1.075	0.778
GOMPtruncatum	0.000	0.488	0.976	0.708	0.441	0.220	0.000	0.146	0.292	0.146	0.000	0.000
GOMP minutum	0.469	0.235	0.000	0.000	0.000	0.000	0.000	0.292	0.585	0.292	0.000	0.240
GYRO attenuatum	4.930	3.806	2.683	4.535	6.388	5.496	4.605	7.273	9.942	8.734	7.527	6.287
NAVIcapitata var. capitata	0.469	0.357	0.244	0.452	0.661	0.330	0.000	0.000	0.000	0.269	0.538	0.509

Diatom Taxon (SD28)	1989.6	1989.1	1988.7	1988.3	1987.6	1986.7	1985.4	1984.1	1982.6	1980.5	1978.5	1976.3
NAVIcryptocephala	5.399	4.407	3.415	3.580	3.744	3.681	3.618	4.295	4.971	4.367	3.763	4.526
NAVIcryptotenella	3.991	3.215	2.439	2.211	1.982	2.471	2.961	2.796	2.632	3.063	3.495	2.108
NAVIcuspidata	0.235	0.361	0.488	0.464	0.441	0.549	0.658	0.329	0.000	0.000	0.000	0.120
NAVIlaevissima	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.292	0.585	0.292	0.000	0.481
NAVIlibonensis	1.878	3.622	5.366	4.225	3.084	3.187	3.289	2.814	2.339	3.589	4.839	4.823
NAVImenisculus	0.000	0.732	1.463	1.062	0.661	0.659	0.658	0.768	0.877	1.514	2.151	1.676
NAVIminima	0.469	0.235	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
NAVIminuscula var. muralis	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
NAVIoblonga	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
NAVIpupula	2.582	1.779	0.976	1.038	1.101	1.044	0.987	1.078	1.170	0.988	0.806	1.004
NAVIradiosa	0.469	0.723	0.976	1.479	1.982	1.978	1.974	2.010	2.047	1.695	1.344	1.994
NAVISD sp. 1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
NAVIseminuloides	0.000	0.122	0.244	0.122	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.240
NAVIseminulum	0.000	0.244	0.488	0.244	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.481
NAVIsubmuralis	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
NAVIsubplacentula	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.269	0.538	0.870
NAVItrivialis	0.235	1.947	3.659	2.160	0.661	0.495	0.329	0.164	0.000	0.269	0.538	1.230
NAVIveneta	0.469	0.479	0.488	0.464	0.441	0.549	0.658	0.329	0.000	0.269	0.538	0.269
NEIDampliatum	0.000	0.122	0.244	0.893	1.542	1.264	0.987	0.493	0.000	0.000	0.000	0.000
NITZacicularis	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.292	0.585	0.292	0.000	0.000
NITZamphibia	0.939	0.957	0.976	0.488	0.000	0.329	0.658	0.329	0.000	0.806	1.613	0.806
NITZfonticola	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Diatom Taxon (SD28)	1989.6	1989.1	1988.7	1988.3	1987.6	1986.7	1985.4	1984.1	1982.6	1980.5	1978.5	1976.3
NITZgracilis	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
NITZliebetruthii	0.939	0.957	0.976	0.708	0.441	0.220	0.000	0.292	0.585	0.561	0.538	0.269
NITZpalea	0.704	0.352	0.000	0.220	0.441	0.220	0.000	0.585	1.170	0.854	0.538	0.750
NITZpaleacea	0.000	0.000	0.000	0.220	0.441	0.220	0.000	0.000	0.000	0.000	0.000	0.000
NITZperminuta	0.000	0.244	0.488	0.244	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
NITZradicula	0.000	0.000	0.000	0.000	0.000	0.329	0.658	0.329	0.000	0.269	0.538	0.269
NITZrecta	1.408	1.436	1.463	1.282	1.101	0.880	0.658	1.499	2.339	2.379	2.419	1.931
NITZsigmoidea	0.704	1.084	1.463	1.062	0.661	0.659	0.658	0.914	1.170	0.719	0.269	0.375
PINNinterrupta	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
PINNmicrostauron	1.643	0.822	0.000	0.110	0.220	0.439	0.658	0.621	0.585	0.427	0.269	0.134
RHOPgibba	1.643	1.431	1.220	2.482	3.744	3.024	2.303	2.029	1.754	2.356	2.957	2.320
STAUanceps	0.235	0.117	0.000	0.000	0.000	0.000	0.000	0.292	0.585	0.292	0.000	0.240
STAUphoenicenteron	0.939	0.957	0.976	1.149	1.322	1.154	0.987	0.932	0.877	0.976	1.075	1.740
STAUsp. 1	0.000	0.122	0.244	0.122	0.000	0.329	0.658	0.621	0.585	0.292	0.000	0.240
STEPminutulus	0.000	2.610	1.220	0.610	1.200	0.987	2.974	1.133	1.292	0.415	2.538	2.711
STEPparvus	2.582	1.535	2.488	0.354	1.220	1.590	2.961	2.065	1.170	1.391	1.613	2.008
SURIangusta	0.235	0.605	0.976	1.038	1.101	0.880	0.658	0.475	0.292	0.415	0.538	0.389
SURIminuta	0.000	0.122	0.244	0.122	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
SYNEulna var. acus	0.939	1.201	1.463	0.513	1.762	0.881	0.000	0.000	0.877	0.273	1.269	0.615
TABEflocculosa	0.000	0.488	0.976	0.488	0.000	0.493	0.987	0.000	0.000	0.134	1.269	0.255

Diatom Taxon (SD28)	1974.1	1971.5	1969	1966.4	1963.2	1960.8	1958.6	1955.1	1952.5	1949.2	1946.1	1943.8
ACHNconspicua	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.231	0.463	0.374	0.286	0.379
ACHNhungarica	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Diatom Taxon (SD28)	1974.1	1971.5	1969	1966.4	1963.2	1960.8	1958.6	1955.1	1952.5	1949.2	1946.1	1943.8
ACHNlanceolata var. frequentissima	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
ACHNlanceolata var. rostrata	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
ACHNminutissima	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
AMPHlibyca	1.923	1.958	1.993	2.422	2.851	2.611	2.372	1.302	0.231	0.259	0.286	0.732
AMPHpediculus	0.240	0.120	0.000	0.110	0.219	0.307	0.395	0.198	0.000	0.143	0.286	0.143
AMPHveneta	6.010	4.500	2.990	3.249	3.509	4.324	5.138	4.305	3.472	3.450	3.429	5.842
CALObacillum	0.481	0.573	0.664	0.771	0.877	0.834	0.791	0.627	0.463	0.517	0.571	0.522
CALOsilicula	0.000	0.000	0.000	0.219	0.439	0.219	0.000	0.000	0.000	0.000	0.000	0.000
COCCplacentula small (<15um)	0.240	0.452	0.664	0.332	0.000	0.593	1.186	0.593	0.000	0.429	0.857	0.429
COCCplacentula var. euglypta	0.962	1.976	2.990	1.934	0.877	1.031	1.186	1.172	1.157	1.150	1.143	1.043
COCCplacentula var. placentula	10.577	8.611	6.645	8.805	10.965	8.447	5.929	6.552	7.176	6.302	5.429	6.724
CRAThalophila	1.683	0.841	0.000	0.329	0.658	0.329	0.000	0.926	1.852	0.926	0.000	0.236
CYCOcf. Tholiformis	3.962	0.647	2.332	2.714	2.096	0.944	0.791	0.511	2.231	1.259	3.286	2.204
CYCOPAD sp. 2	3.960	0.979	0.997	1.718	2.439	0.615	0.791	0.395	1.270	0.000	2.140	0.943
CYMBmicrocephala	0.240	0.452	0.664	0.990	1.316	0.658	0.000	0.116	0.231	1.259	2.286	1.850
CYMBminuta	0.000	0.000	0.000	0.219	0.439	0.219	0.000	0.463	0.926	0.606	0.286	0.143
CYMBproxima	0.000	0.000	0.000	0.439	0.877	0.439	0.000	0.000	0.000	0.000	0.000	0.236
DIATmoniliformis	1.570	0.000	0.000	1.320	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
DIATtenuis	1.923	2.623	3.322	3.196	3.070	3.081	7.091	5.124	1.157	1.722	2.286	1.143
EPITadnata	1.683	1.174	0.664	1.319	1.974	1.382	0.791	0.974	1.157	1.007	0.857	1.490
EPITturgida	1.683	0.841	0.000	0.439	0.877	2.020	3.162	2.275	1.389	0.980	0.571	1.465
EUNObilunaris	0.962	0.481	0.000	0.439	0.877	0.636	0.395	1.355	2.315	1.729	1.143	1.043
EUNOimplicata	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
EUNOincisa	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Diatom Taxon (SD28)	1974.1	1971.5	1969	1966.4	1963.2	1960.8	1958.6	1955.1	1952.5	1949.2	1946.1	1943.8
FRAGbrevistriata	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
FRAGcapucina var. gracilis	0.721	0.693	0.664	0.332	0.000	0.000	0.000	0.463	0.926	0.463	0.000	0.236
FRAGcapucina var. rumpens	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
FRAGcapucina var.mesolepta	1.683	0.841	0.000	1.316	2.632	1.316	0.000	0.000	0.000	0.000	0.000	0.000
FRAGconstruens	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
FRAGconstruens f. binodis	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
FRAGconstruens var. venter	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
FRAGfamelica	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
FRAGpinnata	3.125	2.725	2.326	3.356	4.386	2.193	0.000	0.810	1.620	1.096	0.571	1.229
FRAGpinnata var. intercedens	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
GOMPacuminatum	0.240	0.619	0.997	0.718	0.439	0.219	0.000	0.000	0.000	0.143	0.286	0.615
GOMPangustatum	0.000	0.166	0.332	0.166	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.118
GOMPangustum	0.962	1.145	1.329	1.542	1.754	2.063	2.372	2.806	3.241	2.906	2.571	2.347
GOMPclavatum	0.962	1.145	1.329	1.322	1.316	0.658	0.000	0.463	0.926	0.463	0.000	0.472
GOMPgracile	0.721	2.520	4.319	2.488	0.658	1.119	1.581	1.022	0.463	0.946	1.429	1.422
GOMPparvulum	0.481	1.237	1.993	1.216	0.439	1.800	3.162	2.970	2.778	1.960	1.143	2.812
GOMPtruncatum	0.000	0.000	0.000	0.219	0.439	0.219	0.000	0.000	0.000	0.571	1.143	0.689
GOMP minutum	0.481	0.240	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.143	0.286	0.615
GYRO attenuatum	5.048	6.345	7.641	5.904	4.167	7.815	11.462	7.583	3.704	5.280	6.857	5.315
NAVIcapitata var. capitata	0.481	0.240	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.286	0.571	0.639
NAVIcryptocephala	5.288	3.641	1.993	3.190	4.386	3.379	2.372	3.501	4.630	4.172	3.714	4.451
NAVIcryptotenella	0.721	1.191	1.661	2.146	2.632	2.502	2.372	2.922	3.472	2.736	2.000	3.123
NAVIcuspidata	0.240	0.785	1.329	0.774	0.219	0.307	0.395	0.545	0.694	0.633	0.571	0.522
NAVIlaevissima	0.962	0.481	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Diatom Taxon (SD28)	1974.1	1971.5	1969	1966.4	1963.2	1960.8	1958.6	1955.1	1952.5	1949.2	1946.1	1943.8
NAVIlibonensis	4.808	3.401	1.993	4.067	6.140	5.244	4.348	4.026	3.704	4.995	6.286	4.322
NAVImenisculus	1.202	1.265	1.329	1.322	1.316	2.634	3.953	2.555	1.157	1.436	1.714	1.211
NAVIminima	0.000	0.166	0.332	0.166	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
NAVIminuscula var. muralis	0.000	0.332	0.664	0.332	0.000	0.000	0.000	0.694	1.389	1.837	2.286	1.143
NAVIoblonga	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
NAVIpupula	1.202	0.933	0.664	0.771	0.877	1.427	1.976	2.030	2.083	2.756	3.429	2.540
NAVIradiosa	2.644	3.149	3.654	1.937	0.219	0.505	0.791	0.858	0.926	1.463	2.000	1.354
NAVISD sp. 1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
NAVIseminuloides	0.481	0.240	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
NAVIseminulum	0.962	0.813	0.664	0.332	0.000	0.000	0.000	0.347	0.694	0.347	0.000	0.000
NAVIsubmuralis	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
NAVIsubplacentula	1.202	1.930	2.658	1.658	0.658	1.317	1.976	0.988	0.000	0.429	0.857	0.429
NAVItrivialis	1.923	0.962	0.000	0.768	1.535	1.558	1.581	2.411	3.241	2.335	1.429	1.776
NAVIveneta	0.000	0.332	0.664	0.332	0.000	0.000	0.000	0.810	1.620	1.239	0.857	0.429
NEIDampliatum	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.231	0.463	0.231	0.000	0.000
NITZacicularis	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
NITZamphibia	0.000	0.997	1.993	1.216	0.439	0.219	0.000	0.347	0.694	0.347	0.000	0.472
NITZfonticola	0.000	0.332	0.664	0.332	0.000	0.000	0.000	0.000	0.000	0.286	0.571	0.286
NITZgracilis	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
NITZliebetruthii	0.000	0.166	0.332	0.385	0.439	0.219	0.000	0.116	0.231	0.401	0.571	0.522
NITZpalea	0.962	0.813	0.664	0.771	0.877	0.439	0.000	0.579	1.157	0.864	0.571	0.757
NITZpaleacea	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.236
NITZperminuta	0.000	0.000	0.000	0.000	0.000	0.395	0.791	0.395	0.000	0.000	0.000	0.000
NITZradicula	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.118

Diatom Taxon (SD28)	1974.1	1971.5	1969	1966.4	1963.2	1960.8	1958.6	1955.1	1952.5	1949.2	1946.1	1943.8
NITZrecta	1.442	2.050	2.658	1.658	0.658	0.527	0.395	1.818	3.241	3.335	3.429	2.894
NITZsigmoidea	0.481	0.240	0.000	0.658	1.316	1.053	0.791	0.395	0.000	0.429	0.857	0.900
PINNinterrupta	0.000	0.000	0.000	0.219	0.439	0.219	0.000	0.116	0.231	0.116	0.000	0.000
PINNmicrostauron	0.000	0.332	0.664	0.332	0.000	0.000	0.000	0.231	0.463	1.089	1.714	0.857
RHOPgibba	1.683	2.669	3.654	2.924	2.193	3.073	3.953	3.134	2.315	2.015	1.714	1.565
STAUanceps	0.481	0.240	0.000	0.000	0.000	0.000	0.000	0.231	0.463	0.231	0.000	0.000
STAUphoenicenteron	2.404	1.368	0.332	0.714	1.096	0.548	0.000	0.231	0.463	0.231	0.000	0.354
STAUsp. 1	0.481	0.240	0.000	0.110	0.219	0.703	1.186	0.709	0.231	0.401	0.571	0.286
STEPminutulus	4.885	1.508	2.332	2.276	2.219	0.505	0.791	0.627	1.463	1.274	3.286	1.850
STEPparvus	3.404	1.030	3.661	3.817	2.974	0.987	0.000	0.579	1.157	1.864	2.571	1.993
SURIangusta	0.240	0.120	0.000	0.329	0.658	0.329	0.000	0.694	1.389	1.409	1.429	0.950
SURIminuta	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.116	0.231	0.116	0.000	0.000
SYNEulna var. acus	1.962	0.979	0.997	1.047	1.096	0.548	0.000	0.694	1.389	1.123	0.857	0.546
TABEflocculosa	1.240	0.286	0.332	0.000	0.877	0.636	0.395	0.000	0.826	0.749	0.571	0.286

Diatom Taxon (SD28)	1941.6	1939.3	1937.6	1935.1	1932.7	1930.3	1927.7	1924.8	1921.4	1919	1917.7	1915.1
ACHNconspicua	0.472	0.236	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
ACHNhungarica	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
ACHNlanceolata var. frequentissima	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
ACHNlanceolata var. rostrata	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
ACHNminutissima	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
AMPHlibyca	1.179	1.161	1.143	2.557	3.970	2.483	0.995	0.640	0.286	0.990	1.695	1.847
AMPHpediculus	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
AMPHveneta	8.255	6.842	5.429	4.823	4.218	3.726	3.234	5.331	7.429	7.104	6.780	6.961

Diatom Taxon (SD28)	1941.6	1939.3	1937.6	1935.1	1932.7	1930.3	1927.7	1924.8	1921.4	1919	1917.7	1915.1
CALObacillum	0.472	0.522	0.571	0.286	0.000	0.249	0.498	1.392	2.286	1.990	1.695	1.419
CALOsilicula	0.000	0.286	0.571	0.286	0.000	0.498	0.995	0.498	0.000	0.000	0.000	0.000
COCCplacentula small (<15um)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
COCCplacentula var. euglypta	0.943	1.615	2.286	1.515	0.744	1.492	2.239	1.548	0.857	1.397	1.937	2.683
COCCplacentula var. placentula	8.019	6.724	5.429	5.692	5.955	6.211	6.468	5.948	5.429	6.104	6.780	9.390
CRAThalophila	0.472	0.379	0.286	0.515	0.744	0.497	0.249	0.410	0.571	0.891	1.211	1.034
CYCOcf. Tholiformis	3.123	1.776	1.429	0.838	1.248	1.243	2.239	2.119	2.000	2.211	3.421	1.354
CYCOPAD sp. 2	2.887	2.372	2.857	1.553	1.248	0.622	2.995	1.069	2.843	1.177	3.211	0.891
CYMBmicrocephala	1.415	0.708	0.000	0.868	1.737	1.366	0.995	1.069	1.143	0.814	0.484	0.956
CYMBminuta	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.429	0.857	0.671	0.484	0.385
CYMBproxima	0.472	0.379	0.286	0.143	0.000	0.000	0.000	0.143	0.286	0.506	0.726	0.649
DIATmoniliformis	2.000	0.000	0.000	0.000	0.000	0.373	2.446	0.516	0.286	0.143	0.000	0.000
DIATtenuis	2.300	0.286	0.571	0.906	1.441	1.615	1.990	1.138	2.286	1.748	1.211	0.105
EPITadnata	2.123	1.490	0.857	1.173	1.489	1.118	0.746	0.659	0.571	0.891	1.211	1.177
EPITturgida	2.358	1.894	1.429	1.086	0.744	0.745	0.746	1.659	2.571	2.375	2.179	2.661
EUNObilunaris	0.943	0.757	0.571	0.782	0.993	0.621	0.249	0.696	1.143	0.571	0.000	0.286
EUNOimplicata	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
EUNOincisa	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
FRAGbrevistriata	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
FRAGcapucina var. gracilis	0.472	1.664	2.857	1.429	0.000	0.249	0.498	0.249	0.000	0.726	1.453	0.726
FRAGcapucina var. rumpens	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
FRAGcapucina var.mesolepta	0.000	0.286	0.571	0.286	0.000	0.249	0.498	0.249	0.000	0.242	0.484	0.242
FRAGconstruens	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
FRAGconstruens f. binodis	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Diatom Taxon (SD28)	1941.6	1939.3	1937.6	1935.1	1932.7	1930.3	1927.7	1924.8	1921.4	1919	1917.7	1915.1
FRAGconstruens var. venter	0.000	0.000	0.000	0.620	1.241	0.620	0.000	0.143	0.286	0.143	0.000	0.000
FRAGfamelica	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
FRAGpinnata	1.887	1.372	0.857	0.677	0.496	0.497	0.498	1.820	3.143	2.056	0.969	1.770
FRAGpinnata var. intercedens	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
GOMPacuminatum	0.943	0.472	0.000	0.248	0.496	0.746	0.995	1.355	1.714	1.826	1.937	1.540
GOMPangustatum	0.236	0.118	0.000	1.117	2.233	1.365	0.498	0.249	0.000	0.000	0.000	0.286
GOMPangustum	2.123	3.204	4.286	2.887	1.489	1.491	1.493	1.318	1.143	0.814	0.484	1.385
GOMPclavatum	0.943	0.615	0.286	0.639	0.993	1.367	1.741	1.442	1.143	0.814	0.484	0.242
GOMPgracile	1.415	1.850	2.286	2.384	2.481	1.241	0.000	0.714	1.429	1.925	2.421	1.925
GOMPparvulum	4.481	3.955	3.429	2.831	2.233	1.863	1.493	1.175	0.857	1.760	2.663	2.903
GOMPtruncatum	0.236	0.261	0.286	0.267	0.248	1.119	1.990	1.138	0.286	0.143	0.000	0.000
GOMP minutum	0.943	0.472	0.000	0.000	0.000	0.249	0.498	0.249	0.000	0.000	0.000	0.000
GYRO attenuatum	3.774	2.744	1.714	3.090	4.467	6.835	9.204	7.459	5.714	6.247	6.780	10.676
NAVIcapitata var. capitata	0.708	0.497	0.286	0.391	0.496	0.248	0.000	0.714	1.429	0.714	0.000	0.000
NAVIcryptocephala	5.189	4.737	4.286	5.245	6.203	6.211	6.219	4.538	2.857	4.213	5.569	3.927
NAVIcryptotenella	4.245	3.123	2.000	1.993	1.985	1.863	1.741	1.156	0.571	2.102	3.632	1.816
NAVIcuspidata	0.472	0.236	0.000	0.124	0.248	0.124	0.000	0.286	0.571	0.286	0.000	0.143
NAVIlaevissima	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.286	0.571	0.286	0.000	0.143
NAVIlibonensis	2.358	3.751	5.143	4.557	3.970	4.846	5.721	4.432	3.143	2.540	1.937	2.969
NAVImenisculus	0.708	0.639	0.571	0.906	1.241	1.367	1.493	0.746	0.000	1.090	2.179	1.232
NAVIminima	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.143	0.286	0.143	0.000	0.000
NAVIminuscula var. muralis	0.000	0.143	0.286	1.011	1.737	0.993	0.249	0.696	1.143	0.571	0.000	0.000
NAVIoblonga	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
NAVIpupula	1.651	1.397	1.143	1.316	1.489	0.993	0.498	0.963	1.429	1.925	2.421	2.068

Diatom Taxon (SD28)	1941.6	1939.3	1937.6	1935.1	1932.7	1930.3	1927.7	1924.8	1921.4	1919	1917.7	1915.1
NAVIradiosa	0.708	1.925	3.143	1.944	0.744	1.367	1.990	1.852	1.714	1.099	0.484	0.814
NAVISD sp. 1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
NAVIseminuloides	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
NAVIseminulum	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
NAVIsubmuralis	0.000	0.286	0.571	0.286	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
NAVIsubplacentula	0.000	0.429	0.857	0.677	0.496	0.497	0.498	0.249	0.000	0.242	0.484	0.528
NAVItrivialis	2.123	2.490	2.857	3.166	3.474	1.986	0.498	1.392	2.286	1.143	0.000	0.286
NAVIveneta	0.000	0.286	0.571	0.286	0.000	0.498	0.995	0.498	0.000	0.605	1.211	0.605
NEIDampliatum	0.000	0.286	0.571	0.286	0.000	0.498	0.995	0.498	0.000	0.000	0.000	0.000
NITZacicularis	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
NITZamphibia	0.943	0.472	0.000	0.248	0.496	0.746	0.995	1.498	2.000	1.000	0.000	0.857
NITZfonticola	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
NITZgracilis	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.143	0.286	0.143	0.000	0.000
NITZliebetruthii	0.472	0.236	0.000	0.744	1.489	1.242	0.995	1.069	1.143	0.814	0.484	0.814
NITZpalea	0.943	0.615	0.286	0.639	0.993	1.367	1.741	0.871	0.000	0.242	0.484	0.242
NITZpaleacea	0.472	0.236	0.000	0.000	0.000	0.249	0.498	0.249	0.000	0.000	0.000	0.000
NITZperminuta	0.000	0.286	0.571	0.782	0.993	0.496	0.000	0.000	0.000	0.242	0.484	0.242
NITZradicula	0.236	0.404	0.571	0.906	1.241	0.620	0.000	0.000	0.000	0.726	1.453	0.869
NITZrecta	2.358	2.322	2.286	1.639	0.993	1.367	1.741	1.299	0.857	0.429	0.000	0.286
NITZsigmoidea	0.943	1.472	2.000	1.124	0.248	0.870	1.493	1.175	0.857	0.671	0.484	0.242
PINNinterrupta	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
PINNmicrostauron	0.000	0.571	1.143	0.571	0.000	0.249	0.498	0.249	0.000	0.121	0.242	0.692
RHOPgibba	1.415	2.279	3.143	2.316	1.489	0.993	0.498	1.534	2.571	1.770	0.969	1.484
STAUanceps	0.000	0.000	0.000	0.248	0.496	0.248	0.000	0.286	0.571	0.286	0.000	0.000

Diatom Taxon (SD28)	1941.6	1939.3	1937.6	1935.1	1932.7	1930.3	1927.7	1924.8	1921.4	1919	1917.7	1915.1
STAUphoenicenteron	0.708	0.782	0.857	1.297	1.737	0.868	0.000	0.143	0.286	0.143	0.000	0.286
STAUsp. 1	0.000	0.286	0.571	0.286	0.000	0.000	0.000	0.286	0.571	0.286	0.000	0.000
STEPminutulus	3.415	0.993	2.571	0.658	2.744	1.740	2.736	2.225	2.714	1.584	2.538	1.726
STEPparvus	3.015	0.850	2.286	1.011	2.737	1.490	1.244	1.479	2.714	1.584	1.453	0.726
SURIangusta	0.472	0.807	1.143	0.944	0.744	0.621	0.498	0.677	0.857	0.671	0.484	0.528
SURIminuta	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
SYNEulna var. acus	1.200	1.118	2.570	0.740	1.489	1.744	0.000	0.229	2.857	1.500	1.726	0.649
TABEflocculosa	0.000	0.286	2.571	1.534	0.496	1.119	1.741	1.299	2.857	2.003	1.695	0.133

Diatom Taxon (SD28)	1912.6	1910.4	1907.9	1905.5	1903.7	1901.1
ACHNconspicua	0.000	0.000	0.000	0.250	0.500	0.375
ACHNhungarica	0.000	0.000	0.000	0.000	0.000	0.000
ACHNlanceolata var. frequentissima	0.000	0.200	0.400	0.200	0.000	0.100
ACHNlanceolata var. rostrata	0.000	0.000	0.000	0.000	0.000	0.000
ACHNminutissima	0.000	0.000	0.000	0.000	0.000	0.000
AMPHlibyca	2.000	1.000	0.000	0.000	0.000	0.000
AMPHpediculus	0.000	0.000	0.000	0.000	0.000	0.000
AMPHveneta	7.143	8.271	9.400	6.700	4.000	5.350
CALObacillum	1.143	1.171	1.200	1.350	1.500	1.425
CALOsilicula	0.000	0.000	0.000	0.000	0.000	0.000
COCCplacentula small (<15um)	0.000	0.000	0.000	0.000	0.000	0.000
COCCplacentula var. euglypta	3.429	2.914	2.400	1.825	1.250	1.538
COCCplacentula var. placentula	12.000	10.400	8.800	6.525	4.250	5.388
CRAThalophila	0.857	0.929	1.000	0.750	0.500	0.625

Diatom Taxon (SD28)	1912.6	1910.4	1907.9	1905.5	1903.7	1901.1
CYCOcf. Tholiformis	0.286	1.943	1.800	3.275	5.750	4.013
CYCOPAD sp. 2	0.571	1.300	1.400	2.325	4.633	2.788
CYMBmicrocephala	1.429	1.014	0.600	0.300	0.000	0.150
CYMBminuta	0.286	0.243	0.200	0.100	0.000	0.050
CYMBproxima	0.571	0.286	0.000	0.000	0.000	0.000
DIATmoniliformis	0.000	0.600	1.200	0.600	0.000	0.300
DIATtenuis	1.714	1.257	0.800	1.525	2.250	1.888
EPITadnata	1.143	0.671	0.200	0.475	0.750	0.613
EPITturgida	3.143	1.771	0.400	1.075	1.750	1.413
EUNObilunaris	0.571	0.286	0.000	0.000	0.000	0.000
EUNOimplicata	0.000	0.000	0.000	0.000	0.000	0.000
EUNOincisa	0.000	0.000	0.000	0.000	0.000	0.000
FRAGbrevistriata	0.000	0.000	0.000	0.000	0.000	0.000
FRAGcapucina var. gracilis	0.000	0.600	1.200	0.600	0.000	0.300
FRAGcapucina var. rumpens	0.000	0.000	0.000	0.000	0.000	0.000
FRAGcapucina var.mesolepta	0.000	0.000	0.000	0.250	0.500	0.375
FRAGconstruens	0.000	0.000	0.000	0.000	0.000	0.000
FRAGconstruens f. binodis	0.000	0.000	0.000	0.000	0.000	0.000
FRAGconstruens var. venter	0.000	0.000	0.000	0.000	0.000	0.000
FRAGfamelica	0.000	0.000	0.000	0.000	0.000	0.000
FRAGpinnata	2.571	2.686	2.800	2.150	1.500	1.825
FRAGpinnata var. intercedens	0.000	0.000	0.000	0.000	0.000	0.000
GOMPacuminatum	1.143	1.171	1.200	1.100	1.000	1.050
GOMPangustatum	0.571	0.286	0.000	0.000	0.000	0.000

Diatom Taxon (SD28)	1912.6	1910.4	1907.9	1905.5	1903.7	1901.1
GOMPangustum	2.286	1.943	1.600	1.550	1.500	1.525
GOMPclavatum	0.000	0.400	0.800	1.025	1.250	1.138
GOMPgracile	1.429	0.714	0.000	0.250	0.500	0.375
GOMPparvulum	3.143	2.471	1.800	1.775	1.750	1.763
GOMPtruncatum	0.000	0.200	0.400	0.200	0.000	0.100
GOMP minutum	0.000	0.000	0.000	0.000	0.000	0.000
GYRO attenuatum	14.571	9.386	4.200	5.350	6.500	5.925
NAVIcapitata var. capitata	0.000	0.200	0.400	0.200	0.000	0.100
NAVIcryptocephala	2.286	3.443	4.600	4.925	5.250	5.088
NAVIcryptotenella	0.000	0.800	1.600	1.300	1.000	1.150
NAVIcuspidata	0.286	0.143	0.000	0.000	0.000	0.000
NAVIlaevissima	0.286	0.143	0.000	0.000	0.000	0.000
NAVIlibonensis	4.000	3.600	3.200	4.225	5.250	4.738
NAVImenisculus	0.286	1.243	2.200	1.850	1.500	1.675
NAVIminima	0.000	0.000	0.000	0.250	0.500	0.375
NAVIminuscula var. muralis	0.000	0.000	0.000	0.000	0.000	0.000
NAVIoblonga	0.000	0.000	0.000	0.000	0.000	0.000
NAVIpupula	1.714	1.557	1.400	1.450	1.500	1.475
NAVIradiosa	1.143	1.271	1.400	2.075	2.750	2.413
NAVISD sp. 1	0.000	0.000	0.000	0.000	0.000	0.000
NAVIseminuloides	0.000	0.000	0.000	0.000	0.000	0.000
NAVIseminulum	0.000	0.000	0.000	0.000	0.000	0.000
NAVIsubmuralis	0.000	0.000	0.000	0.000	0.000	0.000
NAVIsubplacentula	0.571	0.286	0.000	0.750	1.500	1.125

Diatom Taxon (SD28)	1912.6	1910.4	1907.9	1905.5	1903.7	1901.1
NAVItrivialis	0.571	1.186	1.800	1.275	0.750	1.013
NAVIveneta	0.000	0.400	0.800	0.900	1.000	0.950
NEIDampliatum	0.000	0.000	0.000	0.500	1.000	0.750
NITZacicularis	0.000	0.000	0.000	0.000	0.000	0.000
NITZamphibia	1.714	1.057	0.400	0.950	1.500	1.225
NITZfonticola	0.000	0.100	0.200	0.225	0.250	0.238
NITZgracilis	0.000	0.000	0.000	0.000	0.000	0.000
NITZliebetruthii	1.143	0.571	0.000	0.750	1.500	1.125
NITZpalea	0.000	0.600	1.200	0.850	0.500	0.675
NITZpaleacea	0.000	0.000	0.000	0.125	0.250	0.188
NITZperminuta	0.000	0.200	0.400	0.450	0.500	0.475
NITZradicula	0.286	0.143	0.000	0.000	0.000	0.000
NITZrecta	0.571	1.986	3.400	2.700	2.000	2.350
NITZsigmoidea	0.000	0.500	1.000	0.875	0.750	0.813
PINNinterrupta	0.000	0.000	0.000	0.000	0.000	0.000
PINNmicrostauron	1.143	0.571	0.000	0.000	0.000	0.000
RHOPgibba	2.000	1.500	1.000	1.000	1.000	1.000
STAUanceps	0.000	0.200	0.400	0.200	0.000	0.100
STAUphoenicenteron	0.571	1.086	1.600	0.800	0.000	0.400
STAUsp. 1	0.000	0.000	0.000	0.000	0.000	0.000
STEPminutulus	2.000	3.000	0.800	2.288	3.750	2.813
STEPparvus	1.430	2.500	1.000	2.795	4.000	3.250
SURIangusta	0.571	0.486	0.400	0.200	0.000	0.100
SURIminuta	0.000	0.000	0.000	0.000	0.000	0.000

Diatom Taxon (SD28)	1912.6	1910.4	1907.9	1905.5	1903.7	1901.1
SYNEulna var. acus	0.571	1.386	2.200	1.475	1.750	1.113
TABEflocculosa	0.571	0.886	1.200	0.725	0.250	0.488

Diatom Taxon (SD20)	2002	2000.5	1999	1997.5	1996	1994	1992	1990.5	1988.9	1987	1985.5	1983.9
ACHNconspicua	0.436	0.000	0.218	0.000	0.327	0.218	0.109	0.054	0.000	0.000	0.000	0.000
ACHNhungarica	0.871	0.500	0.940	0.250	0.654	0.436	0.218	0.109	0.504	0.000	0.000	0.000
ACHNlanceolata var. frequentissima	3.922	5.100	2.969	3.800	3.441	2.961	2.480	5.000	2.008	2.250	2.000	2.500
ACHNlanceolata var. rostrata	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
ACHNminutissima	12.636	11.990	9.528	12.495	12.477	12.318	12.159	12.580	9.210	12.500	12.000	13.000
AMPHlibyca	0.218	0.100	0.109	0.550	0.788	1.359	1.929	1.465	1.250	1.750	2.500	1.000
AMPHpediculus	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
AMPHveneta	1.089	0.500	1.150	0.250	0.817	0.545	0.272	0.136	0.605	0.000	0.000	0.000
CALObacillum	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
CALOsilicula	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
COCCplacentula small (<15um)	8.000	7.000	14.823	9.500	7.124	9.416	12.708	12.354	11.407	14.000	16.000	12.000
COCCplacentula var. euglypta	2.397	2.000	1.198	1.500	2.422	2.448	2.474	1.737	1.250	1.750	2.500	1.000
COCCplacentula var. placentula	22.658	18.000	18.486	17.000	23.618	20.407	25.539	22.270	24.579	22.750	26.500	19.000
CRAThalophila	0.436	0.000	0.621	0.000	0.327	0.218	0.109	0.054	0.403	0.000	0.000	0.000
CYCOcf. Tholiformis	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
CYCOPAD sp. 2	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
CYMBmicrocephala	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
CYMBminuta	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
CYMBproxima	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
DIATmoniliformis	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Diatom Taxon (SD20)	2002	2000.5	1999	1997.5	1996	1994	1992	1990.5	1988.9	1987	1985.5	1983.9
DIATtenuis	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
EPITadnata	1.961	3.000	2.291	3.000	2.721	3.480	4.240	3.620	3.810	4.000	5.000	3.000
EPITturgida	1.089	1.000	0.545	1.000	1.192	1.295	1.397	1.199	0.750	1.250	1.500	1.000
EUNObilunaris	0.436	0.000	0.218	0.250	0.452	0.468	0.484	0.492	0.250	0.500	0.500	0.500
EUNOimplicata	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
EUNOincisa	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
FRAGbrevistriata	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
FRAGcapucina var. gracilis	0.871	0.000	1.000	0.000	0.654	0.436	0.218	0.109	0.565	0.000	0.000	0.000
FRAGcapucina var. rumpens	2.614	1.000	2.436	1.000	2.336	2.057	1.779	1.389	1.879	1.250	1.500	1.000
FRAGcapucina var.mesolepta	4.139	2.000	3.199	3.000	3.230	2.320	1.410	2.705	1.379	2.250	0.500	4.000
FRAGconstruens	0.218	0.000	0.109	0.000	0.163	0.109	0.054	0.027	0.000	0.000	0.000	0.000
FRAGconstruens f. binodis	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
FRAGconstruens var. venter	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
FRAGfamelica	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
FRAGpinnata	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
FRAGpinnata var. intercedens	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
GOMPacuminatum	1.743	1.000	0.871	1.000	1.432	1.121	0.811	0.905	0.250	0.750	0.500	1.000
GOMPangustatum	0.436	2.000	0.218	2.000	0.952	1.468	1.984	1.992	1.250	2.250	2.500	2.000
GOMPangustum	4.793	3.000	3.352	3.000	3.595	2.397	1.198	2.099	0.955	1.500	0.000	3.000
GOMPclavatum	2.397	3.000	2.312	2.000	2.047	1.698	1.349	1.175	1.614	1.000	1.000	1.000
GOMPgracile	0.871	1.000	1.072	1.000	1.279	1.686	2.093	1.546	1.887	1.750	2.500	1.000
GOMPparvulum	4.357	4.000	4.725	3.000	3.893	3.429	2.964	2.482	3.797	2.250	2.500	2.000
GOMPtruncatum	1.525	0.500	0.763	0.250	1.144	0.763	0.381	0.191	0.000	0.000	0.000	0.000
GOMP minutum	0.000	0.500	0.796	0.250	0.125	0.250	0.375	0.188	1.046	0.250	0.500	0.000

Diatom Taxon (SD20)	2002	2000.5	1999	1997.5	1996	1994	1992	1990.5	1988.9	1987	1985.5	1983.9
GYRO attenuatum	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
NAVIcapitata var. capitata	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
NAVIcryptocephala	3.050	2.000	3.037	1.000	2.413	1.775	1.138	0.569	1.762	0.250	0.500	0.000
NAVIcryptotenella	2.397	2.000	1.904	1.500	2.047	1.698	1.349	1.175	1.206	1.000	1.000	1.000
NAVIcuspidata	1.307	1.000	0.855	1.000	1.355	1.404	1.452	1.226	0.952	1.250	1.500	1.000
NAVIlaevissima	0.871	0.000	0.940	0.000	0.654	0.436	0.218	0.109	0.504	0.000	0.000	0.000
NAVIlibonensis	0.000	0.000	0.302	0.000	0.000	0.000	0.000	0.000	0.302	0.000	0.000	0.000
NAVImenisculus	0.436	0.000	0.218	0.000	0.327	0.218	0.109	0.054	0.000	0.000	0.000	0.000
NAVIminima	4.139	4.000	5.094	3.750	4.105	4.070	4.035	3.767	5.024	3.750	4.000	3.500
NAVIminuscula var. muralis	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
NAVIoblonga	0.000	0.000	0.202	0.000	0.000	0.000	0.000	0.000	0.202	0.000	0.000	0.000
NAVIpupula	0.000	0.000	0.605	0.750	0.500	1.000	1.500	1.500	1.605	1.750	2.000	1.500
NAVIradiosa	2.179	0.800	1.291	0.400	1.634	1.089	0.545	0.272	0.202	0.000	0.000	0.000
NAVISD sp. 1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
NAVIseminuloides	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
NAVIseminulum	0.436	0.000	0.218	0.500	0.827	1.218	1.609	1.304	1.000	1.500	2.000	1.000
NAVIsubmuralis	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
NAVIsubplacentula	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
NAVItrivialis	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
NAVIveneta	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
NEIDampliatum	0.000	0.000	0.403	0.250	0.000	0.000	0.000	0.250	0.403	0.250	0.000	0.500
NITZacicularis	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
NITZamphibia	4.139	3.500	3.582	4.250	5.105	4.070	3.035	4.517	3.512	4.500	4.000	5.000
NITZfonticola	0.436	0.000	0.218	0.000	0.327	0.218	0.109	0.054	0.000	0.000	0.000	0.000

Diatom Taxon (SD20)	2002	2000.5	1999	1997.5	1996	1994	1992	1990.5	1988.9	1987	1985.5	1983.9
NITZgracilis	0.000	0.500	0.000	0.500	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
NITZliebetruthii	0.436	0.000	0.218	0.000	0.327	0.218	0.109	0.054	0.000	0.000	0.000	0.000
NITZpalea	0.871	1.000	2.250	0.500	0.779	0.686	0.593	0.296	2.065	0.250	0.500	0.000
NITZpaleacea	0.218	0.000	0.512	0.000	0.163	0.109	0.054	0.027	0.403	0.000	0.000	0.000
NITZperminuta	0.218	0.000	0.311	0.000	0.163	0.109	0.054	0.027	0.202	0.000	0.000	0.000
NITZradicula	0.436	0.000	0.419	0.000	0.327	0.218	0.109	0.054	0.202	0.000	0.000	0.000
NITZrecta	1.307	0.800	0.855	0.900	1.355	1.404	1.452	1.226	0.952	1.250	1.500	1.000
NITZsigmoidea	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
PINNinterrupta	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
PINNmicrostauron	0.000	0.000	0.000	0.250	0.125	0.250	0.375	0.438	0.250	0.500	0.500	0.500
RHOPgibba	0.436	0.500	0.218	0.250	0.577	0.718	0.859	0.429	0.500	0.500	1.000	0.000
STAUanceps	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
STAUphoenicenteron	0.218	0.200	0.109	0.600	0.413	0.609	0.804	0.902	0.500	1.000	1.000	1.000
STAUsp. 1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
STEPminutulus	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
STEPparvus	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
SURIangusta	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
SURIminuta	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
SYNEulna var. acus	1.525	0.000	0.863	1.000	1.269	1.013	0.756	0.378	0.351	0.250	0.500	0.000
TABEflocculosa	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Appendix C

Sediment core chronologies for lakes SD2, SD28 and SD20

Appendix C

Sediment Core Chronologies for lakes SD2, SD28 and SD20

The following appendix provides data on the chronologies of sediment cores from lakes SD2, SD28 and SD20, including, dating activity profiles and age-depth relationship plots.

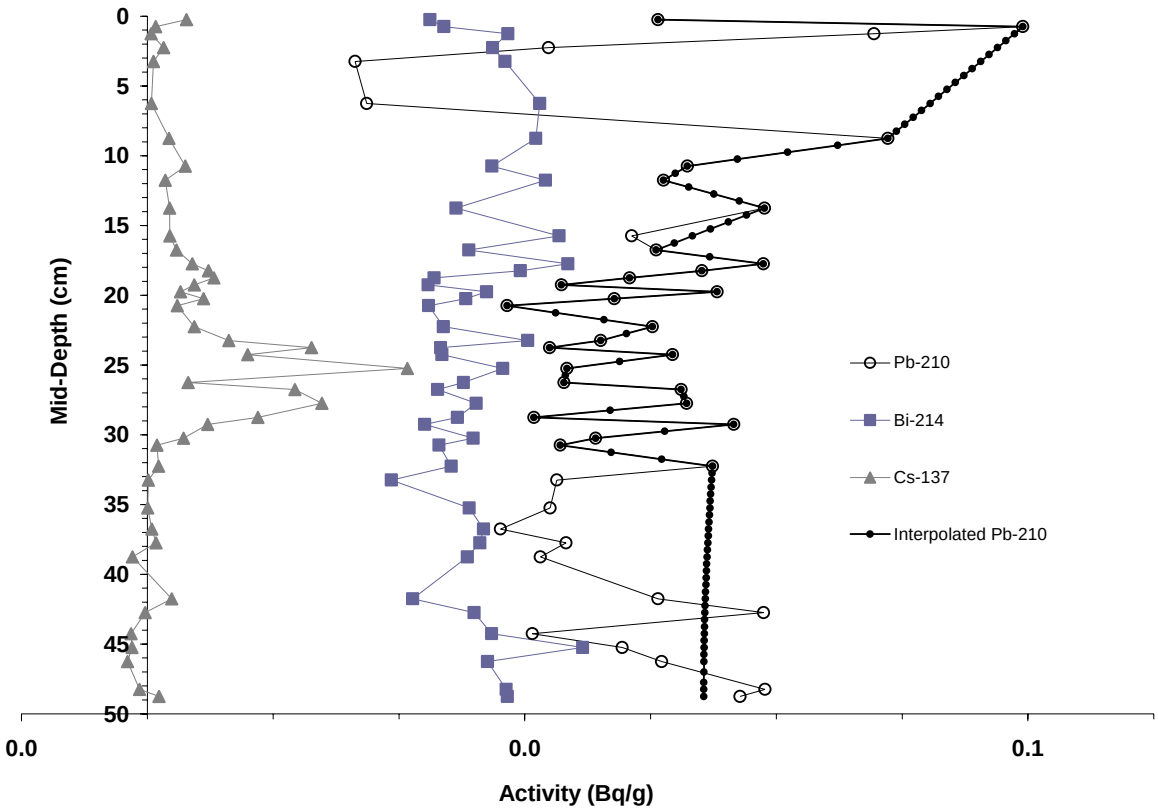

Figure C1 ^{210}Pb, ^{214}Bi and ^{137}Cs activity profiles for SD2. The 'Pb-210 series' represents activity values measured in all samples analysed in the gamma spectrometer. The 'Interpolated Pb-210' series is based on the 'Pb-210 series', with outliers removed and values interpolated for samples that were not analysed. ^{210}Pb values below 38.75 cm do not follow the typical exponential decay curve. A ^{137}Cs peak occurs at 25.25 cm.

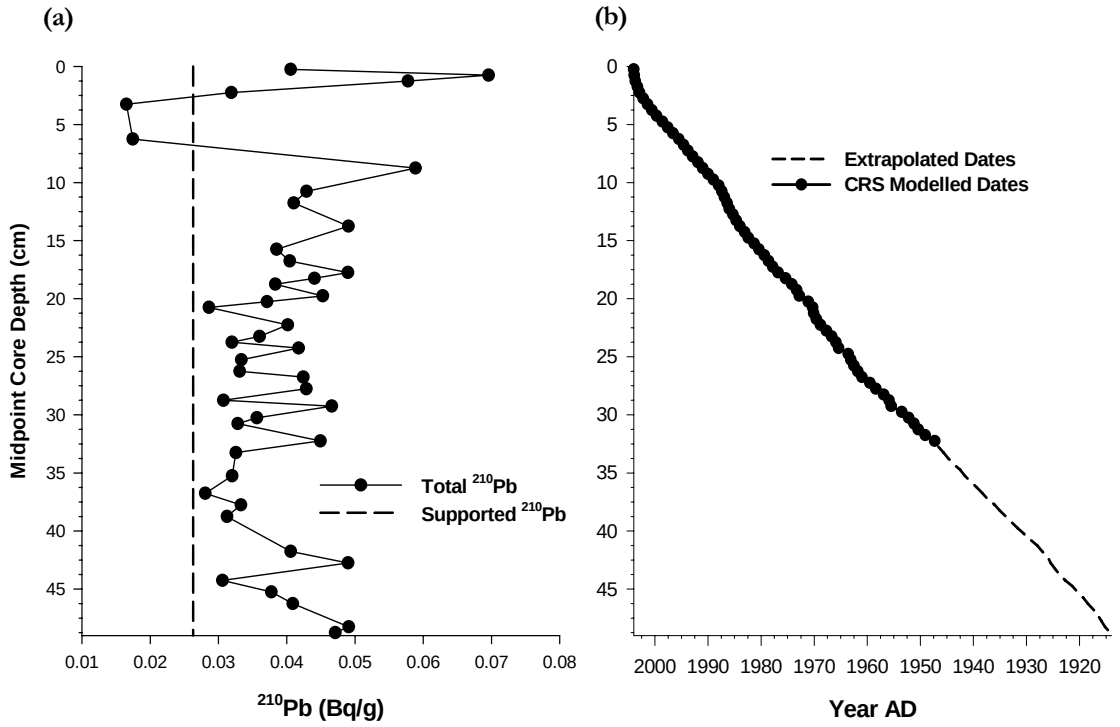

Figure C2 ^{210}Pb activity versus depth for SD2 (a) and SD2 sediment core chronology (b) based on the Constant Rate of Supply model (Oldfield and Appleby 1984).

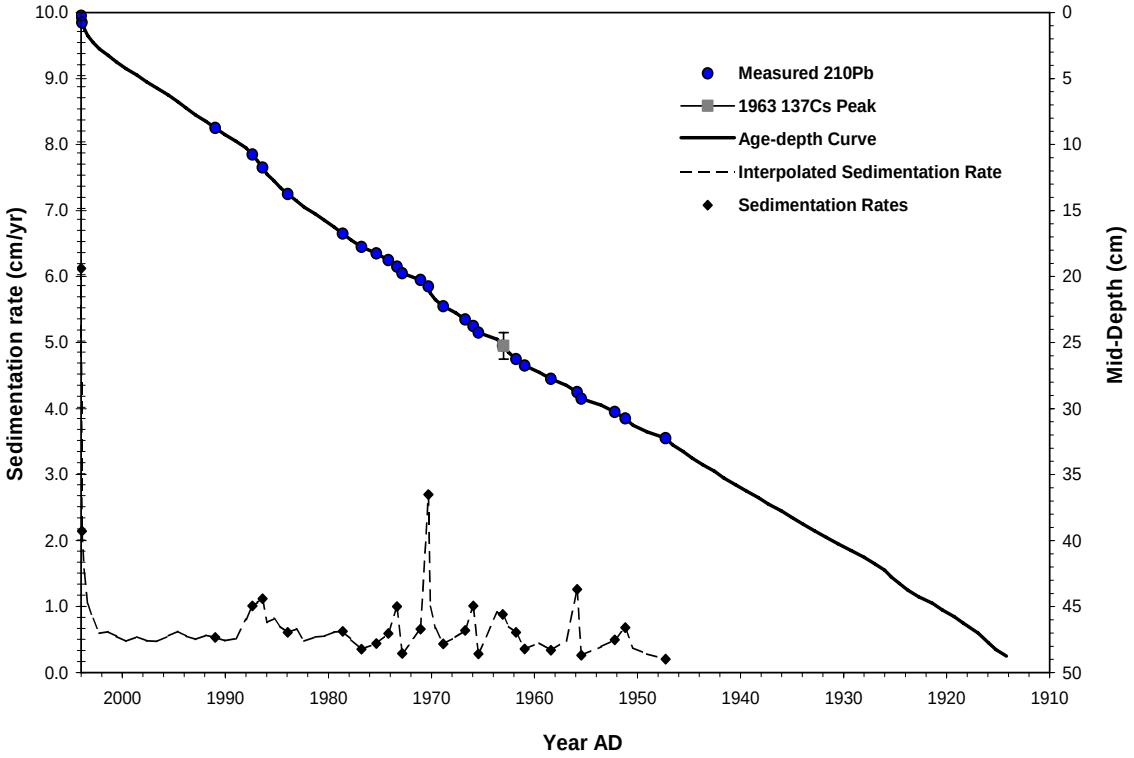

Figure C3 CRS-modelled chronology for SD2 KB-5. The age-depth curve is based on interpolated ^{210}Pb activity, and has been forced to pass through the ^{137}Cs peak at 25.25 cm. The interpolated sedimentation rate is based on interpolated ^{210}Pb.

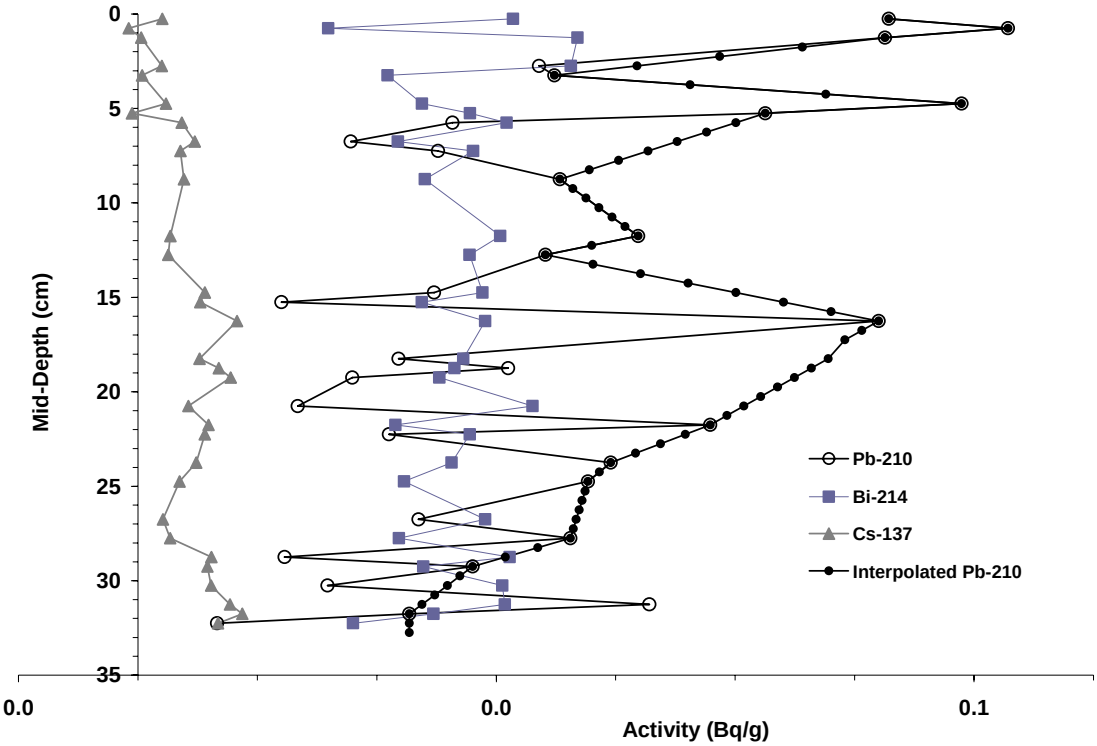

Figure C4 ^{210}Pb, ^{214}Bi and ^{137}Cs activity profiles for SD28. The 'Pb-210 series' represents activity values measured in all samples analyzed in the gamma spectrometer. The 'Interpolated Pb-210' series is based on the 'Pb-210' series, with outliers removed and values interpolated for samples that were not analyzed.

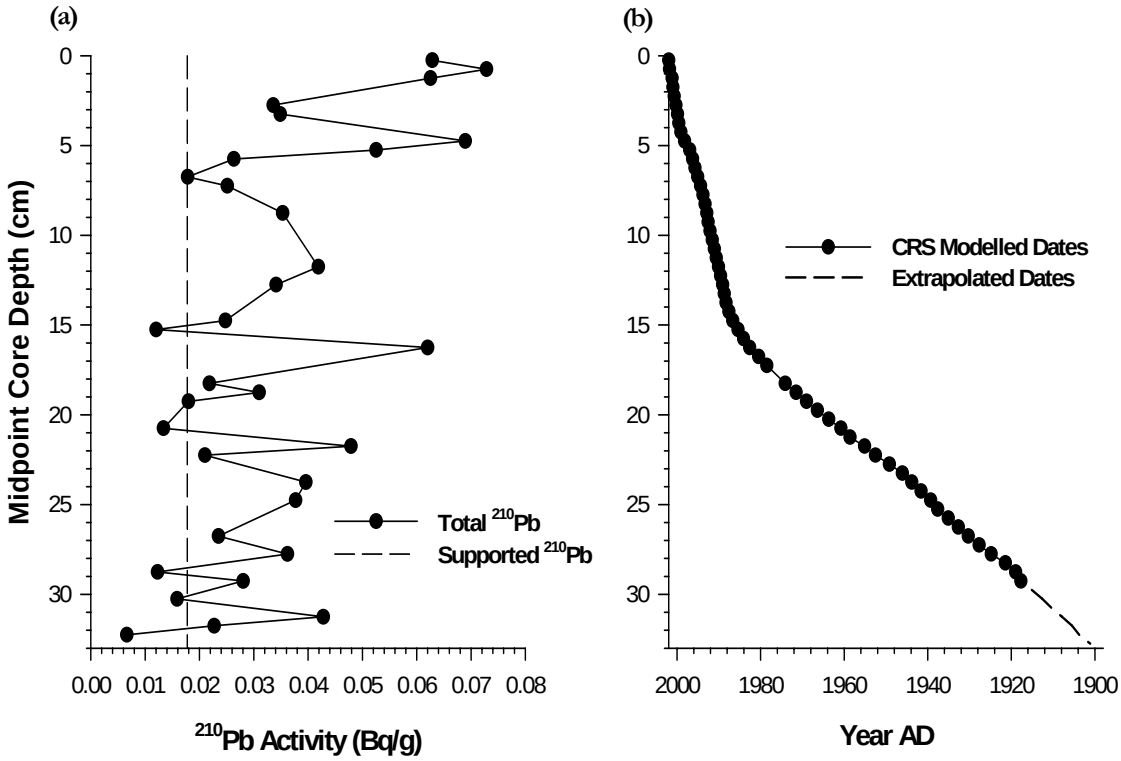

Figure C5 ^{210}Pb activity versus depth for SD28 (a) and SD28 sediment core chronology (b) based on the Constant Rate of Supply model (Oldfield and Appleby 1984).

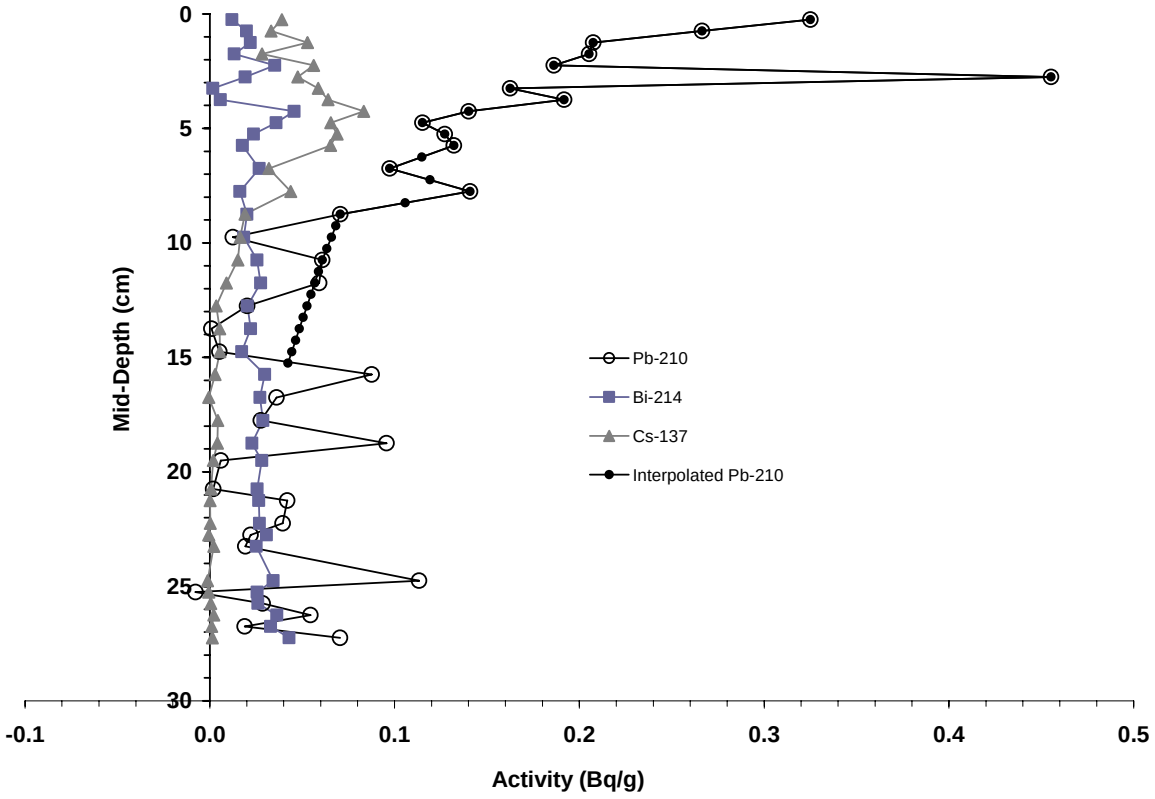

Figure C6 ^{210}Pb, ^{214}Bi and ^{137}Cs activity profiles for SD20 KB-1. 'Pb-210 series' represents activity values measured in samples analysed in the gamma spectrometer. 'Interpolated Pb-210' series is based on 'Pb-210 series' with outliers removed and values interpolated for samples that were not analyzed in the gamma spectrometer. Interpolated ^{210}Pb values from 0 cm to 15.25 cm were used to calculate CRS dates for sediment intervals from 0 cm to 15.25 cm, as they follow the typical exponential decay curve. Background supported 210Pb was measured to be 0.0210 Bq/g. Supported ^{210}Pb is reached between 15.25 cm (0.0213 Bq/g) and 15.75 cm (0.0193 Bq/g).

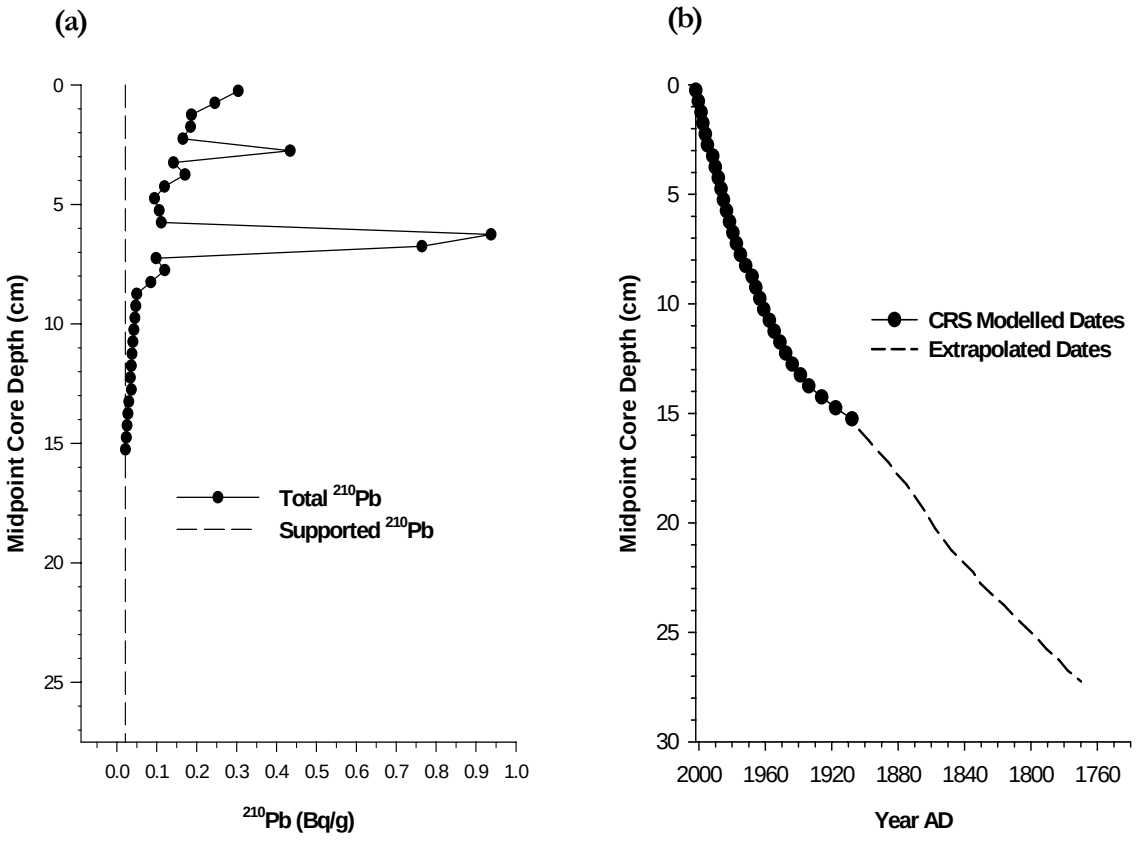

Figure C7 Total ^{210}Pb activity based on average background levels of supported ^{210}Pb versus depth for SD20 (a) and SD 20 sediment core chronology (b) based on the Constant Rate of Supply model (Oldfield and Appleby 1984).

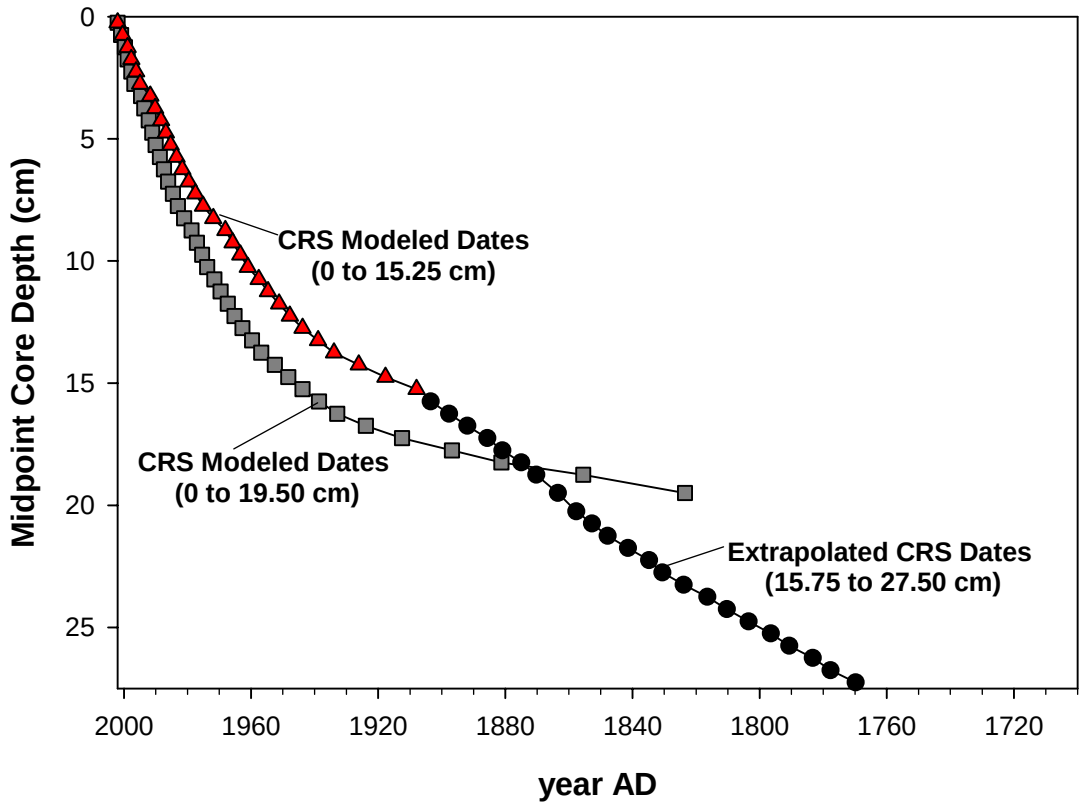

Figure C8 Chronology modeling for SD20 KB-1.